ADDENDUM TO THE PROBABLE HYDROLOGIC CONSEQUENCES

SKYLINE MINE
CANYON FUEL COMPANY,LLC

JULY 2002

ADDENDUM TO THE PHC
JULY 2002

REVISED OCTOBER 2002 AND APRIL 2003

Addendum to the Probable Hydrologic Consequences

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2. Scofield Reservoir Restoration through Phosphorous Control, Prepared by Utah Department of Environmental Quality in cooperation with Southeastern Association of Local Governments and the United States Environmental Protection Agency, Region VIII

3. Synopsis of Water Quality Issues at Scofield Reservoir, February 24, 1989, Walter K. Donaldson, Utah Division of Wildlife Resources

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5. Why Scofield Reservoir is Eutrophic: Effects of Nonpoint-Source Pollutants on a Water-Supply Reservoir in Utah, Doyle Stephens, U.S. Geological Survey, Salt Lake City, Utah

6. Scofield Reservoir Phase I, 314 Clean Lakes Study, 1980 - 1982, Richard L. Denton, Project Officer; Myron I Cox, Water Quality Specialist; Lavere B Merritt, Ph. D., Brigham Young University in cooperation with the Utah Department of Health, Division of Environmental Health, Bureau of Water Pollution Control, and Brigham Young University

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27 October 2002
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Appendix I Petersen Hydrologic Electric Lake Dye Letter Report
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Appendix J HCI Ground Water Flow Modeling of Skyline Mine and Surrounding Area
A ground water model of the Star Point Sandstone aquifer that discharges to Skyline Mine was completed in October 2003 by HCI of Lakewood, CO. The model incorporates all of the available well, surface flow, and ground water discharge data available and germane to the model area. The model also was used to predict the future volume of ground water inflows to the mine using the most current mine plan.

Appendix K Supplemental Report to the Ground-Water Flow Modeling of Skyline Mine and Surrounding Area, Carbon, Sanpete, and Emery Counties, Utah
This is a supplemental report to the initial HCI groundwater model report included in this document as Appendix J. It includes clarifications of some aspects of the initial report, calibration of the initial model (2003), and some predictive simulations.

Statement of Qualifications

The majority of the text of this addendum to the PHC was prepared by Chris D. Hansen, an employee of Canyon Fuel Company, LLC and Mr. Erik Petersen. Mr. Hansen has been employed by Canyon Fuel Company at the Skyline Mine since 1998 as the Environmental Coordinator. Mr. Hansen has been responsible for the collection, interpretation and reporting of the data collected as part of the hydrologic monitoring requirements of the mine's permit. Prior to coming to Canyon Fuel Company, Mr. Hansen was employed by EarthFax Engineering, an environmental and geotechnical engineering consulting firm, as a senior project manager from 1992 to 1998. While at EarthFax, Mr. Hansen worked on several ground water projects including contamination investigations at a major oil refinery located in Salt Lake City, Utah and helped prepare several mine ground water studies and PHCs for several coal mines in Utah and Colorado.

Mr. Hansen has a Bachelor of Science degree and Masters of Science degree in Geology from Brigham Young University. He has also taken post graduate courses in hydrogeology offered through BYU.

Erik Petersen is the Principal and Senior Hydrogeologist for Petersen Hydrologic. Mr. Petersen has more than 10 years of experience performing hydrologic investigations in the Wasatch Plateau and Book Cliffs coal fields. He has performed major ground water and surface water investigations at nearly every active coal mine in Utah.

Mr. Petersen has a Bachelor of Science degree in Geology and Masters of Science degree in Hydrogeology from Brigham Young University. Mr Petersen has authored Probable Hydrologic Consequences determinations and prepared hydrologic monitoring plans for many Utah coal mines. He has also had more than 10 years experience performing ground water age dating and stable isotopic investigations.

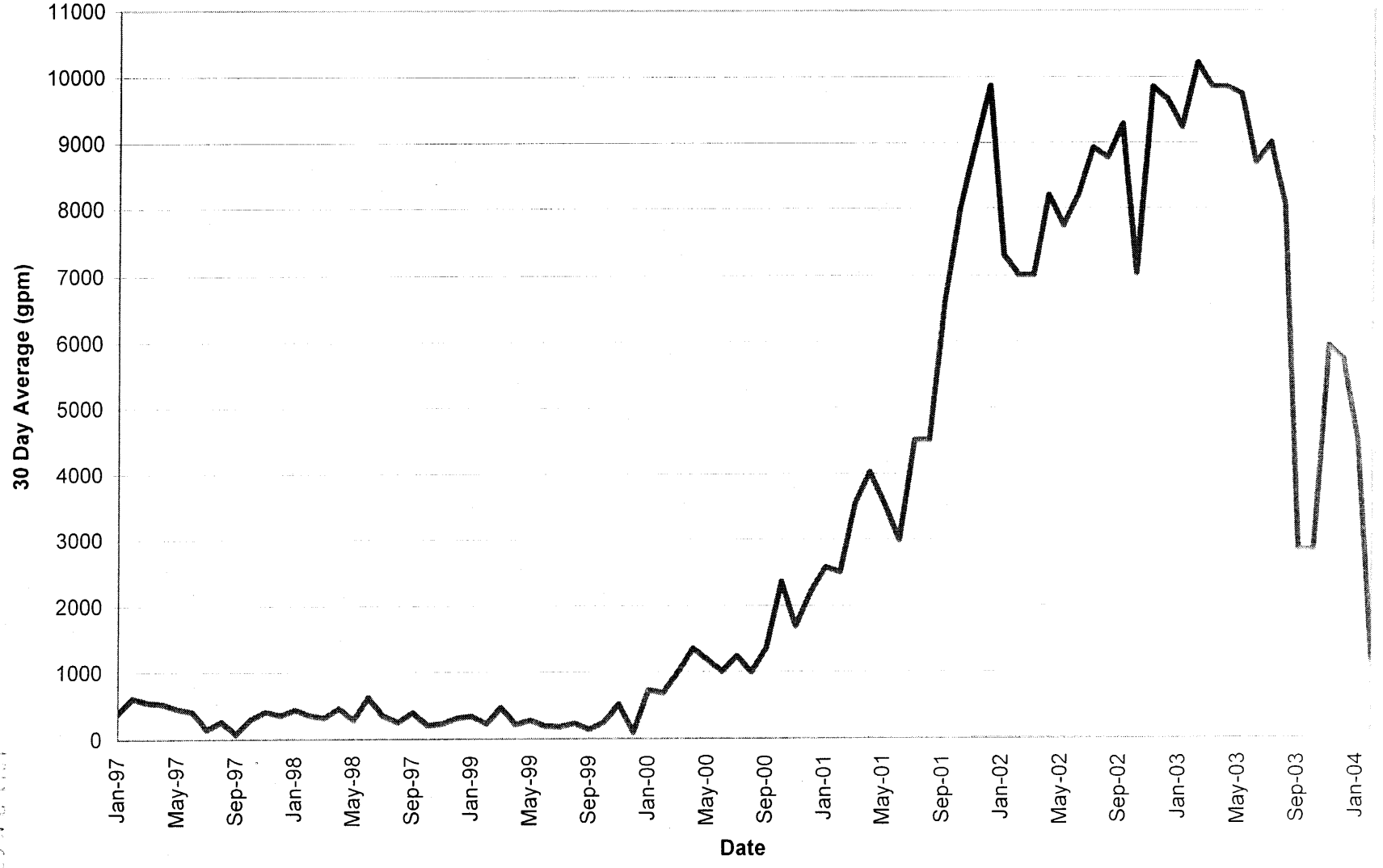
Introduction

This addendum to the Probable Hydrologic Consequences (PHC) has been included in this permit to address the effects of recent ground water inflows into the active mine workings of Skyline Mine 2, the completion of three ground water wells in James Canyon near the southwest extent of current mining constructed to alleviate mine in-flows, and the effects of discharging significant volumes of water to both Eccles Creek and Electric Lake. This addendum describes the effects to the surface waters and ground waters within the permit and adjacent areas of the recent inflows to the mine and the pumping of the James Canyon wells. This addendum contains this introduction, a discussion of the recent mine inflows, the effects of the flows on both surface and ground water, and conclusions. Appendices to this addendum contain graphs, discussions, and tables concerning monitoring data of numerous spring, well, and stream monitoring sites, reports by consultants related to water issues at Skyline, and reports prepared by or for State agencies regarding the water quality of Scofield Reservoir. This addendum is included as supplemental information to the existing PHC and, in some cases, updates or supercedes information provided in the existing PHC. It is important to bear in mind while reviewing the consultants reports included in this addendum that data collected after publication of the reports may have resulted in updates and refinements to previous theories and conclusions.

History of Recent Inflows

Prior to January 1999, Skyline Mine discharged exclusively to Eccles Creek, a Price River tributary, at an average rate of approximately 350 gpm or less of water intercepted during mining (Figure PHC A-1). This volume was somewhat representative of the average inflows of ground water into the mine. Significant new inflows were encountered in March of 1999 during the development of the south end of the 14 Left panel in Mine 2 (Drawings PHC A-1 and PHC A-2). Ground water flowed into the mine from a small displacement fault at a rate of approximately 1,600 gpm. Initially the water flowed from both the roof and floor but soon only discharged from the floor. The water was captured and pumped to the abandoned workings of Mine 1 and Mine 3 (Drawing PHC A-2). Mine personnel anticipated that this inflow,

FIGURE PHC A-1
SKYLINE MINE DISCHARGE



as with previous significant inflows, would soon diminish and possibly cease altogether. However, in December 1999, another water producing fault was encountered in the headgate of the 16 Left panel. The inflow from this fault was initially estimated to be greater than 1200 gpm and resulted in significant mine flooding. This new water was also pumped to the abandoned Mine 1 and Mine 3 workings. By January 2000, the abandoned Mine 3 workings were flooded and water was pumped from behind the Mine 3 seals to the mine site sediment pond. Eventually, the water was pumped to the overflow structure of the sediment pond and directly to Eccles Creek. In March 2000, approximately 1,000 gpm of ground water was encountered in the West Submains near the head of 8 Left (Drawing PHC A-2). Water discharge rates from the mine to Eccles Creek were generally between 700 gpm and 1,200 gpm until September 2000. Pumping and piping changes made underground allowed the mine to discharge more of the stored water from Mines 1 and 3 and mine discharge flows reached about 2,400 gpm in March of 2001.

Additional mine inflows were encountered during development mining in the 9 Left panel area in March of 2001. At nearly the same time, additional pumping capacity was added to the mine water system allowing more of the water stored in Mine 1 and Mine 3 to be discharged. This increased the total discharge from the mine from 2,400 gpm to between 3,500 to 4,500 gpm. Significant water inflows were encountered in the development of the 10 Left panel of Mine 2 in August 2001. The new inflows from this area of the mine alone were initially estimated to be approximately 6,000 to 6,500 gpm but shortly thereafter stabilized at about 4,500 gpm. The new water flooded significant portions of the mine, caused a halt in production, and required emergency action by the mine to deal with the water. Several tens of miles of 8- to 28-inch diameter steel and HDPE pipe were laid within the mine to pump water to other active and inactive workings as well as to the surface and Eccles Creek.

In February and March of 2002, three additional inflows of approximately 1,000 gpm to 1,500 gpm were encountered in the headgate and set-up room of the 11 Left panel (Drawing PHC A-2). Decreases in the flow rates of the 14 Left, 16 Left, and 10 Left ground water inflows have occurred over time. As of June 2002, the flow rates in the 14 Left and 16 Left had dropped to approximately 800 gpm each (these areas are not accessible as of June 2002). The flow rates

in the 10 Left area in the first week of July 2002 appeared to have dropped to approximately 4,700 gpm or less. In the last week of September 2002, the inflows in the 10 Left area were estimated to be approximately 3,200 to 3,800 gpm. In October 2002, the 10 Left area was sealed and flooded. The 10 Left and 9 Left areas were allowed to partially fill with water up to the entrance of the 8 Left panel. Seals and a containment dam were built in this area and the water is pumped from behind the seals to Eccles Creek.

The total discharge rate from the mine in June 2002 averaged approximately 8,200 gpm but measurements in the first week in July indicated that discharges increased to approximately 9,200 gpm due primarily to the draining of Mines #1 and #3. From July to September 2002, the discharge volume fluctuated between approximately 8,400 gpm and 9,400 gpm due to an increase in new ground water inflows encountered in the 11 Left panel. While this water was originally encountered in February and March 2002, a great deal of time was involved in getting pumps, piping, and the collection systems set up. Frequently, water from new inflow locations encountered during mining is sent to gob areas such as the 14, 15, and 16 Left panels or the abandoned portions of Mines 1 and 3 to allow for the suspended load to drop out of the water column. Water removed from the active mine faces in the 11 Left panel has been pumped both to the south end of the 14, 15, and 16 Left gob areas and to Mine 1. Until October 2002, water in the 14, 15 and 16 Left gob area was picked up on the north end of the panels and pumped to the surface to temporary sand filters. After the water passed through the sand filters, it was discharged directly to Eccles Creek. The portion of the water pumped to Mine 1 dropped into the southeast end of panels 1 Right, 2 Right, and 3 Right. This water moved through the gob and passed through 2-inch diameter drill holes connecting Mine 1 with Mine 3 at the west-northwest end of each panel (Drawing PHC A-2). Eventually, this water was pumped from Mine 3 and directly to Eccles Creek. Water pumped from the 10 Left area and the West Submains contained very little suspended load and was pumped directly to temporary sand filters and then to Eccles Creek. Table PHC A-1 summarizes this information.

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Skyline Mine sealed the 8, 9, and 10 Left area of the mine in September 2002 and flows from this portion of the mine were reduced by approximately 20 % as the area flooded and hydrostatic head built on the inflow point. Additionally, while the 10 Left area flooded, a decrease of about 3,200 to 3,800 gpm of mine discharge occurred for about 24 days. Seals and a retention dam were built at the entrance to 8 Left Diagonal Mains and pumps were installed to take water from behind the seals and discharge it to Eccles Creek. Also, the majority of the clean water encountered in the 11 and 12 Left areas of the mine was pumped behind the 8 Left seals. This allowed for a simplified pumping system to be installed where most of the water encountered in the southwest area of the mine could be picked-up at one location and pumped to Eccles Creek. The water laden with coal fines generated during mining activities in the 11 and 12 Left panel areas is pumped through a horizontal borehole into the 14, 15, and 16 Left sump.

In October 2002, the sand filters were removed from the mine water discharge system since the 14, 15, and 16 Left sump was fully functional and the 8, 9, and 10 Left areas were sealed. All water carrying suspended solids is directed through underground sump systems and allowed settling time before discharge. This allowed the mine to remove the expensive sand filtering systems and still discharge water without suspended loads and compliant with the Mine's UPDES Permit.

Skyline Mine has removed a portion of the water previously stored in the abandoned Mine 3 workings in advance of mining new areas to the north. The dewatering started about the same time as the 10 Left flooding occurred. Dewatering is accomplished by withdrawing 1,100 to 2,000 gpm of water from Mine # 3 through a series of in-mine horizontal boreholes. In July of 2003, the discharge rate of water from the Mine #3 area dropped to between 100 and 400 gpm, the rate being dependant upon the mines ability to discharge water from the horizontal boreholes from Mine #3 to the 14, 15, 16 Left sumps. New ground water inflow points were not encountered in panels 12 Left A and 12 Left B and the mine discharge has diminished gradually over time.

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TABLE PHC A-1

MINE INFLOWS				
Location	Initial Volume gpm	Date	Current Volume March 2004	Current Discharge Location
14 Left Headgate Fault	1600	Mar-99	300*	To Eccles Creek
16 Left Headgate Fault	1200	Dec-99	300*	To Eccles Creek
West Submains Fault	1000	Mar-00	209**	To Eccles Creek/JC-3
10 Left Fault	6200	Aug-01	3200*	To JC-3
East Submains XC 5	1000	Oct-01	380**	To JC-3
11 Left Headgate XC 24	1000	Feb-02	500***	To JC-3
11 Left Headgate XC 40	1000	Feb-02	700***	To JC-3
11 Left Set-up Room	1500	Mar-02	700***	To JC-3

*Flows estimated from pumping rates.
**Flows measured 1-7-04 before sealing area.
***Flows estimated from pumping rates prior to sealing area in January 2004.

Revised 03/2004

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The proposed timetable for abandoning the mined out areas of Mine #2 has been included with this document as Appendix F. This timetable was prepared on October 1, 2002 and distributed at Skyline Mine in the form of an Internal Correspondence addressed to the Mine Manager. Four figures accompanied the document and illustrated the locations within the mine to be abandoned and flooded. The document itself discusses the timing of abandonment, the location of present significant inflows into the mine with initial and current estimated inflow rates, and anticipated inflow rates after flooding has occurred. Following is a brief discussion regarding the timing of mining and flooding of the mined areas of Mine #2.

The 10 Left area of Mine #2 was abandoned in late September 2002. The pumps that were used to remove water from the 10 Left area and the southern portions of the 8 Left and 9 Left panels were removed. Seals were constructed at the entrance to the 8 Left panel and Diagonal Mains where the water was expected to rise and pump stations were established to handle the water once it flooded the 10 Left and western portions of the 9 Left panels. The initial estimate of the volume of water to be pumped from these seals was approximately 2500 gpm. However, actual volume was estimated to be slightly more than 3000 gpm after the area was flooded. The 10 Left area of the mine was abandoned to reduce the cost of maintaining a mined out portion of the mine and improve mine ventilation.

Skyline Mine completed mining the 11 Left, 12 Left A, and 12 Left B panels in December 2003. Seals were built at the head of the 7 Left panel. In January 2004, the 11 Left, 12 Left A, and 12 Left B panel areas were allowed to flood. JC-3 was operated at rates between 2,980 and 5,100 gpm, thus maintaining the water level behind the 8 Left seals at an elevation less than the base of the seals. It was anticipated that after the 11 Left, 12 Left A and 12 Left B panel areas flood and JC-3 operated at approximately 3,000 gpm, the water level in the mine would rise to the of the 6 Left panel by August 2004 and spill over into the 14 Left area. .
A follow-up modeling report prepared by HCI (Appendix K) in June 2004 suggests that water may not flow over into the 6 Left panel once water reaches an elevation of 8290 feet. This

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scenario is based on assumption that as the head builds on the groundwater inflow points in the flooded portions of the mine, inflow rates will significantly decrease.

In May, 2004, the 6 Left B panel was completely mined and seals were built to completely seal the mined areas south of the West Mains (panels 1 Left through 6 Left). By the end of 2004, the only areas of Mine #2 that will be ventilated will be the West Mains to allow access to the 14, 15, 16 Left sump. Leaving these mains open will allow access to the area west of sump if additional mining is deemed economically feasible.

Once mining is completed at Skyline and the mine abandoned, the water level in the flooded portions of the mine may reach as high as approximately 8550 feet above sea level. Since the lowest most portal is approximately 8580 feet above sea level, it is not anticipated water will discharge from the mine.

In addition to pumping water from within the mine to Eccles Creek, two ground water wells were drilled and completed in James Canyon in September and October 2001 (Drawings PHC A-1 and PHC A-3). JC-1 was completed with 14-inch casing and screen while JC-2 was completed with 20-inch casing and screen. Both wells were screened in the Star Point Sandstone approximately 70 feet below the current mine workings in the Lower O'Conner B seam. JC-1 encountered a significant fracture and initially produced about 2,200 gallons per minute using a 600 hp down hole electric pump. JC-2 did not encounter significant fractures and produced approximately 320 gpm using a 300 hp down hole electric pump. JC-2 was operated for only a short period of time and has not operated since December 2001.

In October 2002, PacifiCorp installed a new pump into the JC-1 well and it is currently producing approximately 4,200 gpm. This new pump was placed in the well to increase the discharge of ground water to Electric Lake to further decrease the volume of water flowing into the mine workings at 10 Left and to increase water available to downstream water users

including the Huntington Power Plant. Operation of the pump beyond that time will depend on how fast the lake refills during spring runoff and the length of time Skyline Mine plans to be mining in the area.

In March and April of 2003, PacifiCorp began drilling a third well, JC-3, at the James Canyon well site to intercept the mine workings in the 10 Left area. The well was completed in July 2003 and began pumping water on July 27, 2003. The purpose of this well is to remove water from the mine as close as possible to its inflow point in 10 Left and discharge it to Electric Lake. The JC-3 well has a down hole casing diameter of 24-inch and is screened through the mine works. PacifiCorp, with Skyline Mines aid, obtained a UPDES discharge permit to allow discharge of mine water to the lake. The pump is controlled by a variable frequency drive allowing PacfiCorp to produce between 1,500 and 6,200 gpm of mine water. The volume of discharge will be dependant upon meeting water quality standards set by the Utah Division of Water Quality UPDES permit.

Water discharged from JC-1 and JC-3 is piped from the James Canyon well site to Electric Lake through a buried 16-inch HDPE pipe. When initially constructed in September 2001, the end of the 16-inch pipe was submerged approximately 8 feet below the water level of Electric Lake. A 90-degree elbow was attached to the pipe at approximately 45 degrees above horizontal to avoid disturbing sediments on the bottom of the lake. However, continuing drought conditions in 2001 and 2002 resulted in the lake water level dropping below the end of the discharge pipe. A small area of lake sediments were washed away and the water discharged onto large rocks and cobbles on the surface of the pre-lake ground surface, in effect creating its own rip-rapped energy dissipation area. In July 2003, PacifiCorp constructed a riprapped energy dissipater at the outlet of the pipe to prevent further erosion of the lake sediments.

The James Canyon wells are considered to be mine dewatering wells. A UPDES permit, however, is only required for the discharge of JC-3 since this is the only water coming directly from the mine works. JC-1 and JC-2 are completed in the Star Point Formation and do not intercept the mine works.

A geologic cross section through wells/drill holes W2-1, JC-1, JC-2, W79-35-1, 75-26-3, 74-26-2, and 79-22-1 has been provided as Drawing PHC A-4. The location of the mined coal seams, faults, apparent dip of the beds along the cross section, and a site index map are provided. Also, the location of the mine in-flows of ground water have been projected horizontally to the cross sections. The location of selected springs have been illustrated on the cross section. The elevation of Electric Lake and the dates these measurements were taken are illustrated on the wells with ground water levels.

Effects of Intercepted Water within the Mine on the Local Ground Water Systems

Skyline Mine has continued to monitor ground and surface water flows at all of the Mining and Reclamation Plan (M&RP) required water monitoring sites. No discernable impacts to surface springs or surface waters from the increased ground water inflows to the mine has been observed to date. Specifically, quarterly flow monitoring of seeps and springs in the Huntington Creek drainage area indicates the significant inflows of ground water to the mine and pumping of the wells in James Canyon has not had an observable effect on ground water discharges in these areas. Furthermore, historical spring and seep data do not indicate a reduction in spring, seep and stream flows related to mining.

Included in this document in Appendix A are several graphs generated from measurements of springs and stream flows and well water levels located throughout the Skyline Mine permit area. Each graph illustrates the discharge or water levels compared to the Palmer Hydrologic

Drought Index (PHDI) for Region 5, which includes the mine area, from 1982 to May 2002. Data from the following springs, stream, and well monitoring locations have been graphed: springs S15-3, S22-11, S24-12, S26-13, S34-12, S35-8, S36-12, 2-413; stream monitoring point Burnout Creek F-5; and wells W2-1, W20-4-1, W20-4-2, W99-28-1, W99-21-1,W79-14-2A, W79-10-1, W79-35-1A, W79-35-1B, and W79-26-1. Also, a single graph illustrating the water levels in W79-35-1A, W79-35-1B, W2-1 and the PHDI is presented to compare the effects of mine dewatering on the three wells. Graphs of transducer data for wells W79-35-1A, W20-4-1, and W2-1, which are completed in the Starpoint Sandstone beneath the mine, are presented to illustrate in greater detail the recent draw down of the wells. These last three graphs can be found following the graphs containing the PHDI. Accompanying each spring, stream and well graph is a brief comparison of the discharge or water level and the PHDI. Table PHC A-2 contains a summary of the well completion and water level measurement data for the Skyline Mine water monitoring wells.

Spring discharges, as shown in the graphs, aptly illustrate that almost all discharges from the shallow ground water aquifers are controlled by the fluctuations in yearly precipitation or drought cycles as illustrated by the PHDI. A notable exception is spring S24-12. The graph appears to illustrate a significant drop in spring discharge beginning in 1989. However, as presented in the text attached to the graph, the apparent change in discharge is related to a minor shift in the location of the discharge and not in the total volume of water released from the aquifer in the spring area.

Several springs, for which graphs of flow data have been provided, have been undermined since mining began at the Skyline Mine in 1982 (Drawing PHC A-3). As stated above, the fluctuations in spring discharge are easily related to fluctuations in climatic conditions and not mining activity. The relationship between spring discharge and mining activity was studied in great detail as part of an EIS performed by the Manti-La Sal National Forest for the Flat

TABLE PHC A-2

WELL SUMMARY DATA

Well Designation	Other Designation	In Monitoring Plan, yes/no	Formation Name & Type	Screened Interval, Top & Bottom Elevations, Mean Sea Level	Date & Current Water Level Elevation, Mean Sea Level	Historical Range of Water Level Elevation, Mean Sea Level	Name of Associated Coal Seam	Vertical Distance From Screened Interval to Associated Coal Seams (Above or Below)	Well Location, Township, Range, & Section
W10-1	W79-10-1A*	Yes	Star Point - Sandstone (Storrs Tongue)	7393.0-7373.0	5 Sept. 2002, 9017.3	9034.6-8891.7	Lower O'Connor "A"	Through Coal Seam	T 13 S, R 6 E, Sec. 10
	W79-10-1B	No							T 13 S, R 6 E, Sec. 10
W14-2	W79-14-2A*	Yes	Star Point - Sandstone (Storrs Tongue)	8342.0-8322.0	5 Sept.2002, 8947.5	8992.04-8963.1	Lower O'Connor "A"	Through Coal Seam	T 13 S, R 6 E, Sec. 14
	W79-14-2B	No							T 13 S, R 6 E, Sec. 14
	W79-22-2-1	No							T 13 S, R 6 E, Sec. 22
W22-2	W79-22-2-2	No							T 13 S, R 6 E, Sec. 22
W26-1	W79-26-1*	Yes	Blackhawk - Sandy Siltsone	8411.0-8391.0	15 Aug 2002, 8919.2	8976.5-8902.9	Lower O'Connor "B"	Through Coal Seam	T 13 S, R 6 E, Sec. 26
W35-1	W79-35-1A*	Yes	Star Point - Sandstone (Storrs Tongue)	8092.0-8072.0	10 Sept 2002, 88381.6	8557.4-8195.19	Lower O'Connor "A"	5' Below Coal Seam	T 13 S, R 6 E, Sec. 35
	W79-35-1B	Yes	Blackhawk - Sandy Siltsone	8542.4-8504.4	10 Sept 2002, 8552.7	8591.5-8547.9	Not associated with coal seam		T 13 S, R 6 E, Sec. 35
W2-1	98-2-1	Yes	Blackhawk - Sandy Siltsone	8030.4-8000.4	2 Aug 2002, 8364.4	8551.4-8364.4	Lower O'Connor "B"	Through Coal Seam	T 14 E, R 6 E, Sec. 2
JC-1		Yes	Star Point - Sandstone (Storrs Tongue)	7918.0-7858.0	No Current Data	No Current Data	Lower O'Connor "B"	11.5' Below Coal Seam	T 13 S, R 6 E, Sec. 35
JC-2		No	Star Point - Sandstone (Storrs Tongue)				Lower O'Connor "B"		T 13 S, R 6 E, Sec. 35
JC-3		Yes	Star Point - Sandstone (Storrs Tongue)	8061.7-8018.0, 7730.5-1-7711.1	Not Yet Completed	No Data Available	Lower O'Connor "B"	Though Coal Seam	T 13 S, R 6 E, Sec. 35
99-4-1		Yes	Blackhawk - Sandy Siltsone	7551.0-7521.0	10 Sept 2002, 8520.5	8571.2-8520.5	Lower O'Connor "B"	Through Coal Seam	T 14 S, R 6 E, Sec. 4
99-21-1		Yes	Star Point - Sandstone (Panther Tongue)	7431.3-7401.3	24 Sept 2002, 8322.6	8419.5-8322.6	Flat Canyon (Middle Seam)	Through Coal Seam	T 13 S, R 6 E, Sec. 21
99-28-1		Yes	Star Point - Sandstone (Panther Tongue)	7477.0-7447.0	24 Sept 2002, 8377.3	8510.0-8377.3	Flat Canyon (Middle Seam)	Through Coal Seam	T 13 S, R 6 E, Sec. 28
20-4-1		Yes	Star Point - Sandstone (Storrs Tongue)	7491.0-7464.0	27 Sept 2002, 8490.7	8559.0-8490.7	Lost Core	Lost Core	T 14 S, R 6 E, Sec. 4
20-4-2		Yes	Star Point - Sandstone (Storrs Tongue)	7574.0-7544.0	10 Sept 2002, 8420.5	8532.0-8420.5	Lower O'Connor "A"	16' Below Coal Seam	T 14 S, R 6 E, Sec. 4
20-28-1		Yes	Blackhawk - Sandy Siltsone	7420.0-7390.0	24 Sept 2002, 8393.7	8403.8-8393.7	Lower O'Connor "B"	Through Coal Seam	T 13 S, R 6 E, Sec. 28
91-26-1	North Lease	Yes	Blackhawk - Sandy Siltsone	7698.1-7668.1	9 Sept 2002, 7941.0	7941.0-7937.1	Lower O'Connor "B"	Through Coal Seam	T 12 S, R 6 E, Sec. 26
91-35-1	North Lease	Yes	Blackhawk - Sandy Siltsone	7616.9-7586.9	5 Sept 2002, 8011.4	8033.9-8011.4	Lower O'connor "B"	Through Coal Seam	T 12 S, R 6 E, Sec. 35

Note:

* The screen interval was determined by using the lowest minable coal seam; the screen was placed 3 feet below top the coal seam; and a 20 foot screen was installed.

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Canyon Tract located west of the existing mine leases. The study was performed by Norwest in the summer of 2000. The water monitoring data compiled by the mine since mining activities began in 1982 were studied for any effects on surface and shallow ground water discharge. The conclusion of the study was there is very little evidence that undermining or mining within the vicinity of the springs in the Skyline Mine area has resulted in the diminishment of discharges from the springs. A copy of the Norwest study has been provided in Appendix B of this document.

A comparison of the water chemistry of five springs, the JC-1 well, and three in-mine sample locations has been provided in Appendix A. Stiff Diagrams are provided for springs S22-11, S26-13, S34-12, S35-8, 2-413 and the James Canyon well JC-1. Stiff Diagrams are also provided for water samples obtained from the 10 Left Entry 3 Borehole, Fault Crossing at the West Submains (now referred to as the East Submains), and the 9 Left Horizontal Borehole. A notable difference between the spring water and the James Canyon and in-mine waters is the amount of magnesium in the water. Significantly greater amounts of magnesium are found in the mine and well water than in the spring waters.

Notable differences in the chemistry of intercepted ground water in the mine and the waters found in Electric Lake were found by Hydrologic Consultants, Inc. (HCI) of Lakewood, Colorado. HCI was contracted by Skyline Mine in August 2001 to aid in determining the source of the ground water entering the mine and to help the mine determine how long the inflows could be anticipated to continue, HCI initially submitted a brief report to Skyline in November 2001 regarding where they thought the water coming into the mine may be originating. Subsequent to their initial report, more data were gathered concerning water chemistries, monitoring well data, and water age dating information (tritium and carbon 14). A copy of their second report is included as Appendix C. Briefly, the conclusion of their report (page 12) was that chemical and isotopic differences between water entering the mine and Electric Lake suggested strongly that no direct conduit exists between the mine and the lake.

Petersen prepared a report titled "Investigation of Fault-related Groundwaters Inflows at the Skyline Mine, 27 October 2002". This report is included as Appendix G to this document. This report expands upon the data presented and conclusions of the Petersen Report in Appendix A and the HCl report in Appendix C. Petersen evaluated the chemical composition of the in-mine and surface waters. He concluded that water in the 10 Left area is significantly dissimilar to surface waters and surface waters cannot evolve chemically into the 10 Left waters in the hydrogeologic environment of the mine (Petersen, October 2002, Appendix G, Section 6.5, p. 17). Following is excerpt from his report that details the differences between surface and in-mine waters:

> "Likewise, solute and isotopic data indicate the Electric Lake cannot be a major source of the fault-related groundwater that is flowing into the Skyline Mine. Based on the solute compositions of Electric Lake water and water from the fracture system associated with
> the 10 Left inflow, it is readily apparent that the water flowing into the mine is chemically distinct from that in Electric Lake. The recent solute chemical composition of the 10 Left inflow water and Electric Lake water are summarized in Table 5. Most notably, the average chloride content of the water in Electric Lake (6.5 mg/l) is nearly four times greater than the average chloride content in the fault-related systems (1.7 mg/l). Chloride is considered a conservative species, meaning that the constituent is not attenuated from a groundwater system, other than by dilution (Fetter, 1988). In other words, there is no mechanism whereby the chloride in the lake water could be removed were it to flow through a fault system, regardless of the residence time in the fracture. Although the calcium contents of the in-mine and lake water are similar (Table 5), the magnesium and bicarbonate content of the waters are dissimilar. The average bicarbonate content of the fault-related groundwater (216 mg/l) is approximately 50% greater than the average lake content (148 mg/l). The average magnesium content of the fault-related groundwater (23.0 mg/l) is more than three times that of the average lake water (7.5 mg/l). Mineral saturation indices for calcite, dolomite, and gypsum are

listed in Table 5. Saturation indices at 0 ± 0.1 indicate that a water is saturated with respect to that mineral. Waters at saturation with respect to a mineral will not dissolve additional quantities of that mineral or precipitate the mineral should the water come into contact with it. Waters with a saturation index less than 0 are undersaturated with respect to that mineral. Undersaturated waters have a thermodynamic tendency to dissolve that mineral if it comes into contact with the water. Waters with a saturation index above about 0.1 are supersaturated and have a tendency to precipitate that mineral. Electric Lake waters are supersaturated with respect to both calcite and dolomite, indicating that they have the thermodynamic tendency to precipitate rather than dissolve those minerals. Thus, in the absence of an external source of CO_2, such as deep, metamorphic CO_2 or bacterially mediated organic decay (both of which are considered unlikely in the sandstones of the Star Point Sandstone), the lake water cannot dissolve carbonate minerals (likely the only plausible mechanism whereby the groundwater could acquire additional bicarbonate and magnesium) along a groundwater flowpath regardless of the residence time in the fracture system. That external sources of CO_2 have not influenced the carbon history of the fault-related groundwater is apparent in the $d^{13}C$ composition of these groundwaters (Table 2). As discussed previously, groundwaters with $d^{13}C$ compositions near -10‰ are consistent with the dissolution of carbonate minerals in the presence of soil-zone CO_2 gas. Groundwaters that have been influenced by metamorphic CO_2 or by biogenic CO_2 will likely have $d^{13}C$ contents that deviate significantly from -10‰."

Numerous age-dating samples of surface and in-mine waters have been obtained over the past nine years. Samples from springs, surface streams, and mine in-flows have been analyzed for tritium and carbon 14 content. This sampling has been done to monitor the ages of the water intercepted underground so that if surface waters, or "young" waters, were encountered, steps could be taken to determine its source and replace the waters at the surface, if necessary. Carbon 14 dates indicate that water intercepted underground ranges in age from 5,500 years to 25,800 years old. A single roof drip sample obtained in Mine 3 in

1996 was dated at 2,500 years old. Generally, tritium analyses of water intercepted in the mine indicates that none of the water is younger than 50 years old. Surface waters and most of the spring waters have been determined to be modern water based on their tritium content. Samples of water from shallow wells, W24-1 and W17-3, and from spring S17-2 analyzed for carbon 14 and tritium content indicate waters about 2,000 to 3,500 years old are mixed with modern water. The well samples suggest water from more than one aquifer is being produced from the JC-1. A table listing the location and ages of samples collected within the mine and permit area is provided in Appendix A.

Petersen (October 2002) discussed in detail the relationship between the stable isotopic composition and tritium and carbon 14 contents of the surface waters and mine waters. His results show significant evidence that the recharge water to the aquifer draining to the mine is fundamentally different from the overlying surface and shallow ground waters systems based upon their stable isotopic composition. Petersen (October 2002) states:

> "Stable and unstable isotopic data from Electric Lake, active-zone springs, and streams, indicate that these systems are not a primary source of the water in the fault-related Star Point Sandstone groundwater systems encountered in the Skyline Mine. As discussed previously, Active-zone groundwaters and surface waters in the region contain abundant tritium, have modern radiocarbon ages, and contain anthropogenic carbon. In contrast, the fault-related groundwaters have very old radiocarbon ages and contain little or no tritium (Table 2). In order to validate the conclusions that the isotopic compositions of groundwaters encountered in the fault-related Star Point Sandstone groundwater system are statistically different from those in Electric Lake, two tailed T-Tests were performed. The T-tests confirm that the fault-related groundwaters are statistically different from the Electric Lake waters based on each of their stable isotopic d^2H, $d^{18}O$ content and unstable tritium and radiocarbon contents at the 95% confidence level."

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Water level data obtained from wells W79-35-1A, W79-35-1B and W2-1 present a fairly distinct picture of the effects the mine inflows and pumping of the James Canyon wells is having on the aquifer beneath the mine and the lack of impact of an aquifer within the Blackhawk Formation above the mine. The graph labeled "Wells W79-35-1 A, B and W2-1" contains water level data for the two W79-35-1 wells beginning in 1982 and water level data for W2-1 beginning in 1999. The PHDI for region 5 is also plotted. Minor fluctuations in the water levels of the two W79-35-1 wells can be seen from 1982 through 1999. The fluctuations do not appear to be related to climatic conditions. Also, both wells appear to have a slight downward trend of the water level elevations. This downward trend is unlikely related to mining since mining did not occur in this area until the mid 1990's. W79-35-1A is completed at a depth of approximately 1000 feet below ground surface into the Starpoint Sandstone, while W79-35-1B is competed to a depth of approximately 220 feet below ground surface. W2-1 is completed to a depth of approximately 1,520 feet below ground surface. In 1999, a sharp decline in the water level in W79-35-1A began, probably related to the mine inflows encountered in 14 and 16 Left panels in Mine 2. In late 2000, a significant drop in the water level in W2-1 began. (This delay in the drop may be related to measuring error. The well is constricted at about 720 feet below ground surface and, until recently, often resulted in false positive readings at that elevation. The cause of the false positive reading is unknown.) The wells appear to be completed in the same fracture zone as the JC-1 well (Drawing PHC A-3). The drop in water level in these wells is undoubtably related to the mine inflow in both the East Submains and 10 Left. The steady decline in both W79-35-1A and W2-1 has continued to this date. However, W79-35-1B did not decline over the same time period as the other wells. The mine related drawdown effects that were observed in W79-35-1A and W2-1 and not in W79-35-1B strongly suggest a disconnect between the deep aquifer and shallow aquifer. In about October 2002, the water level in W79-35-1A appeared to slowly rise by approximately one foot until mid-December 2002. Since that time the water level has dropped about six feet. The slight rise in the water level and subsequent drop appears to be related to the approach and subsequent passing by of the well location of longwall mining activities. Since this well is

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located only a few hundred feet east of the 11 Left panel, this type of response to mining and subsidence is not unexpected. The change in water level in the well will continue to be monitored.

As discussed previously, the water encountered in the western- and southern-most portions of Mine 2 generally enters the mine through fractures in the floor. The potentiometric head on the water has been measured at up to 200 psi in horizontal boreholes that have been drilled into fractures and faults from within the mine. As illustrated on Drawing PHC A-4, water levels in wells W2-1 and W79-35-1A were several hundred feet above the mined coal seam prior to 1999. Also illustrated on the cross-section are Electric Lake water level measurements that were obtained within a few weeks of the well data. The level of the water initially in W2-1 was higher than the Electric Lake level but dropped below the lake level after the significant flows were encountered in the 14 and 16 Left panels in the mine. At the same time, the lake water level was higher than the ground water measured in W79-35-1A. Once the fractures in 14, 16, and 10 Left panels were encountered, the water levels in these wells began to drop noticeably and were consistently lower than the lake level.

Figure "W2-1 James Canyon South Ridge Transducer Data" (Appendix A), formerly provided as Figure PHC A-5 in an earlier version of the PHC James Canyon Addendum (November 2001), illustrates 1) there is hydraulic communication between the well and the 10 Left fractures; and 2) the fractures system in the Star Point Sandstone is being dewatered and depressurized as the result of 10 Left discharge and pumping JC-1. As evidenced by the stabilization and flattening of the recovery curve observed while the pump was off mid-November to mid-December 2002, the system is indeed being dewatered and not recharging at a significant rate. Activities related to mining, pump operation, discharge of water from the fracture to the mine have introduced numerous unknown variables to the aquifer system thus precluding more detailed analysis of the drawdown data.

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The water levels in these wells represent a potentiometric surface and not a saturated ground water table surface. As discussed in the PHC and extensively in Petersen (October 2002), the Blackhawk Formation forms an effective seal overlying the Starpoint Sandstone, thus creating a confined aquifer. No evidence has been found that water rose to the surface through any of the recently encountered fractures and faults. Indeed, monitoring of the surface seeps, springs, and streams overlying fractures and faults that discharge ground water to the mine indicate reductions in flow are most certainly related to climatic conditions and not mining activities as evidenced by the PHDI.

Drawdown and/or depressurization of the deep aquifer related to mine dewatering can also be observed in wells W20-4-1, W20-4-2, and W 99-21-1. These wells are located west of Electric Lake (Drawing PHC A-3). The graphs of the monitored water levels in these wells show some responses to changes in the operation of the JC-1 well. This suggests that the aquifer underlying the mine is continuous to the west. As discussed in the main body of the PHC, the calculated velocity of water passing through the Starpoint Sandstone is 0.01 foot per day. The rapid response of these wells and wells W2-1 and W79-35-1 to the mine dewatering suggest that the sandstone is fractured and water is moving toward the mine through these fractures.

No significant sustained inflows of water were encountered in Mine 1. However, as illustrated on Drawing PHC A-2, Mine 1 did not develop far enough west to mine through the fracture locations in the14, 16, 10, and 11 Left panels of Mine 2 that produce water.

The results of the age dating work at Skyline Mine suggest waters currently being intercepted in Mine 2 are "old" waters and not recharging directly from the surface. Age-date samples are periodically obtained both underground and from JC-1. Specifically, samples of the water from the 14, 16, 10, and some of the 11 Left panel inflow points have been obtained and analyzed for tritium and carbon 14 content. The results of the sampling and corresponding sampling

times are listed in Table 2 of the Petersen (October 2002) report. The tritium analyses in the 10 Left area and East Submains E1 XC 5 Fault site has not significantly changed since sampling began in these areas. Additional tritium and carbon 14 results for these sites is pending.

Since the initial start-up of the JC-1 well, periodic samples have been obtained of the discharge water and analyzed for tritium content. The results of the analyses are included as Table 2 of Appendix G. The average tritium value measured in the water discharged from the well since September 2001 is 2.00 TU. Initially, the first sample had a tritium concentration of 0.24 TU. Samples obtained between May and September 2002 had tritium concentrations ranging from 0.98 to 1.50 TU. In October 2002, PacifiCorp installed a pump in JC-1 capable of pumping approximately 4,200 gpm of water, approximately 2,100 gpm greater than the last production rate of the pump previously in the well. Initially, the tritium concentrations increased to 2.22 TU. but then declined to 1.71 TU. It appears that since January 7, 2003 the tritium concentration in the JC-1 well water has increased slightly to approximately 2.5 TUs. This suggests that between 6 and 29 percent of the water being pumped from the JC-1 well has a component of water that could be considered younger than 50 years old (The percentages are based on tritium concentrations measured in water samples from area springs and Electric Lake and range between 8.6 and 30 TU. Table 2 of Appendix G). During the same time period in which the tritium values have fluctuated in the JC-1 well water, no significant changes have occurred in the in-mine water ages.

HCI and mine personnel have attempted to determine the geometry of the aquifer that lies beneath the mine. Most of the coal exploration drill holes in the mine area do not penetrate more than a couple hundred feet into the Star Point Sandstone. However, logs from oil and gas exploration drill holes in the general permit area have been obtained and studied. From these drill hole logs, the thickness of the Star Point Sandstone is estimated to be approximately 900 to 1,000 feet thick in the permit area. The sandstone appears to thicken to

the west. The Star Point is not one continuous unit of sandstone but is comprised of interbedded sandstone, siltstone, and shale. While the sandstone fraction dominates the overall formation in the area, many of the sandstone tongues of the formation are separated by thin units of less permeable siltstone and shale. This relationship is illustrated on Plate III of HCI report (Appendix C).

HCI has prepared a ground water model of the aquifer within the Star Point Sandstone related to the discharges affecting Skyline Mine. One purpose of the model is to help the mine define the recharge and discharge locations of the Star Point Sandstone aquifer and determine potential impacts, if any, to surface waters and their beneficial uses. Several assumptions have been made on the volume, porosity, and transmissivity of the aquifer. However, to construct an accurate ground water model, several ground water monitoring points are needed. No additional monitoring wells in the permit area are planned at this time. Thus the model that HCI has produced contains a number of assumed aquifer parameters including the aquifer geometry. The summary report of the HCI model is included with this Addendum as Appendix J.

Currently, Skyline Mine believes the available data suggests the water entering the mine is sourced by the Star Point Sandstone. The water in the Star Point is under potentiometric head and is forced up through faults and fractures encountered during development mining. Water moves slowly out of the sandstone formation into the fractures and faults and then along the fractures and faults toward the mine (Petersen October 2002, pages 11 through 13). Vertical movement above the Star Point Sandstone is limited by the tight, impermeable beds of the Blackhawk Formation. The current mine inflows are depressing the potentiometric surface of the aquifer in the mine area (HCI Figure 6, Appendix C and Petersen Figure 4 Appendix G, HCI Figure 19 Appendix J). The boundaries of the aquifer discharging ground water to the mine from the Star point is illustrated on Plate II of the HCI Ground Water Model (Appendix J).

The boundaries of the Star Point Sandstone aquifer contributing ground water inflows to the mine as depicted by the HCI ground water model are the Gooseberry Fault on the west, Fish Creek Graben on the north, Pleasant Valley and portions of the O'Connor, Connelville, and Valentine Faults on the east, and the structural and topographic divide to the south in the Northern Joe's Valley Graben. The portions of the Gooseberry, Fish Creek, and Pleasant Valley Faults that define the boundary of the aquifer have significant displacement and juxtapose the Star Point Sandstone against the much less permeable Blackhawk Formation, thus forming a no-flow boundary. The segments of the O'Connor, Connelville, and Valentine Faults that form the eastern and southeastern aquifer boundary also have significant displacement and have juxtaposed of the Star Point Sandstone against the Blackhawk. Additionally, the segments of these three faults forming the eastern boundary in the mine area are down to the west in an areas where the regional dip of the stratigraphy is toward the west - southwest. A more detailed discussion of the both the aquifer and model boundaries is presented in Sections 3.2 and 3.3 of the HCI ground water model report included with this document as Appendix J.

The southern boundary of the aquifer is not a fault-related boundary as are those on the west, north, and east. The south and southwestern boundary of the model and aquifer is defined by a surface water divide between Joe's Valley and Paradise Creek Valley. The topography slopes away both to the north and south of the topographic high that forms this divide.

HCI has illustrated in their ground water model report the potentiometric surface of the aquifer has a gradient from south to north. This gradient is based on water level data from wells in place before and while mining occurred in the area. Figure 16 of the HCI report illustrates a projected potentiometric surface rising from south to north. If this is an accurate depiction of the pre-mining potentiometric surface within the Star point Sandstone in the mine area, it is therefore reasonable to assume that the source of the aquifer water is south of the mine and the Electric Lake basin.

Recharge to the Star Point Sandstone appears to be slow as evidenced by the continued draw down of the aquifer and the age of the in-mine water. The drawdown rate of 0.08 feet per day in W79-35-1A was calculated for the time period between April 17, 2002 and July 1, 2002 (6 feet of drawdown over 74 days). However, the drawdown rate has significantly slowed as the 8, 9 , 10, 11, 12A and 12B Left area of the mine has been flooded. In fact, the drawdown in this well has nearly flattened and may begin to rise as the southern and southwestern portion of the mine is allowed to flood.

According to HCI's first model report, the flows to the mine should diminish to approximately 3,700 gpm by 2013, assuming the mine remains in operation and no additional areas of the mine were flooded. Because mining conditions, mine plans, and flooding plans changed at Skyline after HCI first report, a follow-up model report was prepared by HCI in June 2004 (Appendix K). This new report included additional model runs to predict the impact of pumping water from the mine on surface flows in the surrounding drainages and the anticipated inflow rates of groundwater to the mine. The model predictive runs suggest that inflow rates to the mine from the 10, 11, 12A and 12B Left panel areas should diminish significantly as the flooding of the portion of the mine south of the main entries continues. In fact, the HCI model indicated that as the southern portion of the mine flooded and head built on the mine groundwater discharge points, inflow rates could drop to insignificant levels.

Skyline Mine began flooding the southwest portion of the mine when mining of the 6 Left B panel was completed. Water should fill the abandoned portions of the mine below the 8290 feet above sea level elevation. At that point, water will flow north from the head of the 6 Left B panel and into the 14 - 16 Left sump. Skyline intends to maintain the mine water at this elevation for the foreseeable future.

The discharge of water to the mine from the Star Point aquifer will cause the cone of depression already forming in the potentiometric surface to continue to grow. As discussed in

the HCI report, the effect of water removal from the Star Point should have minimal impacts on the down gradient discharge points. However, concerns have been expressed as to what effect the drawdown will have on discharge locations up gradient of the mine at an elevation at or above 8300 feet (the projected approximate elevation of the life-of-mine pool). The Star Point Sandstone is exposed in a small area up gradient of the mine within the boundaries of the aquifer discharging to the mine above the 8300 foot elevation. These exposures are located east of the Connelville Fault near the Electric Lake dam and southeast of the lake and the O'Connor Fault in Huntington Canyon. Small springs with minor flows have been noted discharging from fractured sandstones near the top of the Star point Sandstone and base of the Blackhawk Formation on the northeastern shore of Electric Lake (the fractures in the sandstone extend from top to bottom of the outcrop but the flow discharges from near the top suggesting the water is not related to the deep sandstone aquifer). More substantial flows have been noted from a spring with in the Star Point Sandstone downstream of the Electric Lake dam and adjacent to Highway 31 between Valentine Gulch and Hughes Creek (SE1/4 NE1/4 Sec. 24 T14S R6E). It is labeled as a sulfur spring on local USGS maps. Additionally, flows discharging from Valentine and Hughes canyons may be sourced from the Star Point. The surface flows and the sulfur spring are located above 8300 feet. The flows at these three locations will be monitored to determine if any impacts are occurring as the Star Point aquifer continues to discharge to the mine. Though these locations are east of the apparent aquifer boundary (Valentine Fault), they are the only reliable Star Point discharge locations with sustained flows within a close proximity to the mine and above the 8300 foot elevation.

As a source of verification of the predictions made in the hydrologic model (Appendix J and K), Skyline Mine commits to conducting an additional simulation of the model in 2006. An evaluation of the 2006 simulation will determine whether future simulations are necessary. The frequency of future simulations, if necessary, will be approximately every three (3) years.

Skyline Mine continues to provide periodic updates to the holders of the water rights in the mine area of the results of the studies the mine is performing to determine the sources and impacts of the mine dewatering on the area ground water resources.

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Effects on Surface Waters

Discharge from the Skyline Mine to Eccles Creek has steadily increased since January 1999 as discussed previously. The mine discharged water to Eccles Creek at a rate of approximately 9,500 to 10,500 gpm, with a portion of the water discharged coming from stored water in Mine #3 until August of 2003. After this date, the discharge from the mine to Eccles Creek dropped to about 3,000 gpm when discharge from Mine #3 was suspended and JC-3 went online and began pumping about 5,000 gpm to Electric Lake. Eccles Creek runs at near bank full conditions when the mine discharges at a rate of 9,000 gpm to 15,000 gpm. The channel has a fairly steep gradient, is well armored, often flows directly over bedrock, has few meanders, and has extensive vegetative growth on its banks (EarthFax, Appendix D). Several abandoned beaver dams have been or are in the process of being eroded. However, the rate of erosion is very slow and addition of sediments from the dams and ponds is slight.

Mud Creek has a much lower gradient than Eccles Creek and has increasing numbers of meanders as it approaches the town of Scofield. The channel banks and floors consist of fine grained sediment with minimal vegetative cover. At current discharge rates, the channel is not yet at bank full conditions and not subjected to significant erosion (EarthFax, Appendix D). Increased flow rates from the mine could impact this stream channel more significantly than the Eccles Creek channel if flows from the mine increase. However, Mud Creek has a significantly higher full carrying capacity than does Eccles Creek. EarthFax was contracted by Skyline to prepare and implement a work plan that involved locating several sites on both Mud and Eccles Creek where the stream channel morphology, vegetation, flow volume, and water chemistry would be monitored on a regular basis. The purpose of the monitoring is to determine what, if any, impacts may be occurring as Skyline Mine discharges large volumes of ground water to these creeks. The monitoring of these aspects of the Mud and Eccles Creeks will continue until at least one year after the mine discharge volume drops to or below pre-March 1999 discharge levels of approximately 350 gpm.

Scofield Reservoir was constructed to serve as flood control, storage for irrigation water, and a drinking water source for Price and the surrounding communities. It has a storage capacity of 73,600 acre feet of water. Assuming the mine continues to discharge at an average rate of approximately 10,000 gpm, this would add approximately 44 acre feet per day of water to the reservoir. This represent approximately 0.06% of the maximum daily storage capacity of the lake. Normally, Eccles Creek drainage contributes less than 1 acre foot per day of water during minimum baseline flow conditions.

The concentration of salts in the mine water discharged to Eccles Creek as measured by the Total Dissolved Solids (TDS) concentration was between 400 and 650 mg/l from July 2000 to June 2001. Between June of 2001 and February 2003, the average TDS concentration of the water discharged from the mine was less than 500 mg/l. Between March 2002 and September 2002, the TDS concentration in the mine discharge water was consistently less than 400 mg/l. Since September 2002, the TDS concentration has ranged between 425 mg/l and 625 mg/l. The increase in TDS since September 2002 is related to the discharge of additional stored Mine #3 water. The average concentration of TDS in Eccles Creek above the mine is slightly less than 300 mg/l with seasonal variations of concentrations between 165 and 435 mg/l.Skyline Mine's current UPDES permit allows the mine to discharge water with a concentration less than 500 mg/l without a volume limit. If the concentration of TDS in the discharge water is 500 mg/l or greater, the mine is limited to a maximum concentration of 1,310 mg/l and 7.1 tons per day of TDS.

Total Suspended Solids (TSS) concentrations in the mine water discharged to Eccles Creek have typically been within the limits set by the mine's UPDES permit. Over the past 10 years, infrequent exceedances of the limit have occurred. These occurrences have become rare since 1999 with one exception. In August 2001, a release of coal fines to Eccles Creek was reported by the mine to DWQ and DOGM. No significant environmental damage occurred as a

result of the release because of its short duration and minimal volume. Changes to the mine's water handling system were instigated to prevent future occurrences of this type of release. No increase in nitrogen or phosphorous compounds above background level has been detected in the mine water discharged to Eccles Creek for several years. A brief study on the effects of mine discharge with regard to total phosphorous was performed by EarthFax in December 2001 as part of the Flat Canyon EIS. A copy of the study is included in Appendix D. The results of this preliminary study indicate that it is unlikely that mine water itself will contribute significant concentrations of total phosphorous to Scofield Reservoir. However, since the Scofield Reservoir is a drinking water source for Price, a top cold water fishery in the State, and has been listed as an impaired water body by the EPA, increases in total phosphorous released to the reservoir is of special concern. Several studies have been conducted since the mid 1970's by the Utah Division of Wildlife Resources, Utah Department of Environmental Quality, and the USGS to determine the sources of phosphorous pollution in the lake. Copies of several of these studies are included in Appendix E. Generally, the studies have identified two significant sources of phosphorous pollution - sediments entering the reservoir and runoff from lands carrying animal waste into the lake. A report written 1992 by Harry Lewis Judd of the Utah Division of Water Quality, Utah Department of Environmental Quality titled "Scofield Reservoir Restoration through Phosphorous Control" suggest that as much as 29% of the total phosphorous load in Scofield Reservoir is delivered by Mud Creek. He sites the poor conditions of stream banks in the lower sections of the creek south of the town of Scofield and the recreational and industrial activities that occur in the drainage as the source of much of the sediment that contains the phosphorous that is detrimental to the lake's water quality. The idea that sediments transported to the lake by its tributaries is a significant source of phosphorous is supported by previous studies.

Beginning in 2002, the total phosphorous concentration in the water discharged into Eccles Creek from the mine has been monitored. Orthophosphate concentrations have historically

been monitored in the discharge water along with periodic monitoring for total phosphorous concentrations. A new monitoring plan to evaluate the effects of increased mine discharges on the stream channels of Mud and Eccles Creek was instigated in the summer of 2002. This study includes monitoring several locations on both creeks for changes in stream morphology and water chemistry. Two sites on Eccles and six sites on Mud Creek will be monitored for total flow, TDS, TSS, and total phosphorous. If significant increases in TDS, TSS, and total phosphorous or changes in stream morphology and/or plant communities are noted, the sources will be investigated. If they are related to Skyline Mine activities, remedial actions will be taken. These actions may consist of, but not limited to, armoring stream channel banks, planting of stream bank stabilizing vegetation, or redirection of some flows to the Huntington Creek drainage. Monitoring information is provided in the "Addendum to the Probable Hydrologic Consequences, July 2002, Appendix D and the work plan for monitoring is provided in Attachment 3 of Section 2.12. Future monitoring information will be provided in the Annual Report.

Total and dissolved iron concentrations in the water are typically below 1 mg/l, similar to background water concentrations. Nickel concentrations have reached as high as 40 μg/l. This concentration is well below the UPDES permit levels. However, it has been determined that levels greater than 15 μg/l in the mine discharge inhibits the reproductive capabilities of Ceriodaphnia dubia, an invertebrate used to biologically monitor the quality of water of industrial and municipal discharges. The mine is working with the DWQ to mitigate the effects of discharging nickel at concentrations below established discharge limits. No other elements or compounds of concern have been detected in the increased mine water discharge.

The increased mine discharges have been a benefit to Scofield reservoir. Scofield Reservoir has a capacity of 73,600 acre feet of water storage. Since August 2001, the mine has discharged approximately 36,352 acre feet (11,845,353,160 gallons) of water to the lake (May 1, 2004). The mine water discharge not only helps to alleviate some of the problems related to

the effects of drought within the Price River drainage area but is also helping to maintain the first class cold water fishery in Scofield Reservoir. Low lake levels in past years have resulted in increased water temperatures and deadly algal blooms. The added water discharged from the mine reduces the potential for algal blooms related to low lake levels.

As of October 2002, PacifiCorp has been discharging ground water from the James Canyon JC-1 well directly to Electric Lake (JC-2 has not operated as of October 2001). The rate of discharge from the well is typically between 3,700 and 4,200 gpm. The quality of the water is similar to the water of James, Huntington, Swen's and Little Swen's Creeks, the major tributaries to Electric Lake. TDS concentrations of the well water range between 175 mg/l to 205 mg/l (Appendix A). TDS concentrations in the waters of the tributaries range from 143 mg/l to 274 mg/l (Division EDI, Skyline Mine). Iron, both dissolved and total, concentration in the well water is less than 0.2 mg/l, similar to or less than stream and ground water concentrations in the Electric Lake basin. Nitrogen and phosphorous compounds have not been detected in the well water above background levels. Since the JC-1 well discharges ground water only, it is reasonable to assume that the chemical composition of the water is similar to the waters discharged by the seeps and springs in the area that feed the tributaries of Electric Lake.

The JC-3 well was permitted to discharge water from the mine workings to Electric Lake in July 2003 when PacifiCorp obtained a UPDES permit for the discharge. The pump in JC-3 is capable of producing at least 6,200 gpm. The water chemistry of the groundwater flowing into the 10 Left area of the mine has similar chemistry as the water described above. It is anticipated the chemistry will not significantly change during its short residence time within the mine works prior to being pumped to the surface. However, as the residency time of the water stored within the mine increases, the TDS and total iron concentrations will likely increase as soluble minerals within the coal and surrounding roof and floor rock go into solution. Samples of water were obtained from the 8 Left area, the upper end of the pool that feeds JC-3, before

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that portion of the mine was flooded. The TDS concentrations in those water samples was measured determined to be between 300 and 350 mg/l.

PacifiCorp has noted an increase in the TDS concentration of the water discharged from JC-3 over the past several months. The concentration in the water discharged from JC-3 appears to be directly related to the rate at which JC-3 is pumped, that is, the higher the rate, the higher the TDS concentration. In late June 2004, PacifiCorp began operating JC-3 at approximately 1,700 gpm to determine if this lower flow rate would reduce the TDS concentration in the water to less than 255 mg/l. If the lower rate reduces the TDS concentration in the discharge water, this would suggest that the rate at which water is flowing into the mine in the area of the intake to the well in the 10 Left area is somewhere in the neighborhood of 1,700 gpm.

PacifiCorp monitors the discharge from JC-3 for the parameters listed in the UPDES permit. The permit for the JC-3 discharge water has a limit of 255 mg/l TDS and less than 0.5 mg/l iron concentrations in the discharge water. Total phosphorous concentrations in the discharge water are monitored by Canyon Fuel on a quarterly basis. If the water quality of the discharged mine water does not exceed the UPDES quality limits, Electric Lake and Huntington Creek waters will not be degraded. The JC-3 well is anticipated to be operated while drought conditions persist in the area and the mine needs to maintain access to the West Mains. If either conditions changes, modification to the operation schedule of JC-1 and JC-3 may be appropriate. Appropriate regulatory organizations and water users will be notified of the operational changes. The mine anticipates there will be short-lived periods of time where the pumps may be taken off-line for maintenance purposes. Plans have been made underground to handle the increased inflows and discharges should this occur.

When JC-3 became operational and direct discharge from Mine #3 was suspended, the total discharge of mine water to Eccles Creek was reduced by approximately 5,000 to 6,000 gpm. As discussed previously and detailed in Appendix F, over time the overall discharge of mine

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water to Eccles Creek will be reduced as portions of the mine are abandoned and allowed to flood. The actual mine inflow and discharge rates will probably vary slightly from the numbers given in Appendix F and Appendix J, but the overall downward trend of the rates is expected to continue.

As discussed previously, water from the James Canyon wells is piped directly to Electric Lake. Initially, when the pipeline was laid, the end of the pipe was beneath the surface of the lake. This allowed water to be discharged without disturbing lake sediments. However, as the lake level dropped throughout the late summer and fall of 2001, the end of the pipe was exposed. This resulted in the slow erosion of the accumulated lake sediments in the immediate area of the pipeline discharge. The erosion of the sediments resulted in the moving of the material a short distance away from the pipeline to the standing lake level where they were redeposited. The pre-lake ground surface has been exposed and it consists of sands, gravels and cobbles. In July 2003, PacifiCorp constructed a riprapped energy dissipater at the outlet of the pipe to prevent further erosion of the lake sediments.

The capacity of Electric Lake is 31,500 acre feet of water. The reservoir was constructed and is operated by PacifiCorp to maintain a reliable source of cooling water to the Huntington Power Plant. Assuming the James Canyon JC-1 and JC-3 wells pump at a combined rate of 9,000 gpm (a current rate of 3,900 gpm from JC-1 and 5,100 gpm from JC-3), a daily average of approximately 40 acre feet of water would enter the lake. During low flow periods, the volume of water entering Electric Lake from all its tributaries is about 4,000 gpm or less. During high flow periods, inflows may be many times this rate, but accurate inflow records have never been kept. The discharge of the wells to Electric Lake represents 0.12% of the total maximum daily storage capacity of the lake. Since low flow periods generally occur when the lake is at or near its lowest annual level, the well water discharge volume should not significantly affect the daily operation of the reservoir. Indeed, in times of drought, the well water is a significant benefit to both the power company and downstream water users.

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The recent drought conditions in the Huntington Creek drainage have resulted in historic low water levels in Electric Lake. This has raised concerns of many of the downstream water users, including PacifiCorp and Huntington Cleveland Irrigation Company. These two entities hold the rights to the water stored in the Huntington Creek drainage. Because of the close proximity of the reservoir to the mine, many naturally have assumed water is entering the mine from the lake. However, age dating of the mine waters, a comparison of the water chemistry of the lake and mine waters, and the low permeability of the formations overlying the coal seam suggest that no direct conduit is present between the lake and the mine (Petersen October 2002). The maximum surface acreage of Electric Lake is 485 acres and a maximum depth of water at the dam is approximately 180 feet. Star Point Sandstone crops out downstream of dam and through Huntington Canyon. The Connelville and O'Connor Faults appear to extend to the south west and into Electric Lake. However, the age-dating and water chemistry data obtained from in-mine water samples does not suggest the faults transmit large volumes of water to the subsurface aquifers intercepted in the mine. Petersen (October 2002) states:

> ".... groundwater flow through the Star Point Sandstone occurs primarily through fracture openings and groundwater flow through the matrix of the sandstone occurs only at a very slow rate. Based on these findings, it is apparent that large volumes of leaking Electric Lake water cannot be the source of the large fault-related inflows in the Skyline Mine. If Electric Lake water was flowing through fractures directly to the 10 Left area, it would be anticipated that the "pulse" of lake water would arrive at the mine in a short period of time. This conclusion is reached because the fracture system in the local area between the lake and the mine has only limited storage potential. Thus, it would be necessary for the potential large volumes of lake water to migrate very rapidly through the fracture network to accommodate continued water movement from the lake into the fracture system. This condition can be likened to the movement of cars on the interstate freeway during rush hour. Because the total surface area available for cars is

limited, the only way to move a large number of vehicles over large distances it to move them rapidly. Calculations of the potential storage capacity of the fracture network in the vicinity of the 10 Left inflow and Electric Lake indicate that were a large inflow of lake water to be migrating through the fracture system, that water should have arrived in the mine in a period of several hours to several days (based on the amount of time required to fill the fracture volume). Based on stable isotopic evidence, solute chemical evidence, tritium concentrations, and radiocarbon contents, it is clear that this is not occurring (i.e., there is not a large slug of modern recharge water anywhere in the Skyline Mine). Similarly, if Electric Lake water were migrating through the pore spaces of the Star Point Sandstone, based on the low hydraulic conductivity of the rock (1.3×10^{-6} to 2.3×10^{-6} cm/sec), it is calculated that the time required for this water to reach the mine workings would likely be measured in the hundreds or thousands of years. Clearly, the lake water could not have migrated through the sandstone pore spaces in the short time that has elapsed since the fracture system was first encountered in the mine."

Skyline Mine continues to study the mine water in-flow problem in an effort to more effectively and efficiently mine coal. The results of these studies are shared with the water right holders and will continue to be shared with the Division.

If operation of the JC-1 and JC-3 wells continues to aid in reducing the overall volume of ground water entering the mine, the well may be operated for the life of mine or until the potentiometric surface of the aquifer has dropped below the mined coal seams. The operation of JC-3 is, and will continue to be, predicated upon the well producing water that is in compliance with the limits of the UPDES discharge permit PacifiCorp maintains for the well. It is reasonable to assume that as the potentiometric surface of the ground water is lowered, the efficiency of the pumps will decrease. This will result in lower rates of water pumped from the wells. Since it appears there is not a direct connection between the water being pumped from

the James Canyon wells and surface waters or surface discharges of ground water, continued operation of the wells should not affect the normal discharge rates of these waters. A table illustrating the daily and computed discharge volumes from the James Canyon wells through February 2004 is attached in Appendix A. More recent discharge data is available online at DOGM's web site.

Several reaches of Burnout Creek have been undermined beginning in 1993. Prior to mining, a study of the effects of undermining the creek was jointly funded by Skyline Mine and the Manti - La Sal National Forest. The study included monitoring the flows of the stream at several locations, monitoring changes to the stream morphology, and maintaining numerous photo monitoring points over the length of the creek. The study was essentially completed in 1998 and the results reported in 2002 by R.C. Sidle in Environmental Geology, volume 39. The conclusion of the study was that no significant impacts to the stream could be related to mining. Flows were not diminished in the stream and the morphology was not significantly modified by subsidence. Norwest used this report along with additional monitoring data to reach essentially the same conclusion (Appendix B). They found that climatic conditions greatly influenced flows in the creek and found no evidence of water loss due to mining induced subsidence. The graph illustrating the stream flows, as measured at flume 5 near the mouth of Burnout Canyon, from 1991 to the present and the PHDI for the same time period is included in Appendix A. The graphed flows demonstrate the changes in stream flow are heavily influenced by climatic conditions.

It is important to note that the June 2004 HCI report (Appendix K) does contain the results of predictive model runs performed to determine the impacts, if any, on the Fish, Mud, and Huntington Creek Drainages based on different mine operation scenerios. The predictions are based upon several different assumptions regarding the water elevations in the flooded portions of the mine, the rate of pumping the JC wells, and the contribution of water to the mine from various sources. These are predictive model runs based on several assumptions

concerning how the mine and wells will be operated in the future. As the basis for these model assumptions change (mining conditions and the operation of the JC wells), the actual impacts to surface and groundwater described in the predictive runs will undoubtably be different.

Conclusions

Significant new ground water inflows into the mine have been encountered since March 1999. The inflows have resulted in increases in the discharge volume of mine water to Eccles Creek. Additionally, two ground water wells have been drilled in James Canyon and one is being pumped in an effort to reduce the volume of ground water entering the mine. A third well will be pumping water from the 10 Left area of the mine to Electric Lake beginning in May, 2003. The water from these wells is discharged directly to Electric Lake. Continued monitoring of the surface seeps and springs and surface water flows in the permit area demonstrates that the increases in ground water inflows to the mine has not adversely impacted the volume of discharges of ground water to the surface in and adjacent to the mine area. Specifically, monitoring of selected wells, springs, and surface waters in Burnout and James Canyons has demonstrated there is no discernable affect to the flow of these water sources by the increase in ground water inflows to the mine. Indeed, most of the fluctuations in spring flows can be attributed to changes in climatic conditions. Analysis of the monitoring of the aforementioned waters further demonstrates the isolation of the ground water encountered in the mine from surface waters in the mine area as described in the existing PHC.

Increased discharges of mine water to Eccles Creek has resulted in near bank full channel conditions. Significant erosion has not been noted in the stream channel. However, if the high discharge volumes continue, erosion of the stream channel will occur at a rate faster than would occur without the mine water discharge. Since the stream channel is well armored and vegetated, increased bank erosion should still occur only at a very slow rate. The Mud Creek channel will need to be monitored closely for increased rates of erosion. Mitigation efforts may

be required for both stream channels if significant erosion is observed. Increased discharges to Scofield Reservoir has helped to alleviate the current drought conditions.

The chemistry of the mine water discharged to Eccles Creek is closely monitored. While TDS concentrations have been reduced in the mine water, the total volume of dissolved solids has increased. The mine is currently working with DWQ in an effort to mitigate TDS and nickel concentrations in the mine water discharge. No other significant chemical impacts due to increased mine water flows have been noted.

Discharges of water from the James Canyon wells should not have a significant impact on the quality of Electric Lake. The well water is piped directly to the lake, thereby eliminating concerns of over loading James Creek. The volume of water discharged to the lake from the wells is a small percentage of the total daily volume of the reservoir. The additional inflows should not adversely impact the operation of the reservoir. In fact, the discharge of ground water and the mine water to Electric Lake should be considered a benefit to the water users in the Huntington Creek drainage.

The operation of JC-3 will benefit the mine since it reduces the overall power, maintenance, and personnel costs associated with discharging mine water to Eccles Creek. If JC-3 were not operated, some or all of that volume of mine water would have to be pumped through the mine works and discharged to Eccles Creek, depending upon what portions of the mine are flooded. Operation of the well will reduce the discharge of water to Eccles Creek and increase the flow of water to Electric Lake. In times of drought, operation of JC-1 and JC-3 could significantly reduce the chance of the Huntington Power Plant needing to scale back their operations and could result in additional agricultural water to users downstream in Emery County.

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PHC ADDENDUM

APPENDIX A
CHARTS AND TABLES

The following graphs and text were prepared by Erik Petersen of Petersen Hydrologic. His statement of qualifications follow this page.

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Petersen Hydrologic

Erik C. Petersen

Education

1989, B.S., Geology, Brigham Young University

1993, M.S., Hydrogeology, Brigham Young University

Work Experience

2000-present, Petersen Hydrologic, Principal, Senior Hydrogeologist

1992-2000, Mayo and Associates, Consultants in Hydrogeology, Senior Hydrogeologist, Company Project Manager

Mr. Petersen has more than 10 years experiencing performing hydrologic investigations in the Wasatch Plateau and Book Cliffs coal fields. He has performed major groundwater and surface water investigations at nearly every coal mine in Utah.

Mr. Petersen has authored Probable Hydrologic Consequences determinations and prepared hydrologic monitoring plans for many Utah coal mines. He has also had more than 10 years experience performing groundwater age dating and performing stable isotopic investigations.

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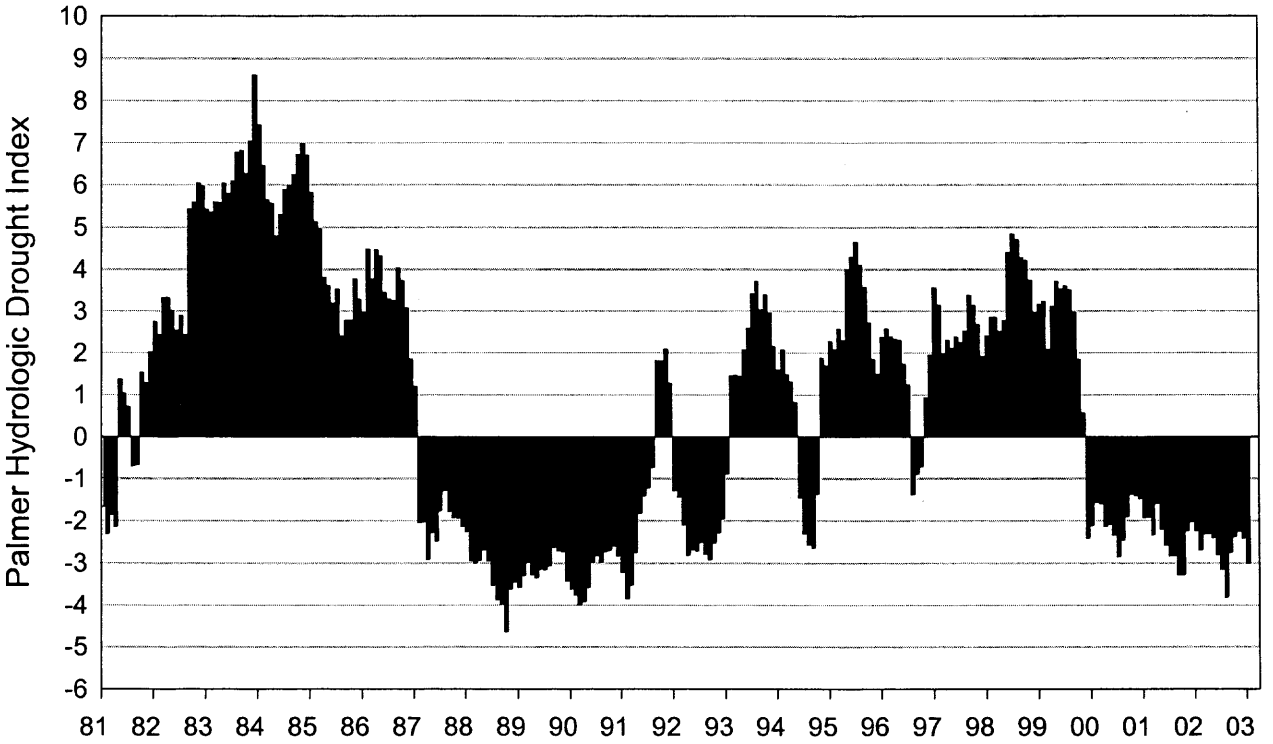
2695 N. 600 E. LEHI, UTAH 84043 (801) 766-4006



-1 to -2	Mild Drought	1 to 2	Mild Wet Spell
-2 to -3	Moderate Drought	2 to 3	Moderate Wet Spell
-3 to -4	Severe Drought	3 to 4	Severe Wet Spell
-4 to -5	Extreme Drought	4 to 5	Extreme Wet Spell

Palmer Hydrologic Drought Index, Utah Region 5 (Skyline Mine area).

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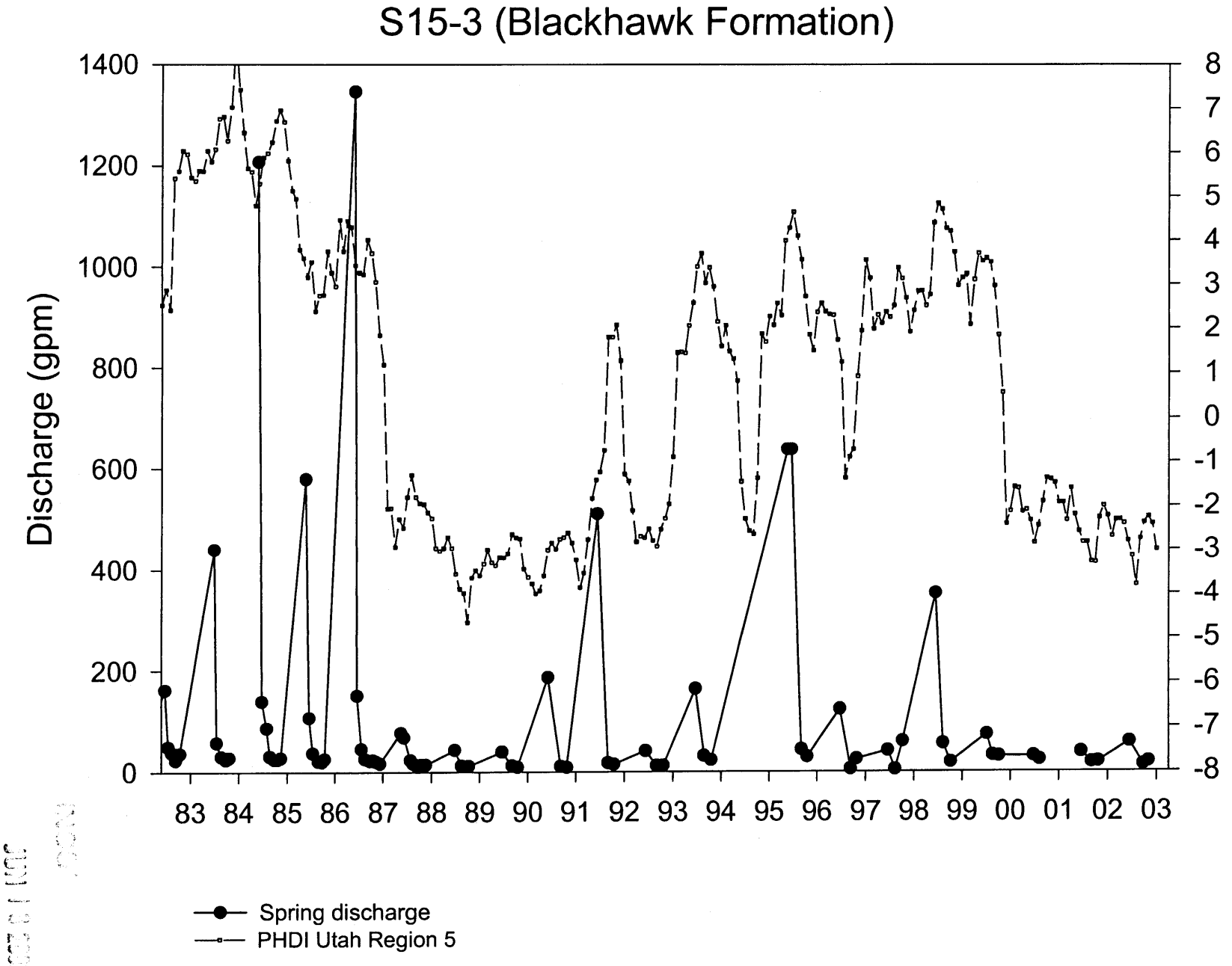
S15-3 (Blackhawk Formation)
Discharge (gpm)
1400
1200
1000
800
600
400
200
0
8
7
6
5
4
3
2
1
0
-1
-2
-3
-4
-5
-6
-7
-8
83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 00 01 02 03
Spring discharge
PHDI Utah Region 5

S15-3

Discharge from spring S15-3 responds rapidly to the annual springtime snowmelt event and shows a strong response to climatic trends. In particular, peak discharges are highly sensitive to climatic conditions. During wet cycles, peak discharges exceeding several hundred gpm are common, while during periods of drought, peak discharges from the spring are commonly less than about 80 gpm. Baseflow discharge rates from the spring during dry years are commonly less than 10 or 20 gpm.

The fact that the spring responds rapidly to season and to climatic cycles indicates that the spring is fed by discharge from a groundwater system that is in good communication with the surface and the annual recharge event. Discharge from the spring is not supported by a deeper, regional type groundwater system. There are no indications of any mining-related impacts to the flow of spring S15-3.

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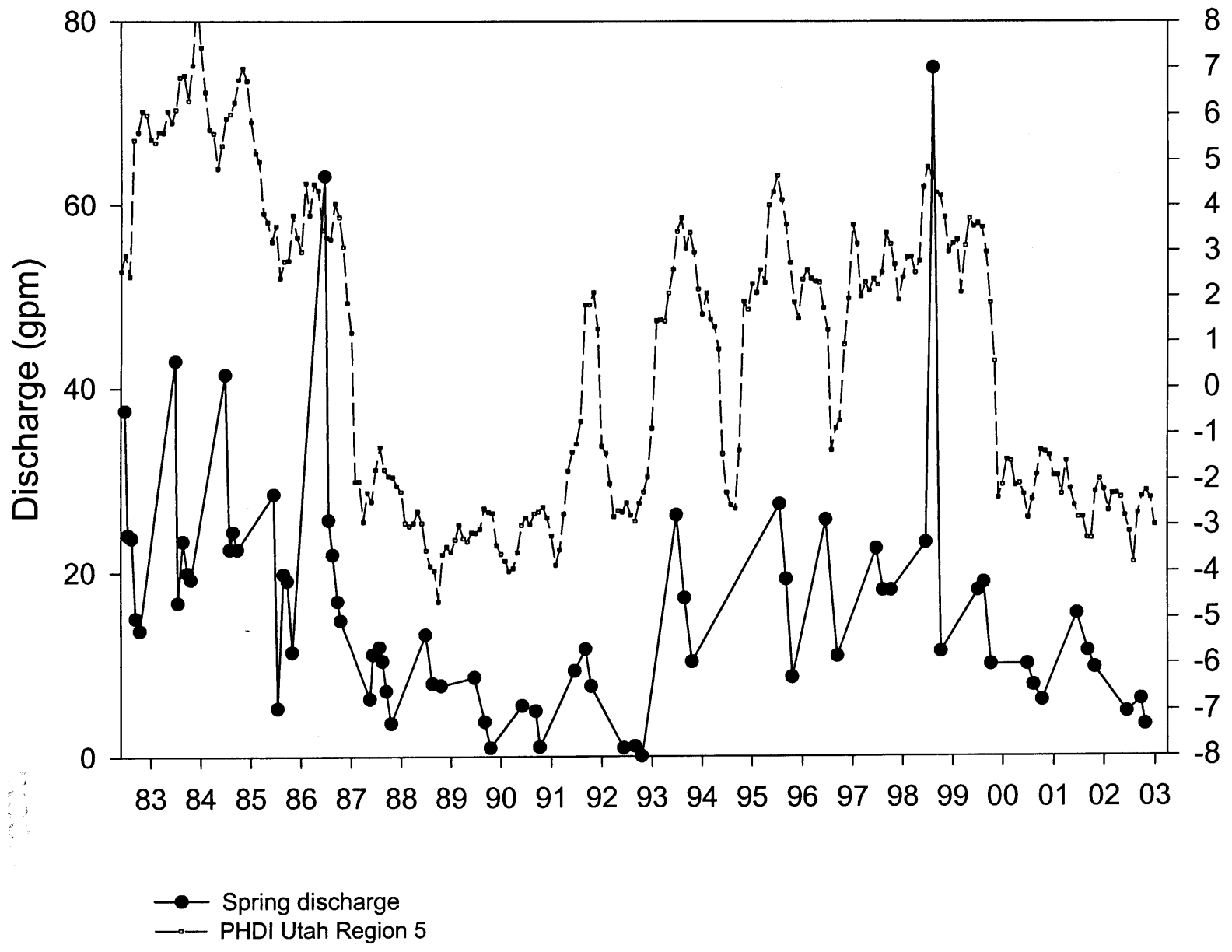
S22-11 (Blackhawk Formation)
Discharge (gpm)
80
60
40
20
0
8
7
6
5
4
3
2
1
0
-1
-2
-3
-4
-5
-6
-7
-8
83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 00 01 02 03
Spring discharge
PHDI Utah Region 5

S22-11

Baseflow and peak discharge from spring S22-11 responds rapidly to season and to climatic cycles. Discharges during the early and middle 1980s were significantly greater than those measured during the protracted drought of the late 1980s and early 1990s. Discharges increased during the wet period of the middle and late 1990s. Beginning in 1999, the region entered a period of drought that continues to the present. Spring discharges measured during the current drought are lower than those measured during previous wet cycles, but are somewhat greater than those measured during the drought of the late 1980s and early 1990s. The discharge from S22-11 rapidly responds to the annual springtime recharge event.

The fact that the spring responds rapidly to season and to climatic cycles indicates that the spring is fed by discharge from a groundwater system that is in good communication with the surface and the annual recharge event. Discharge from the spring is not supported by a deeper, regional type groundwater system. There are no indications of any mining-related impacts to the flow of spring S22-11.

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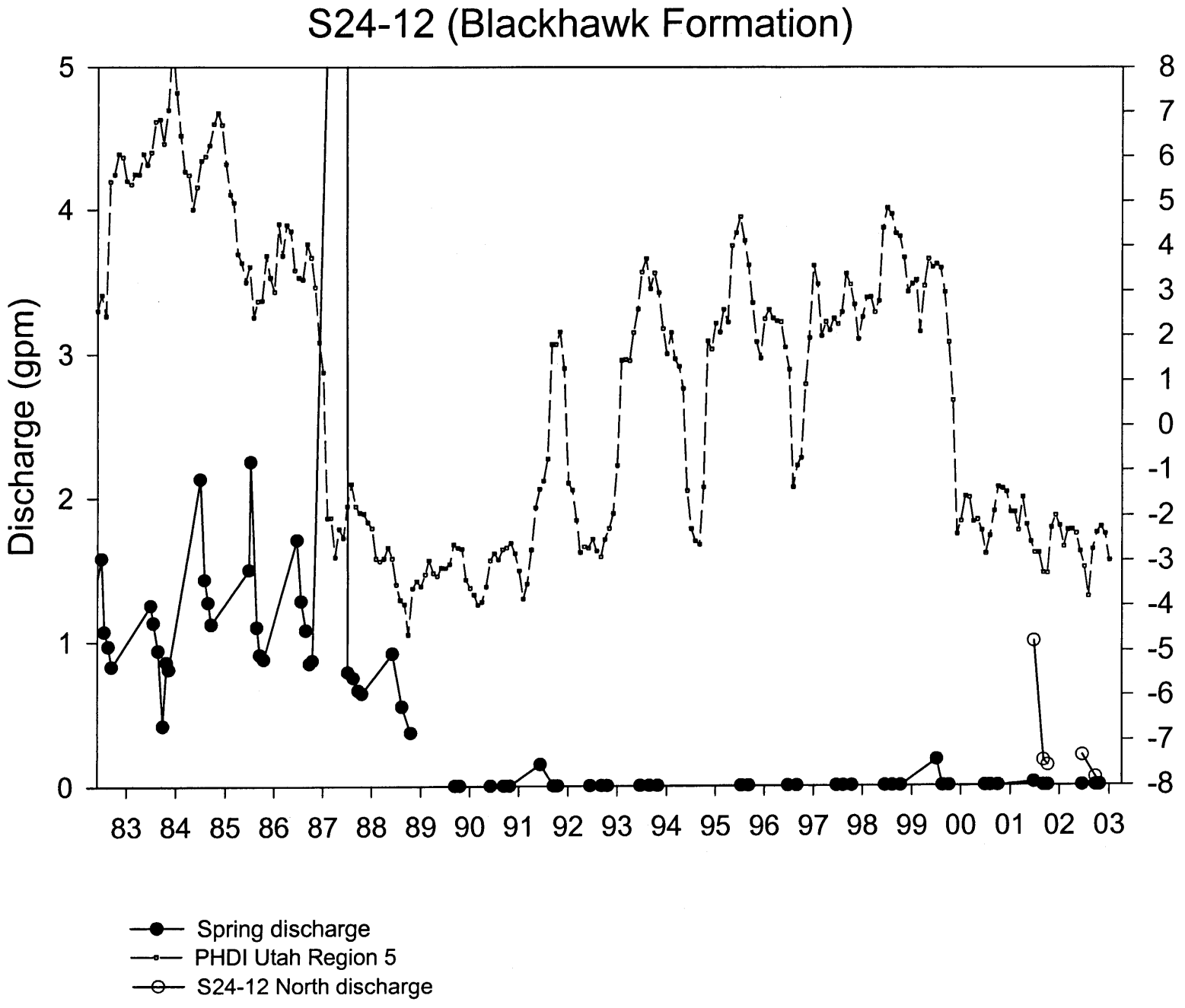
S24-12 (Blackhawk Formation)
Discharge (gpm)
5
4
3
2
1
0
8
7
6
5
4
3
2
1
0
-1
-2
-3
-4
-5
-6
-7
-8
83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 00 01 02 03
Spring discharge
PHDI Utah Region 5
S24-12 North discharge

S24-12

Prior to 1990, discharge from S24-12 exhibited marked response to both season and the annual springtime snowmelt event. Peak discharges measured during the extremely wet period of the middle 1980s generally ranged from about 1 to 2 gpm (with the exception of a single questionable reading of 10.64 gpm measured during the transitional climatic period in 1987). Since 1990, the discharge measured at the spring monitoring location has been significantly lower. These discharge data indicate that the spring is fed by discharge from a groundwater system that is in good communication with the surface and the annual recharge event. Discharge from the spring is not supported by a deeper, regional type groundwater system.

Spring S24-12 is a small spring complex that discharges from a colluvial/landslide deposit along the trace of a major fault. In 1989, the landslide deposits slumped and the soft sediments were redistributed. As a result of this movement, the diffuse discharge location of the spring became refocused in a location approximately 15 to 20 feet north of the previous discharge location. Consequently, the discharge from the spring is currently not captured in the old measuring flume and the spring has been reported as dry or as having only a very small flow. Beginning in 2001, the discharge from adjacent north spring has been monitored together with the previous S24-12 location. It is apparent from the discharge hydrograph of the north spring (measured during a drought period) that the overall discharge from the landslide deposit has likely not diminished significantly. It is very unlikely that coal mining activities have had any significant impact on the discharge from the spring complex.

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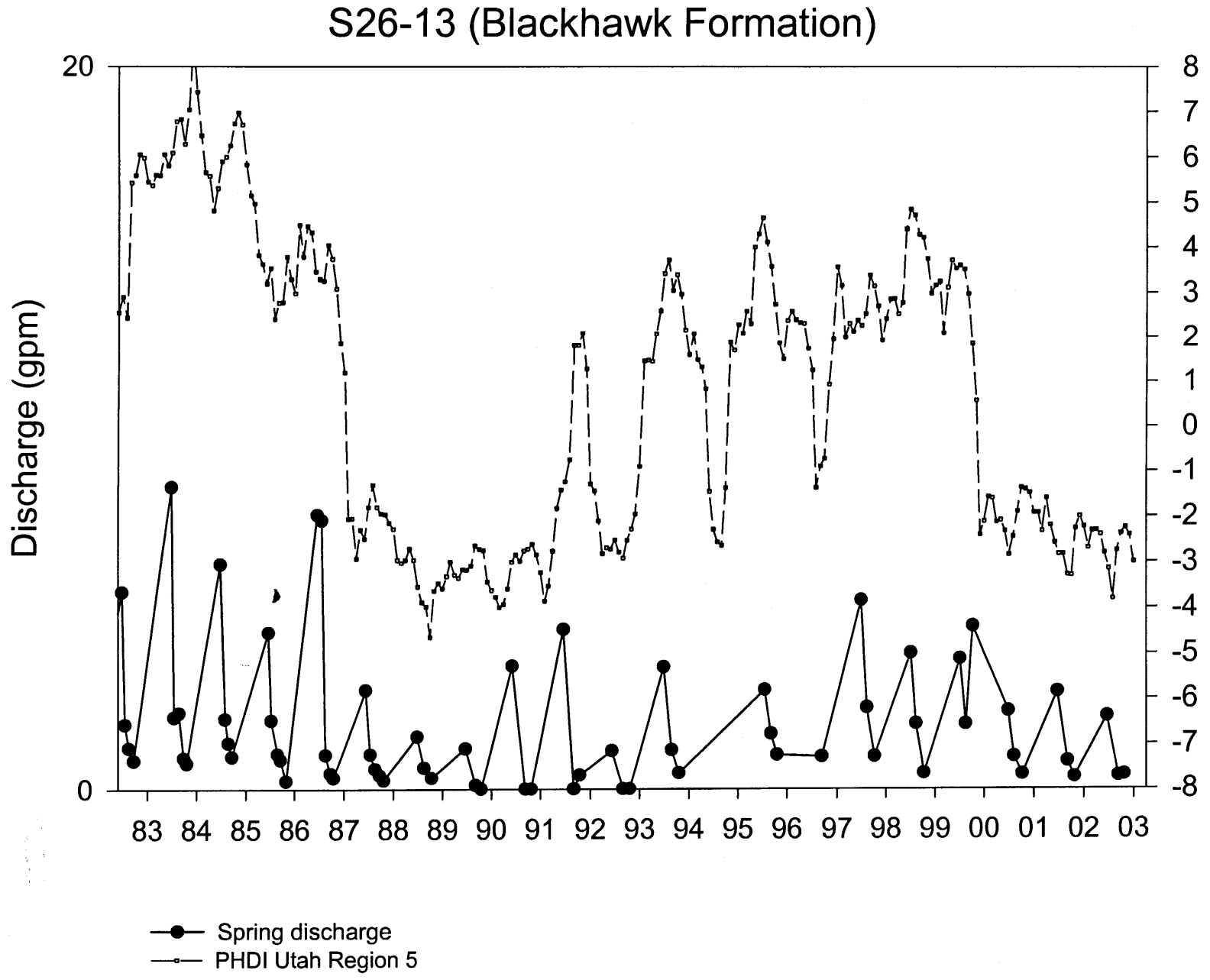
S26-13 (Blackhawk Formation)
Discharge (gpm)
20
0
8
7
6
5
4
3
2
1
0
-1
-2
-3
-4
-5
-6
-7
-8
83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 00 01 02 03
Spring discharge
PHDI Utah Region 5

S26-13

Baseflow and peak discharges from spring S26-13 respond rapidly to season and to climatic cycles. Discharges during the early and middle 1980s were significantly greater than those measured during the protracted drought of the late 1980s and early 1990s. Discharges increased somewhat during the wet period of the middle and late 1990s. Beginning in 1999, the region entered a period of drought that continues to the present. Spring discharges measured during the current drought are somewhat lower than those measured during previous wet cycles. The discharge from S22-11 rapidly responds to the annual springtime recharge event.

The fact that the spring responds rapidly to season and to climatic cycles indicates that the spring is fed by discharge from a groundwater system that is in good communication with the surface and the annual recharge event. Discharge from the spring is not supported by a deeper, regional type groundwater system. There are no indications of any mining-related impacts to the flow of spring S~~22-11~~ 26-13.

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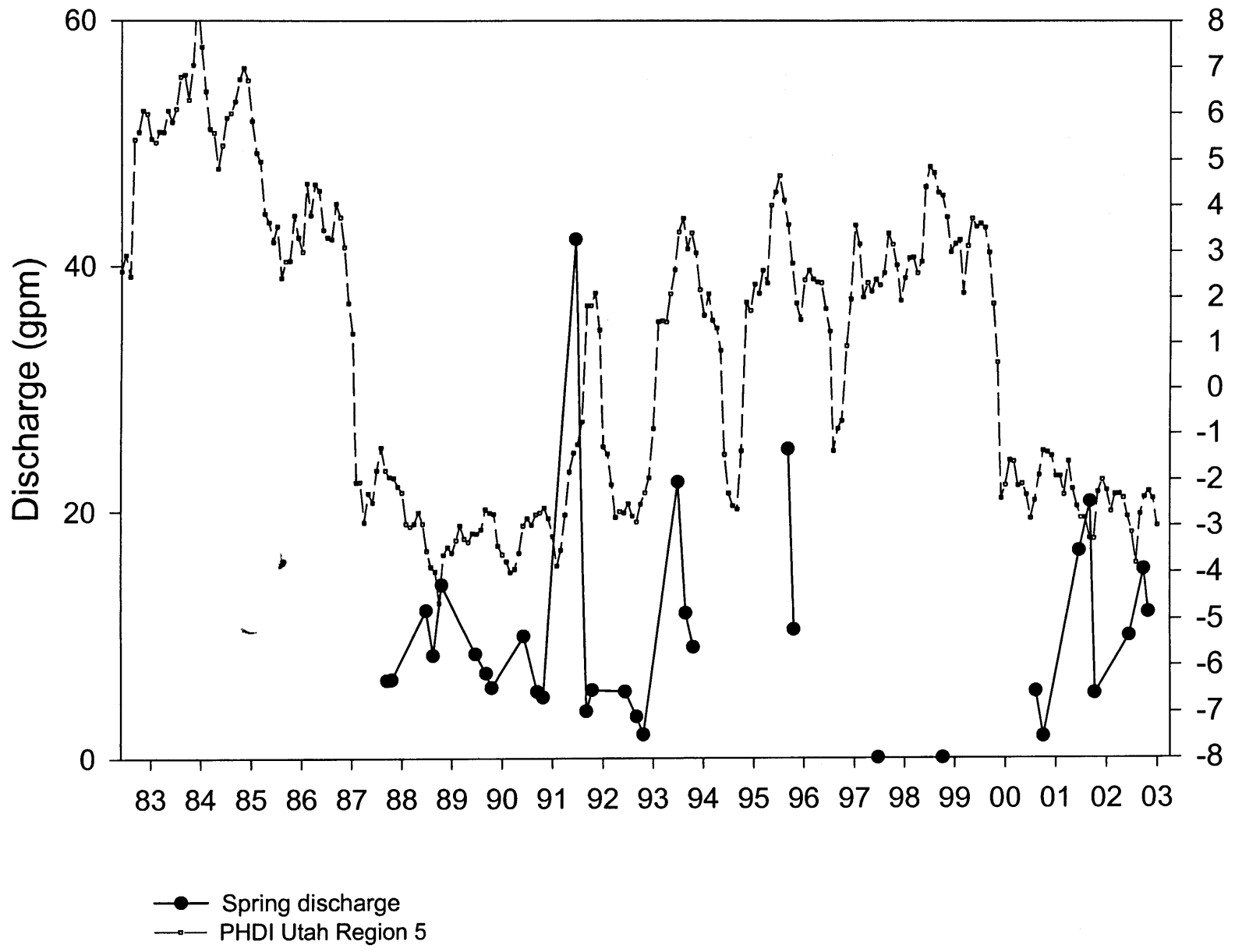
S34-12 (Blackhawk Formation)
Discharge (gpm)
60
40
20
0
8
7
6
5
4
3
2
1
0
-1
-2
-3
-4
-5
-6
-7
-8
83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 00 01 02 03
Spring discharge
PHDI Utah Region 5

S34-12

Spring S34-12 is located near the banks of Electric Lake. During periods of wetness, the spring is inundated by lake water and is often not accessible for monitoring. Consequently, discharge data for the spring are generally only available during periods of relative dryness. However, based on limited data it is apparent that the spring does respond rapidly to climatic cycles. As the region gradually recovered from the drought of the late 1980s, the discharge from the spring increased significantly in response to the increased wetness. The discharge hydrograph also indicates that the spring responds rapidly to the annual springtime recharge event.

The fact that the spring responds rapidly to season and to climatic cycles indicates that the spring is fed by discharge from a groundwater system that is in good communication with the surface and the annual recharge event. Discharge from the spring is not supported by a deeper, regional type groundwater system. There are no indications of any mining-related impacts to the flow of spring S34-12.

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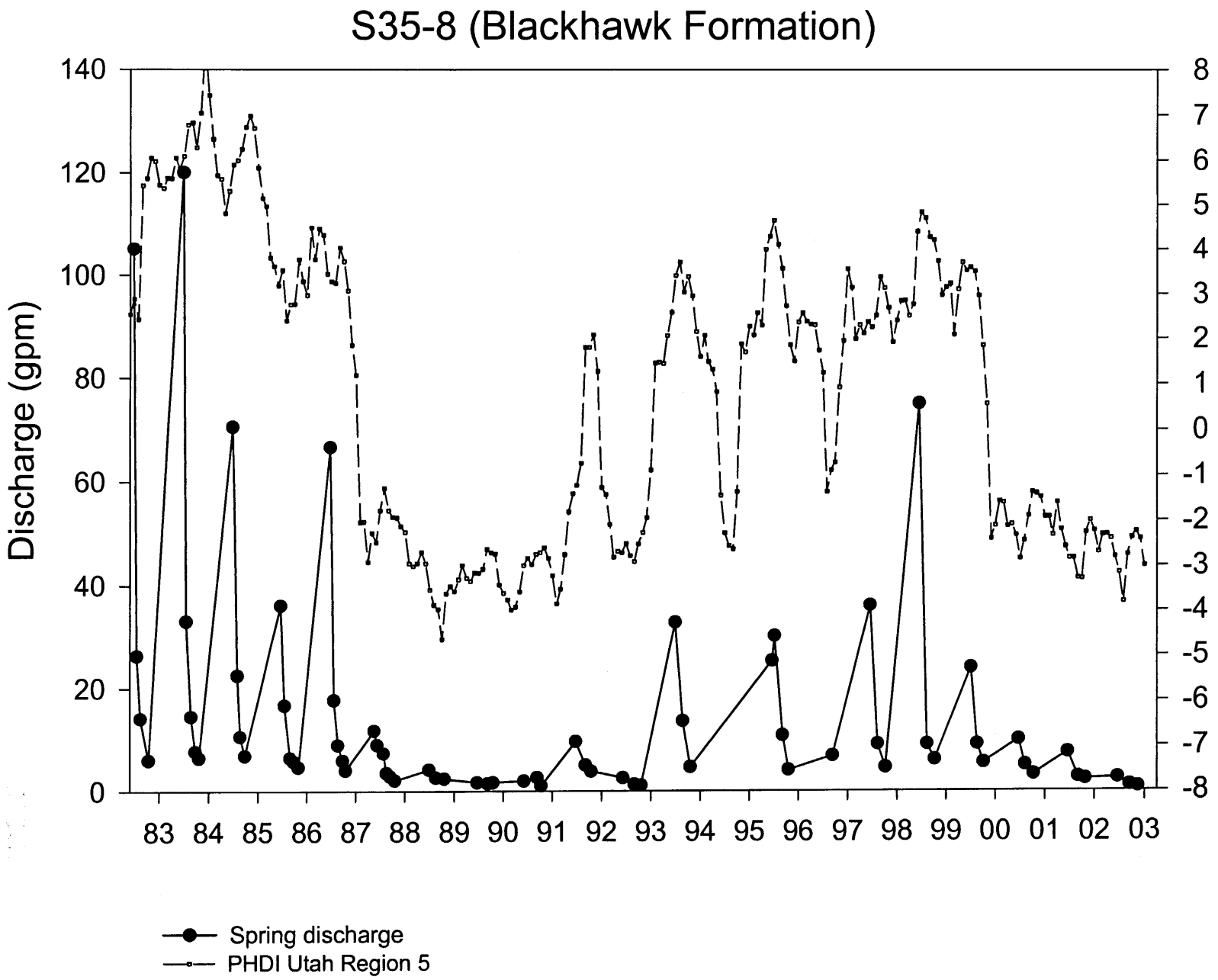
S35-8 (Blackhawk Formation)
Discharge (gpm)
140
120
100
80
60
40
20
0
8
7
6
5
4
3
2
1
0
-1
-2
-3
-4
-5
-6
-7
-8
83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 00 01 02 03
Spring discharge
PHDI Utah Region 5

S35-8 discharge

Discharge from spring S35-8 is plotted against time on the attached figure. The Palmer Hydrologic Drought Index (PHDI) for Utah Region 5 is also plotted on the figure. The discharge from the spring closely follows the PHDI. Peak spring discharges measured during the mid-1980s were large (>100 gpm) in response to the period of extreme wetness the region experienced during that time. During the protracted drought the region experienced during the late 1980s and early 1990's, peak discharges measured at the spring were much lower (generally <10 gpm). During the wet period of the mid and late 1990s, peak spring discharges again increased significantly. Beginning in 1999, the region again entered a period of drought that continues at the current time. Peak spring discharges measured during the current period of drought are lower than those measured during the previous wet cycles, but are somewhat greater than those measured during the drought of the late 1980s and early 1990s. Baseflow discharge rates measured at S35-8 during the late summer and fall months are greater during wet cycles than during periods of drought. The discharge from S35-8 rapidly responds to the annual springtime recharge event.

The fact that the spring responds rapidly to season and to climatic cycles indicates that the spring is fed by discharge from a groundwater system that is in good communication with the surface and the annual recharge event. Discharge from the spring is not supported by a deeper, regional type groundwater system. There are no indications of any mining-related impacts to the flow of spring S35-8.

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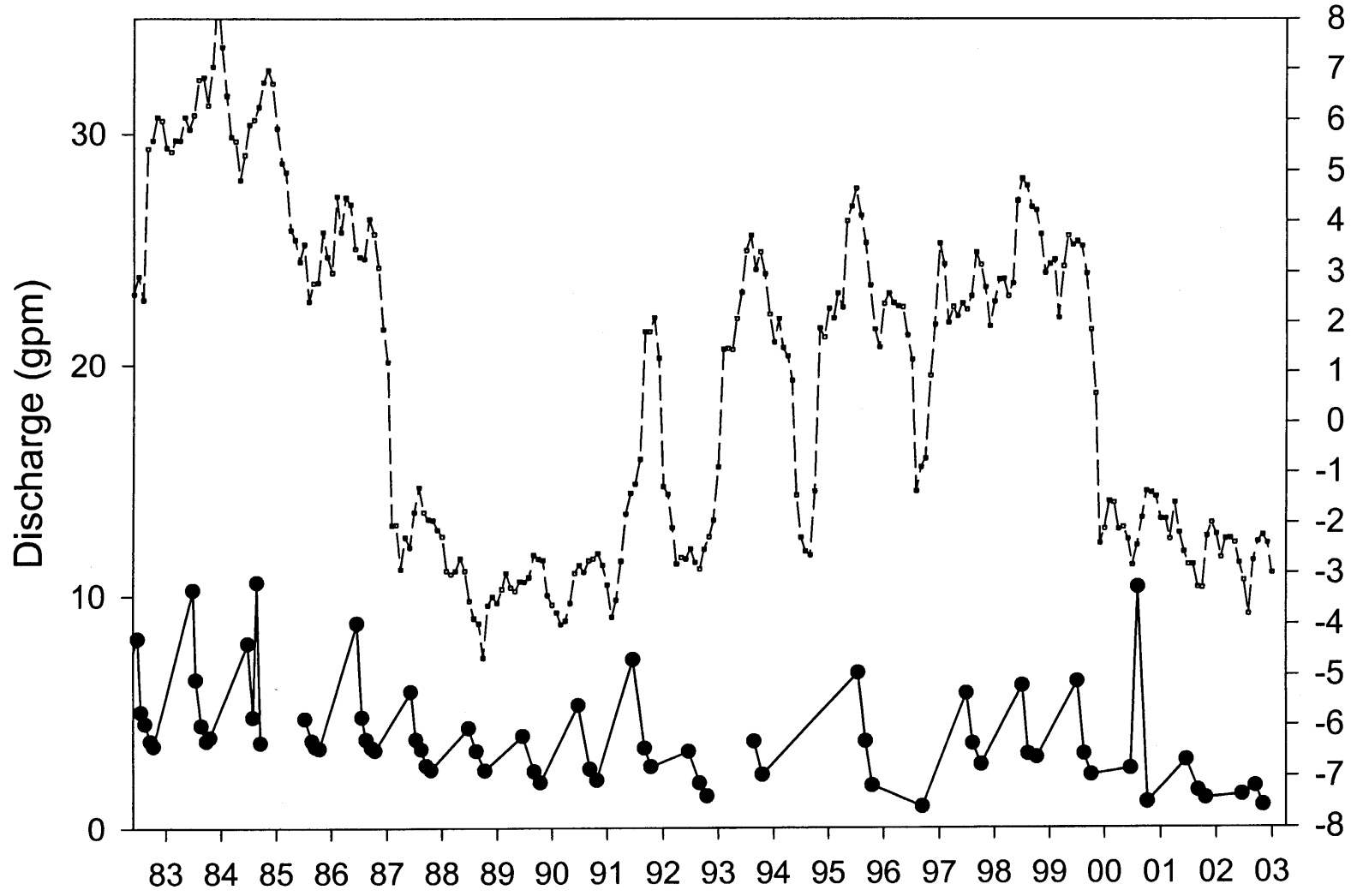
S36-12 (Blackhawk Formation)



S36-12

Discharge from S36-12 responds rapidly to the annual springtime snowmelt event, as evidenced by the sharp annual peaks in the discharge hydrograph. The spring also responds to climatic cycles, although the degree of variability in the discharge rate is less pronounced in S36-12 than it is in some of the other springs in the Skyline Mine area.

The fact that the spring responds rapidly to season and to climatic cycles indicates that the spring is fed by discharge from a groundwater system that is in good communication with the surface and the annual recharge event. Discharge from the spring is not supported by a deeper, regional type groundwater system. There are no indications of mining-related impacts to the flow of spring S36-12.

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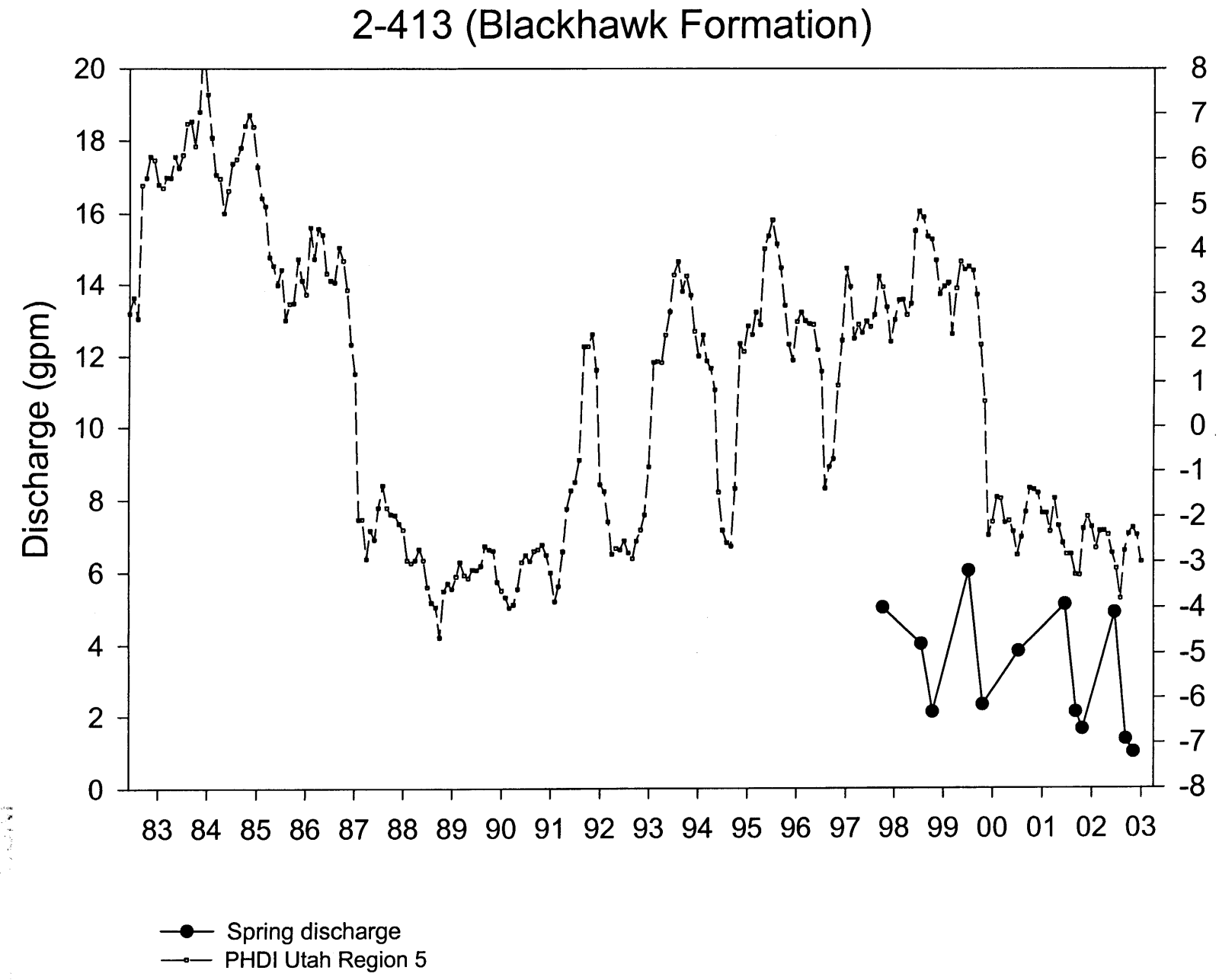
2-413 (Blackhawk Formation)
Discharge (gpm)
20
18
16
14
12
10
8
6
4
2
0
8
7
6
5
4
3
2
1
0
-1
-2
-3
-4
-5
-6
-7
-8
83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 00 01 02 03
Spring discharge
PHDI Utah Region 5

2-413

Discharge data for spring 2-413 are only available since late 1997. Consequently, it is not possible to evaluate the response of the spring to long-term climatic cycles. The discharge from the spring has remained relatively stable over the period of record of the data. The spring discharge responds rapidly to the annual springtime snowmelt event, indicating that the spring is not supported by a deeper, regional type groundwater system. It is important to note that spring 2-413 is located above the area of the mine in which the major groundwater inflows have occurred. There have been no measurable impacts to the discharge rate from the spring as a result of the recent mine water inflows

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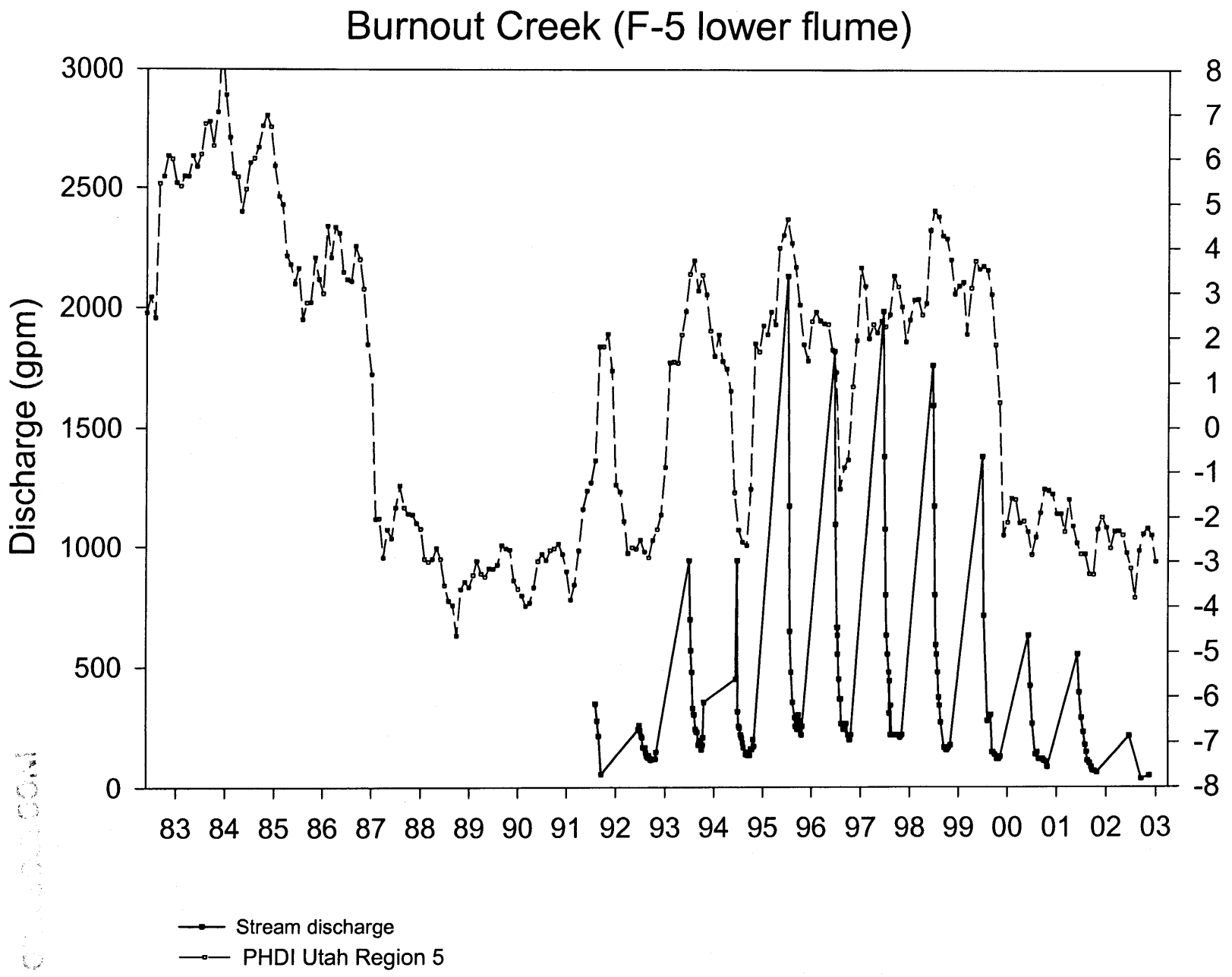
Burnout Creek (F-5 lower flume)
Discharge (gpm)
3000
2500
2000
1500
1000
500
0
8
7
6
5
4
3
2
1
0
-1
-2
-3
-4
-5
-6
-7
-8
83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 00 01 02 03
Stream discharge
PHDI Utah Region 5

Burnout discharge

A discharge hydrograph showing discharge from Burnout Canyon Creek is presented in the attached figure. A plot of the PHDI for Utah Region 5 is included on the figure.

The discharge from Burnout Canyon Creek responds rapidly to the annual springtime recharge event. It also responds to longer term climatic cycles. Beginning in 1991 and 1992, the baseflow and peak discharge rates increased steadily as the region moved from a period of significant drought to the wet cycle of the late 1990s. Similarly, as the region began drying out and entered the period of drought that continues at present, both baseflow and peak flow discharge rates have gradually declined.

There is no indication that mining activities have had any significant impact on discharge rates in the stream. The fact that the streamflow responds rapidly to season and climate, and the fact that the stream dries out rapidly during drought conditions, indicates that the stream is not sustained by discharge from deep, regional type groundwater systems.

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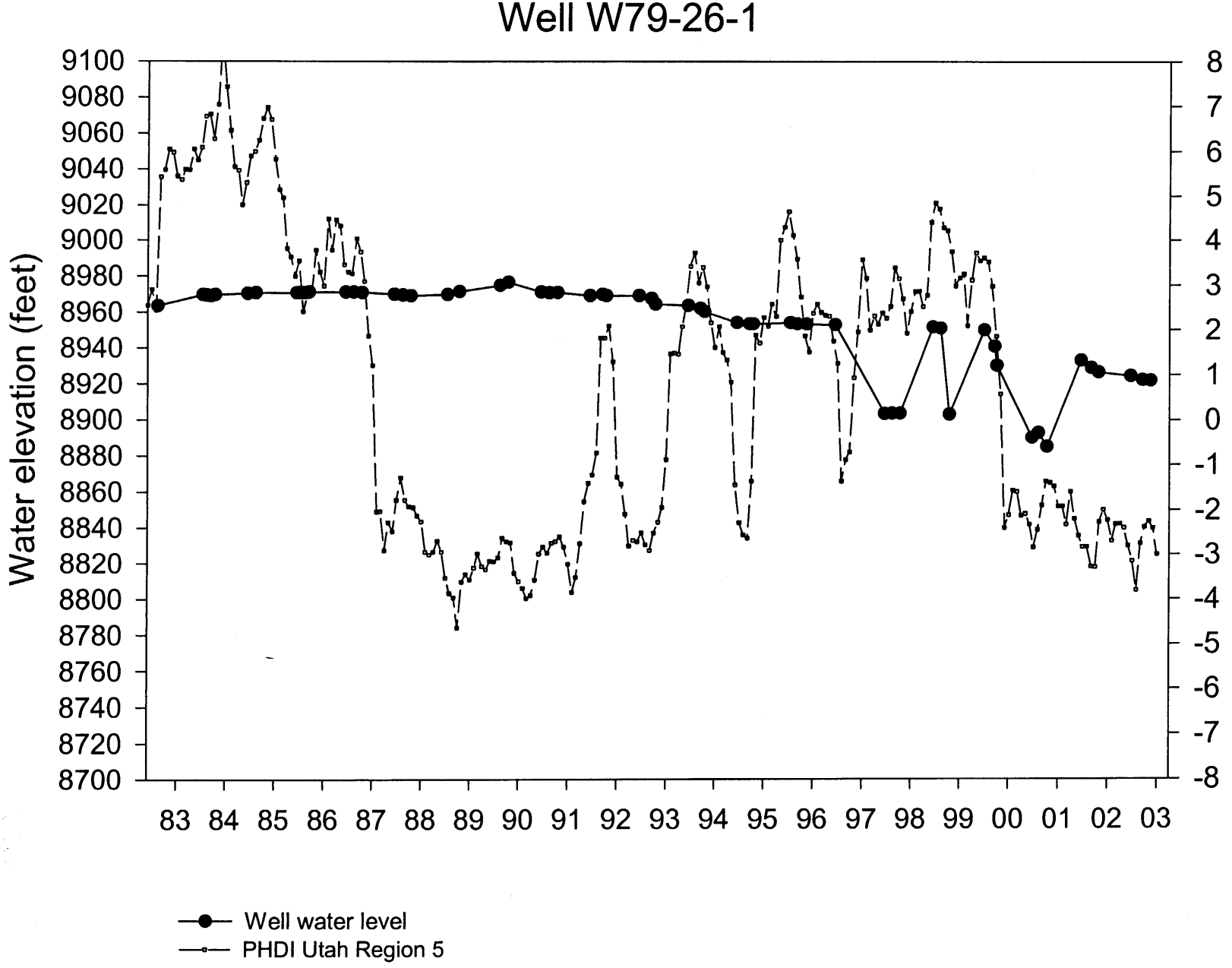
Well W79-26-1
Water elevation (feet)
9100
9080
9060
9040
9020
9000
8980
8960
8940
8920
8900
8880
8860
8840
8820
8800
8780
8760
8740
8720
8700
8
7
6
5
4
3
2
1
0
-1
-2
-3
-4
-5
-6
-7
-8
83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 00 01 02 03
Well water level
PHDI Utah Region 5

W79-26-1

There are no indications of seasonal or climatic variability in water levels measured in W79-26-1. Beginning in 1992 there has been a gradual decline in water levels in the well accompanied by several short-lived larger water level fluctuations. Panels in Mine 1 and Mine 3 were mined in this area beginning in 1992 and completed in 2000. This well appears to respond when mining activity occurred in the area by a drop in water levels. However, since mining has ceased in the area, water levels appear to have somewhat stabilized in the aquifer at slightly lower than pre- mining elevations.

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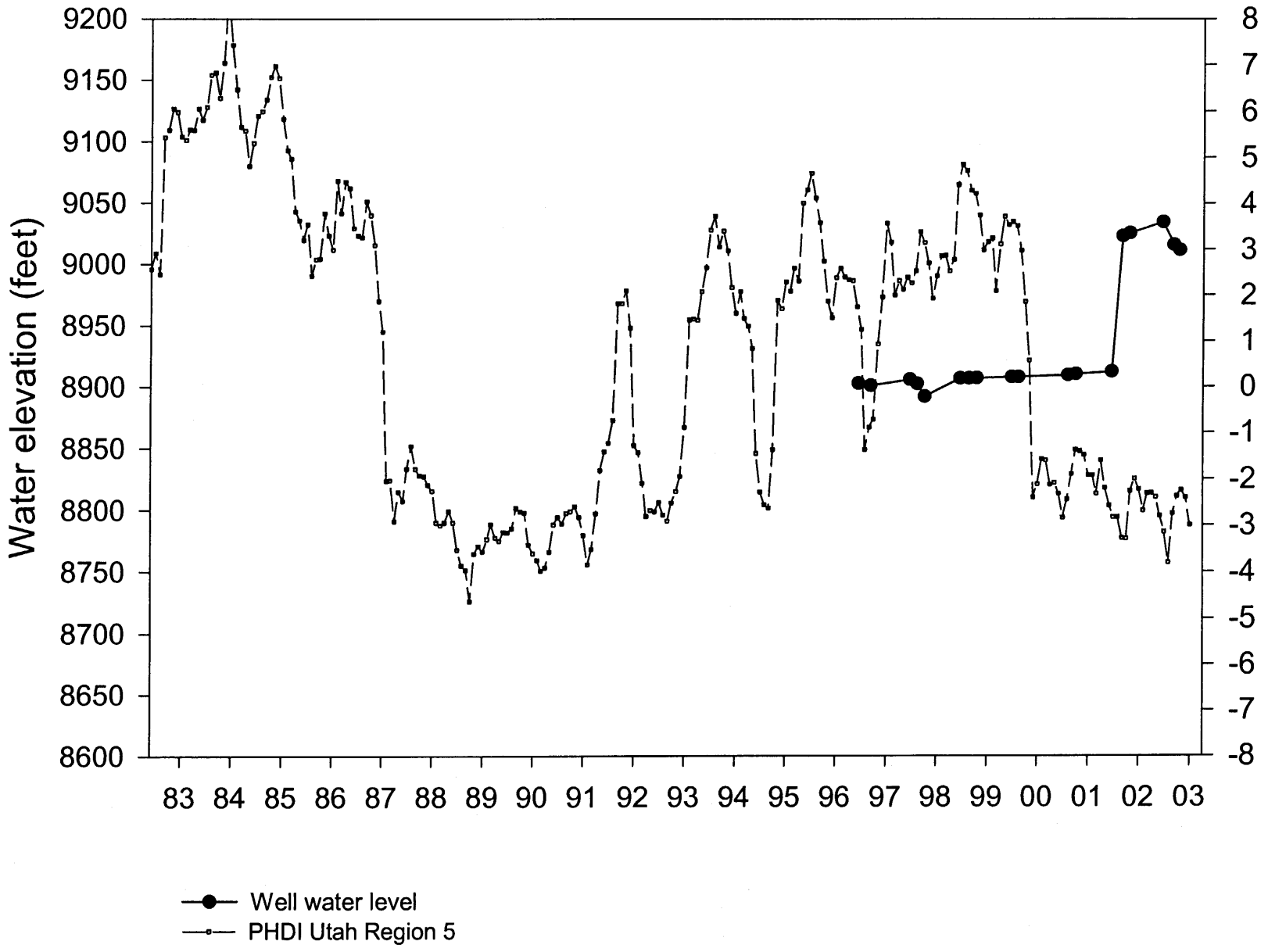
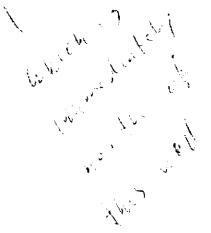
Well W79-10-1


Water elevation (feet)
9200
9150
9100
9050
9000
8950
8900
8850
8800
8750
8700
8650
8600
8
7
6
5
4
3
2
1
0
-1
-2
-3
-4
-5
-6
-7
-8
83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 00 01 02 03
Well water level
PHDI Utah Region 5

W79-10-1

Prior to 2001, water levels in well 10-1 remained relatively constant and there was no indication of climatic or seasonal variability. This is because the deep groundwater horizon in which the well is completed is not in communication with the shallow subsurface.

Since mid 2001, the water level in W10-1 has risen significantly. This water level rise is likely related to recent mining activities that have occurred in the vicinity of the well. This includes the flooding of Mine 3.



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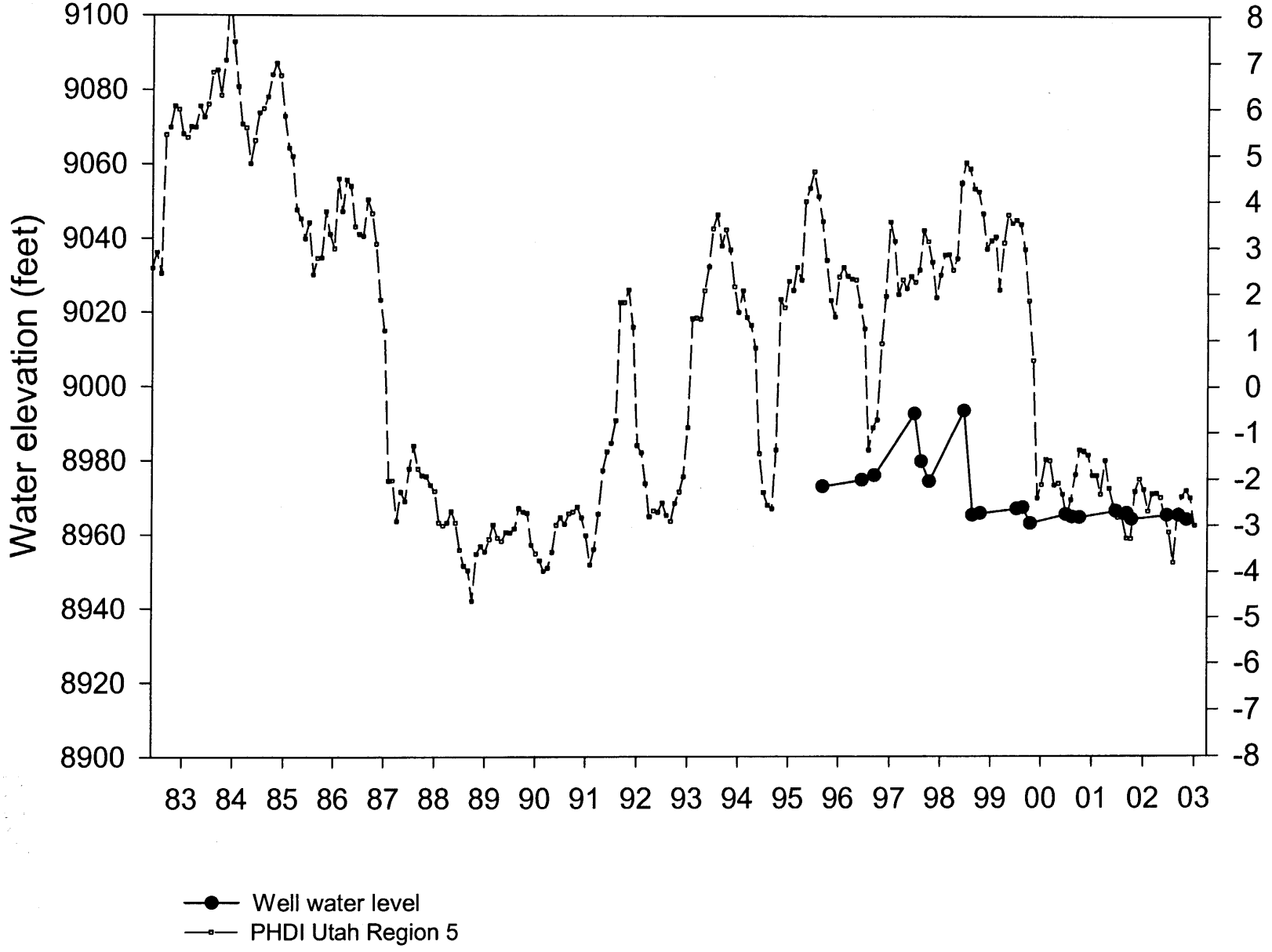
Well W79-14-2A



W79-14-2

The water level hydrograph for well 14-2 does not show seasonal or climatic variability. With the exception of some water level fluctuation measured in 1997 and 1998, water levels have remained relatively constant.

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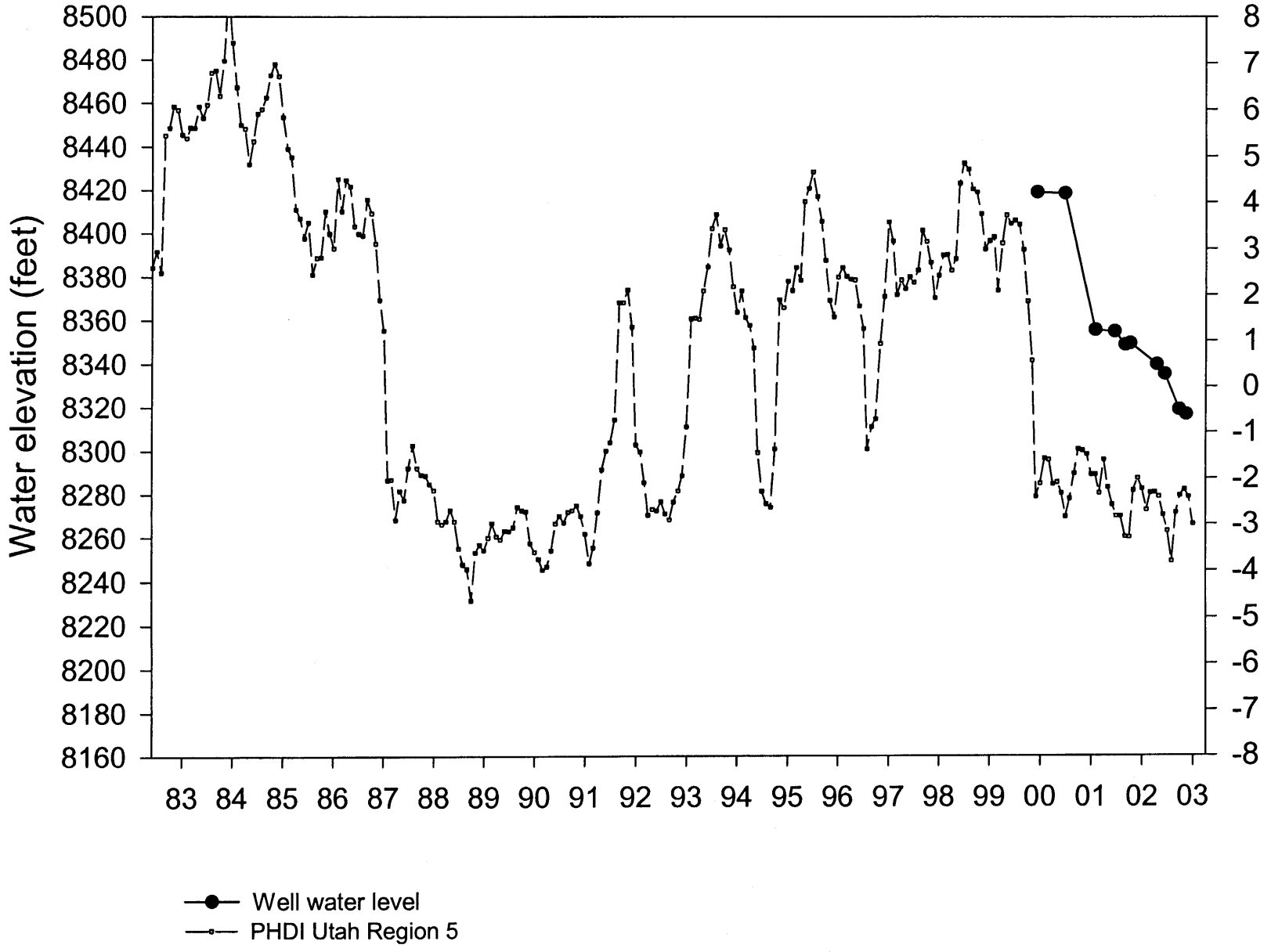
Well W99-21-1


Water elevation (feet)
8500
8480
8460
8440
8420
8400
8380
8360
8340
8320
8300
8280
8260
8240
8220
8200
8180
8160
8
7
6
5
4
3
2
1
0
-1
-2
-3
-4
-5
-6
-7
-8
83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 00 01 02 03
Well water level
PHDI Utah Region 5

W99-21-1

Water levels in well 21-1 have recently experienced steady declines. These declines are the anticipated result of the mine dewatering activities in the sandstones underlying the mined coal seams. The deep horizons monitored by well 21-1 are not in communication with the shallow subsurface and consequently, there is no seasonal or climatic variation apparent in the hydrograph.

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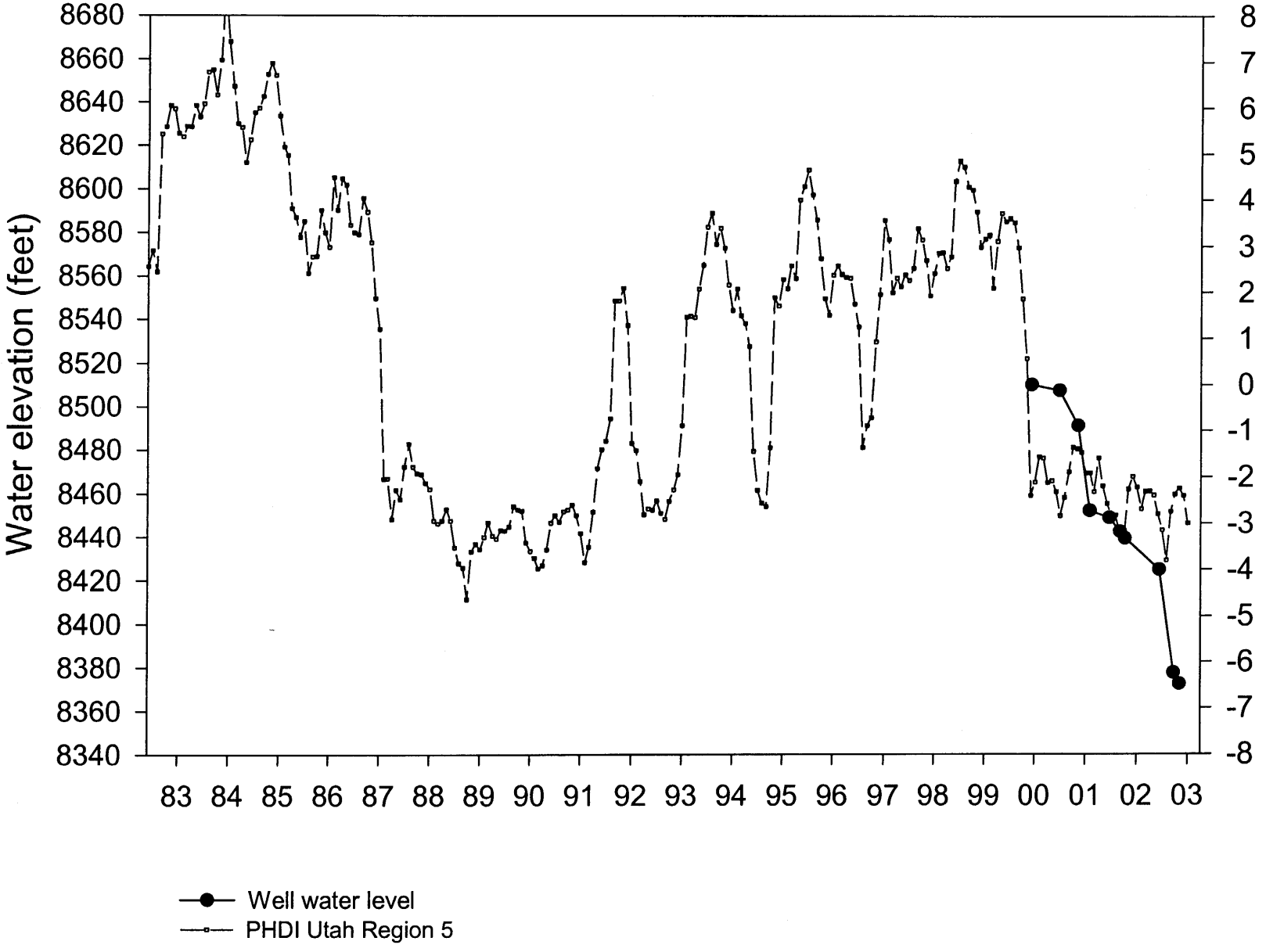
Well W99-28-1


Water elevation (feet)
8680
8660
8640
8620
8600
8580
8560
8540
8520
8500
8480
8460
8440
8420
8400
8380
8360
8340
8
7
6
5
4
3
2
1
0
-1
-2
-3
-4
-5
-6
-7
-8
83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 00 01 02 03
Well water level
PHDI Utah Region 5

W99-28-1

Water levels in well 28-1 have recently experienced steady declines. These declines are the anticipated result of the mine dewatering activities in the sandstones underlying the mined coal seams. The deep horizons monitored by well 28-1 are not in communication with the shallow subsurface and consequently, there is no seasonal or climatic variation apparent in the hydrograph.

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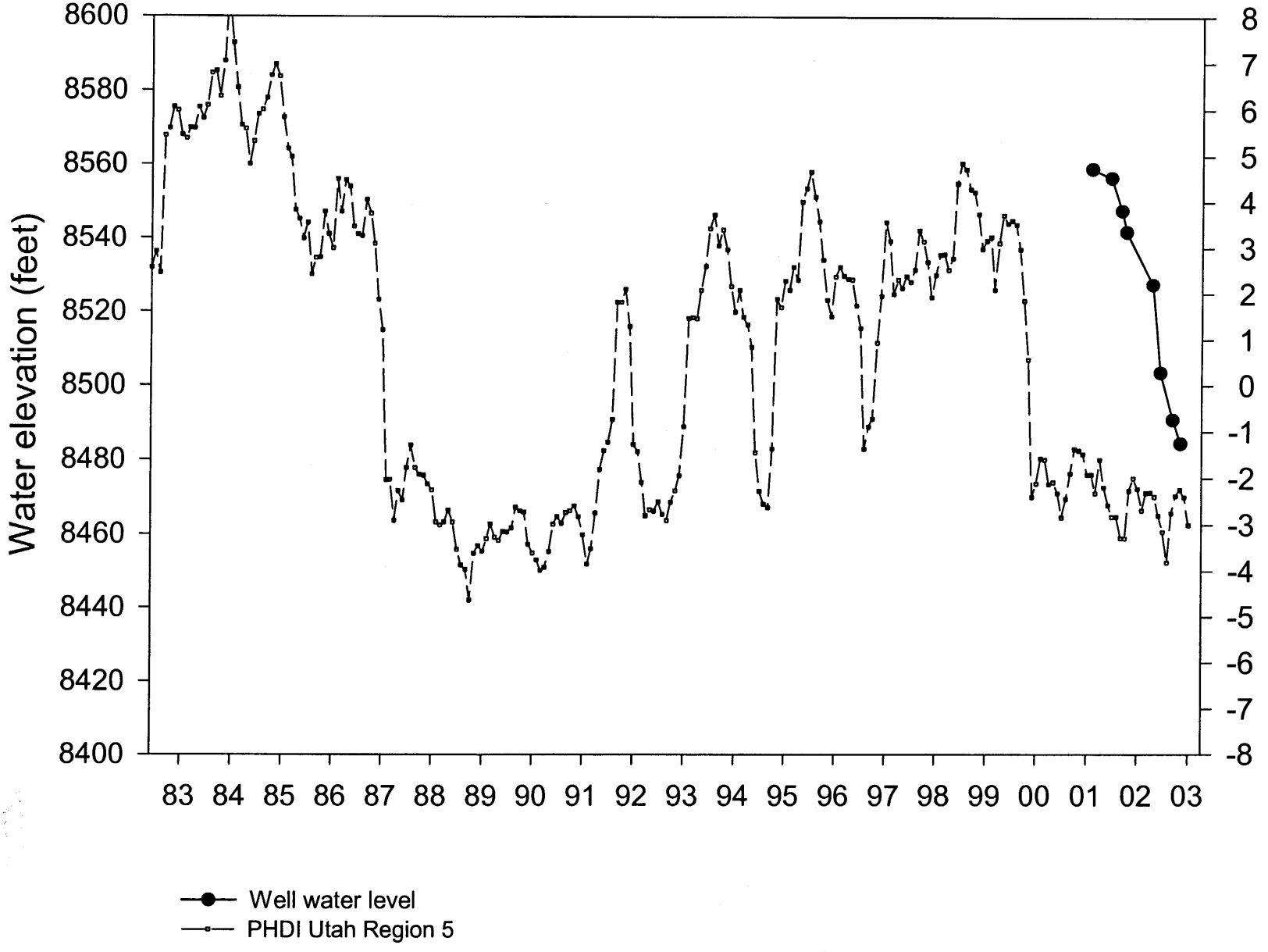
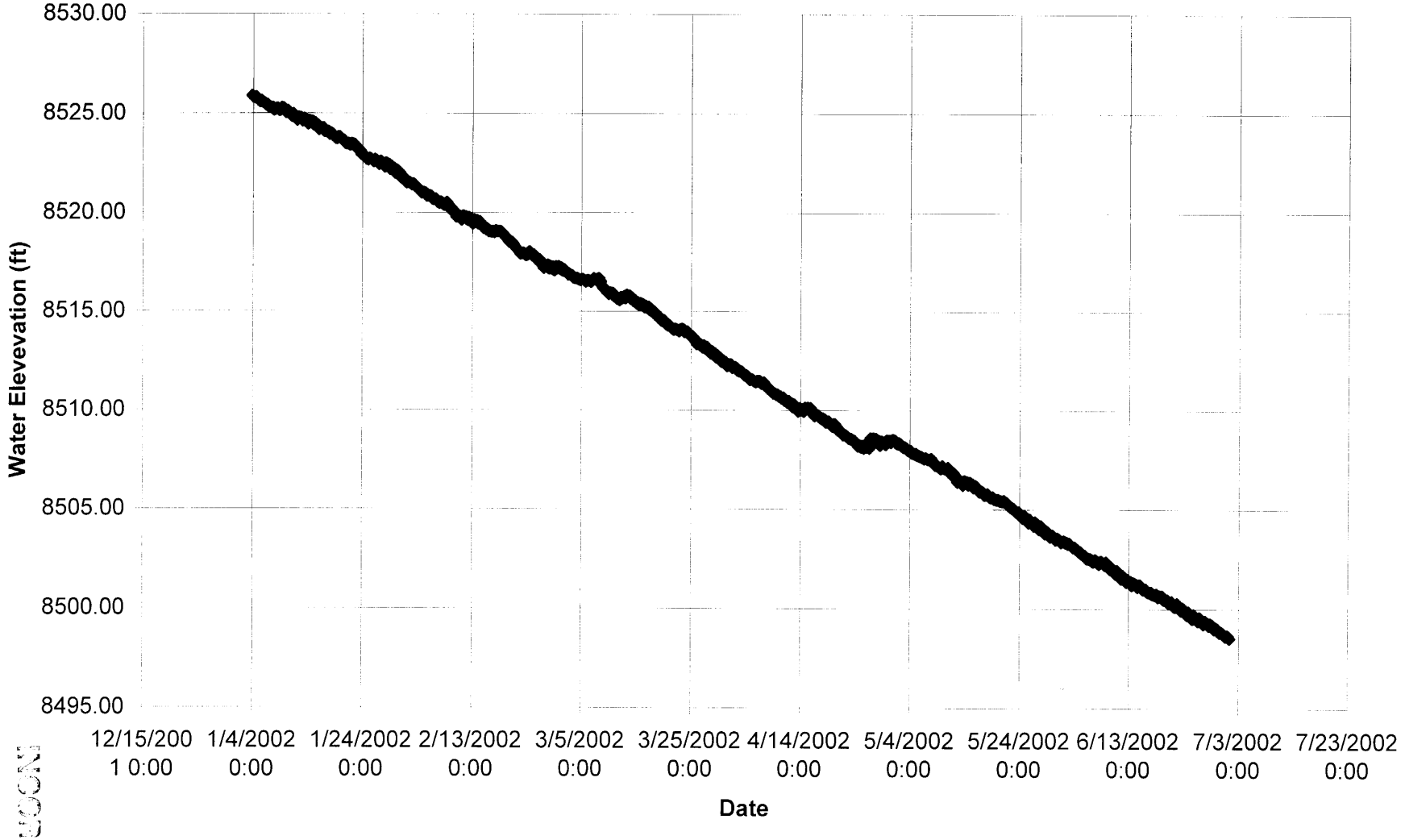
Well W20-4-1


Water elevation (feet)
8600
8580
8560
8540
8520
8500
8480
8460
8440
8420
8400
8
7
6
5
4
3
2
1
0
-1
-2
-3
-4
-5
-6
-7
-8
83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 00 01 02 03
Well water level
PHDI Utah Region 5

W20-4-1 BOULGER CANYON
Transducer Data



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W20-4-1

Water levels in well W20-4-1 have recently experienced steady declines. These declines are the anticipated result of the mine dewatering activities in the sandstones underlying the mined coal seams. The deep horizons monitored by the well are not in communication with the shallow subsurface and consequently, there is no seasonal or climatic variation apparent in the hydrograph.

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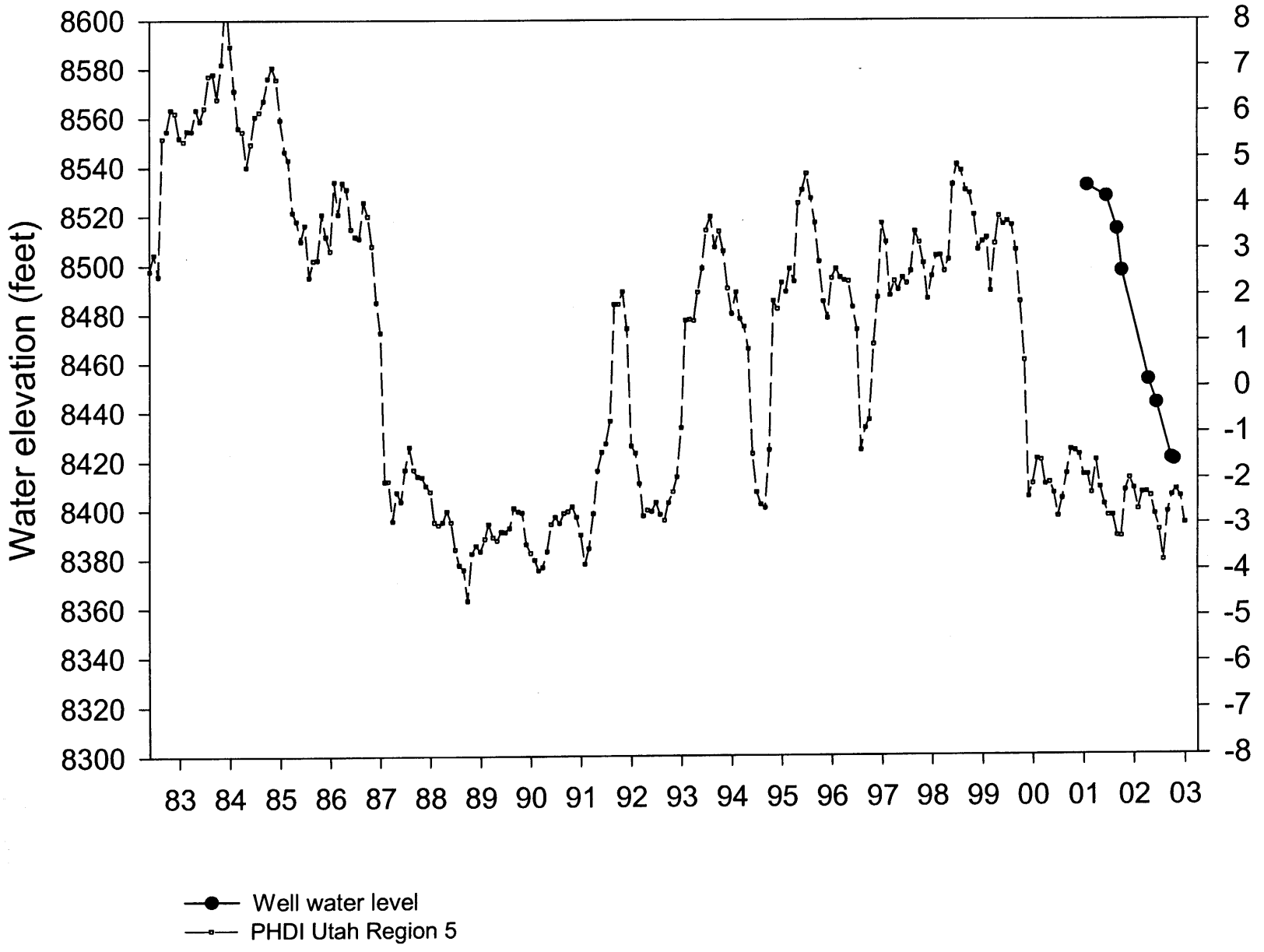
Well W20-4-2


Water elevation (feet)
8600
8580
8560
8540
8520
8500
8480
8460
8440
8420
8400
8380
8360
8340
8320
8300
8
7
6
5
4
3
2
1
0
-1
-2
-3
-4
-5
-6
-7
-8
83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 00 01 02 03
Well water level
PHDI Utah Region 5

W20-4-2

Water levels in well W20-4-2 have recently experienced steady declines. These declines are the anticipated result of the mine dewatering activities in the sandstones underlying the mined coal seams. The deep horizons monitored by well W20-4-2 are not in communication with the shallow subsurface and consequently, there is no seasonal or climatic variation apparent in the hydrograph.

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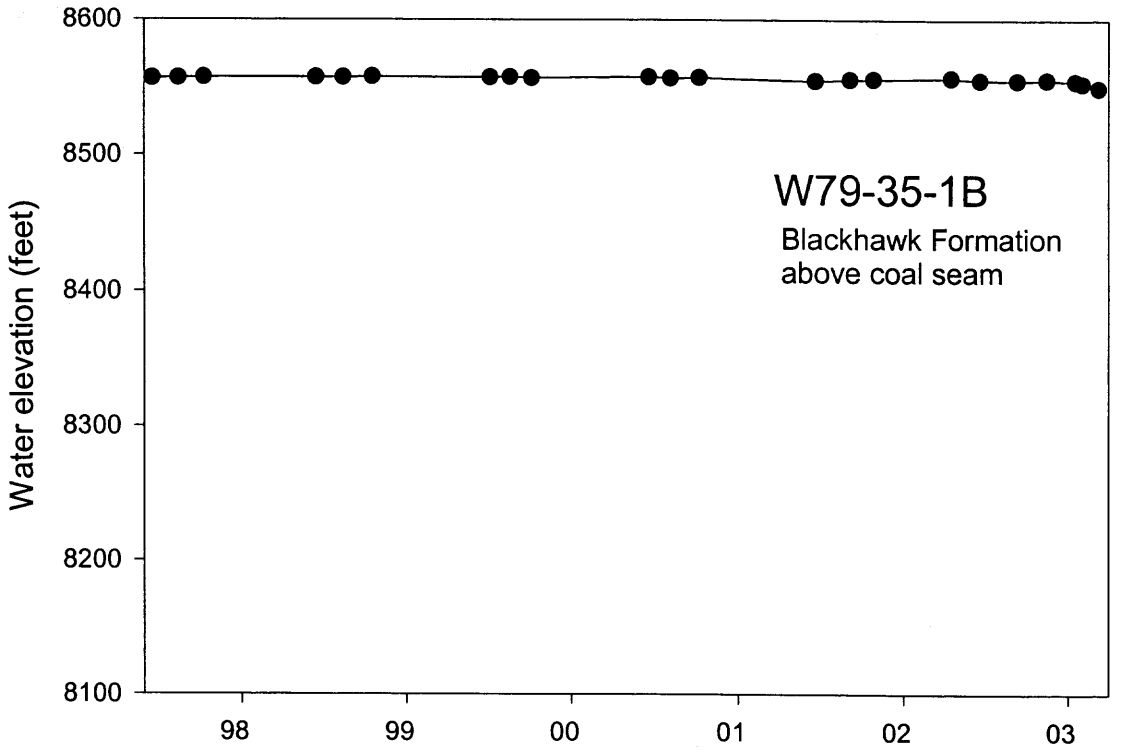


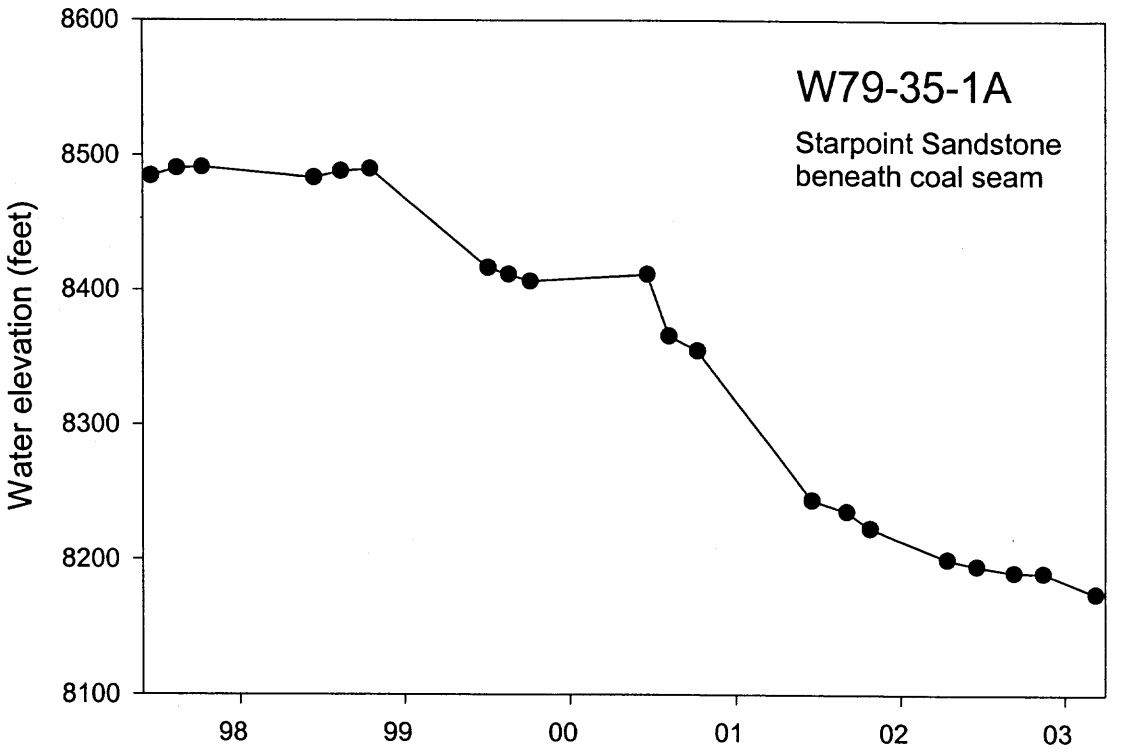
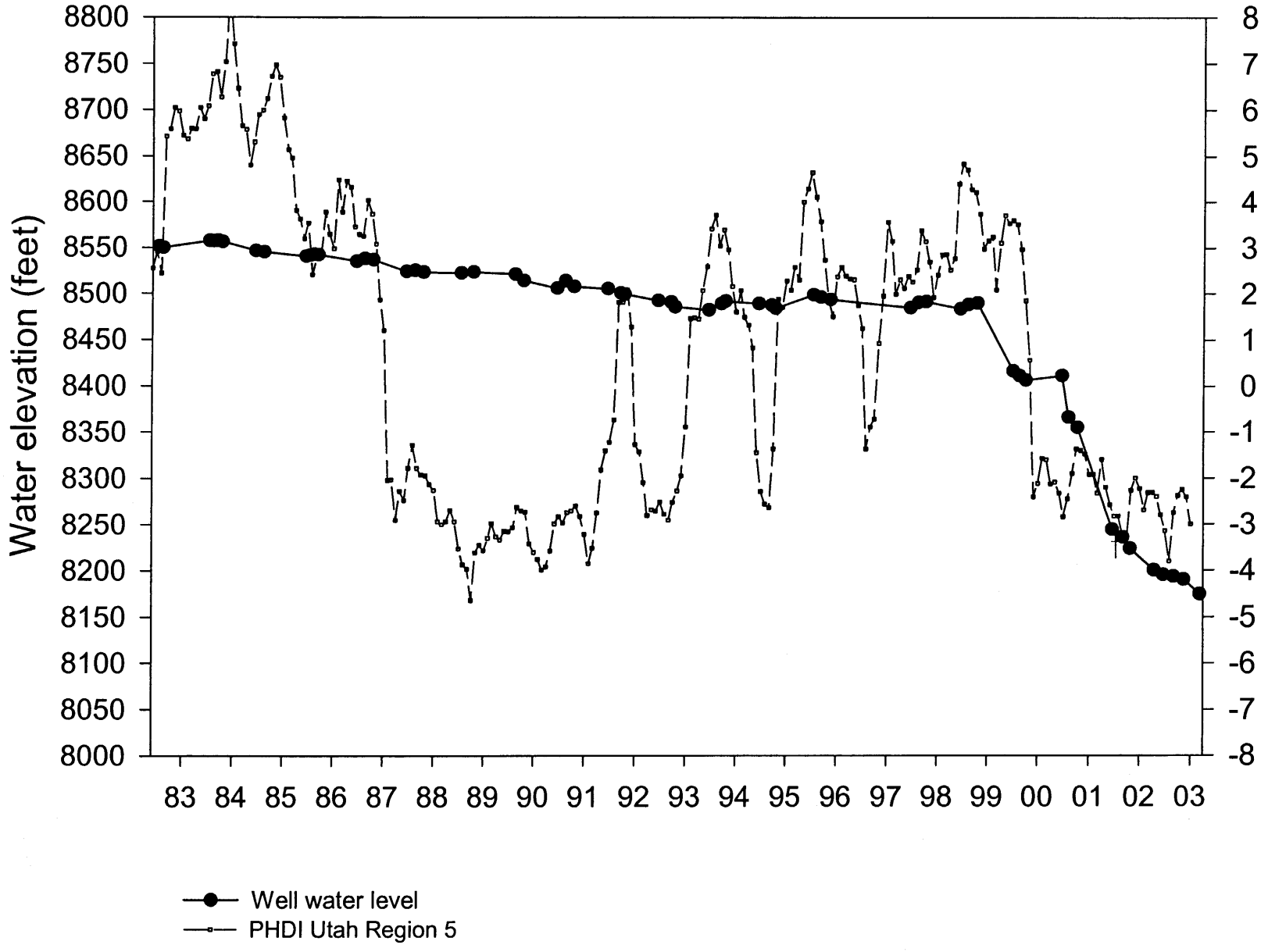
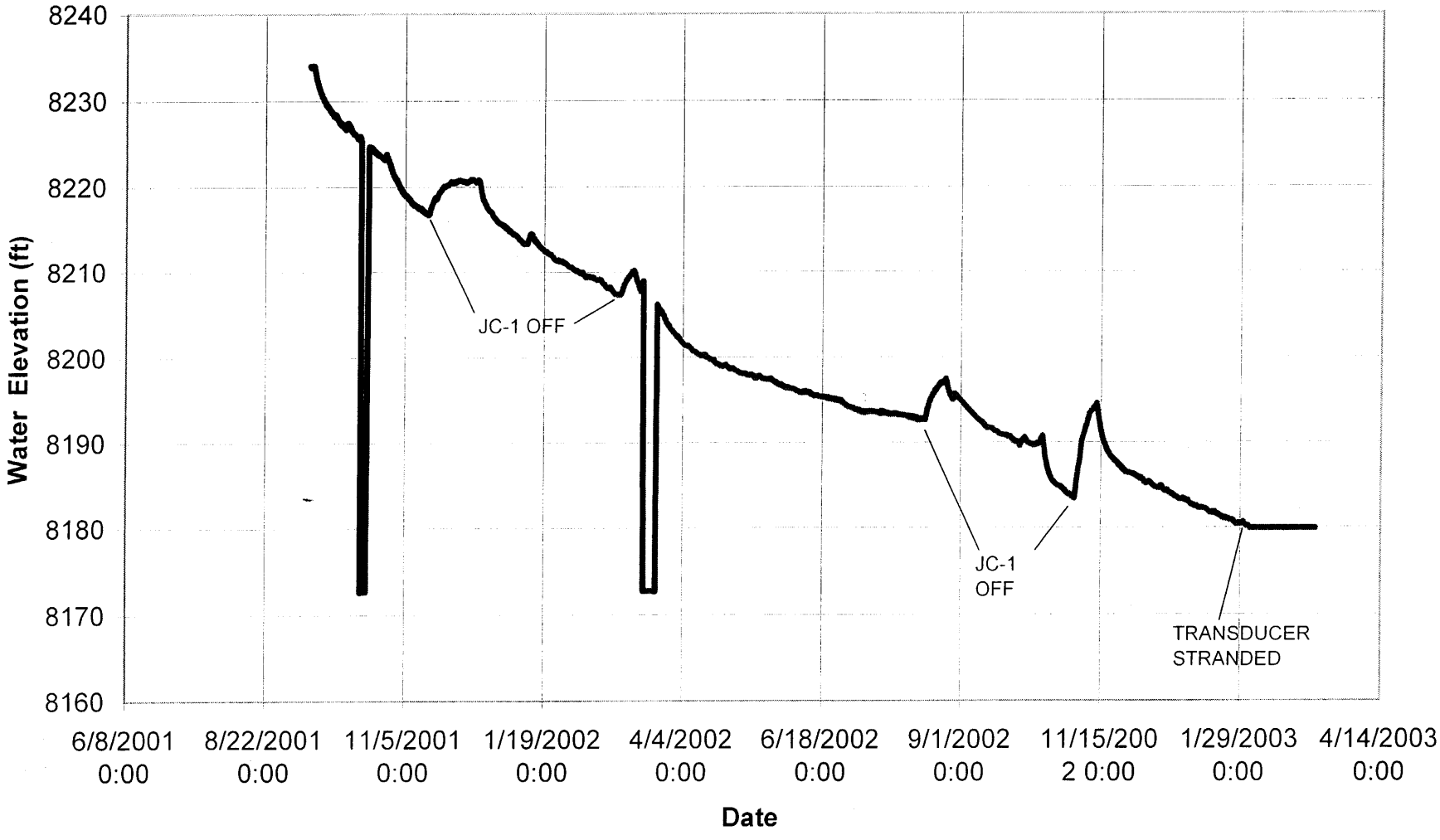


Figure 5 Comparison of water level declines at the nested piezometers at W79-35-1.

Well W79-35-1A



W79-35-1A BURNOUT CANYON
Transducer Data



W79-35-1A

W79-35-1A is completed below the coal seams. Until 1999 the water level in the well was relatively stable and the well did respond to climate. Since that time, the water level in the well has declined steadily. These declines are the anticipated result of the mine dewatering activities in the sandstones underlying the mined coal seams. The graph containing the down hole transducer data illustrates the impact that periodic shutdowns of the JC-1 well have on the water level within the well. This suggest that W79-35-1A is completed in or near the fracture system JC-1 is completed in.

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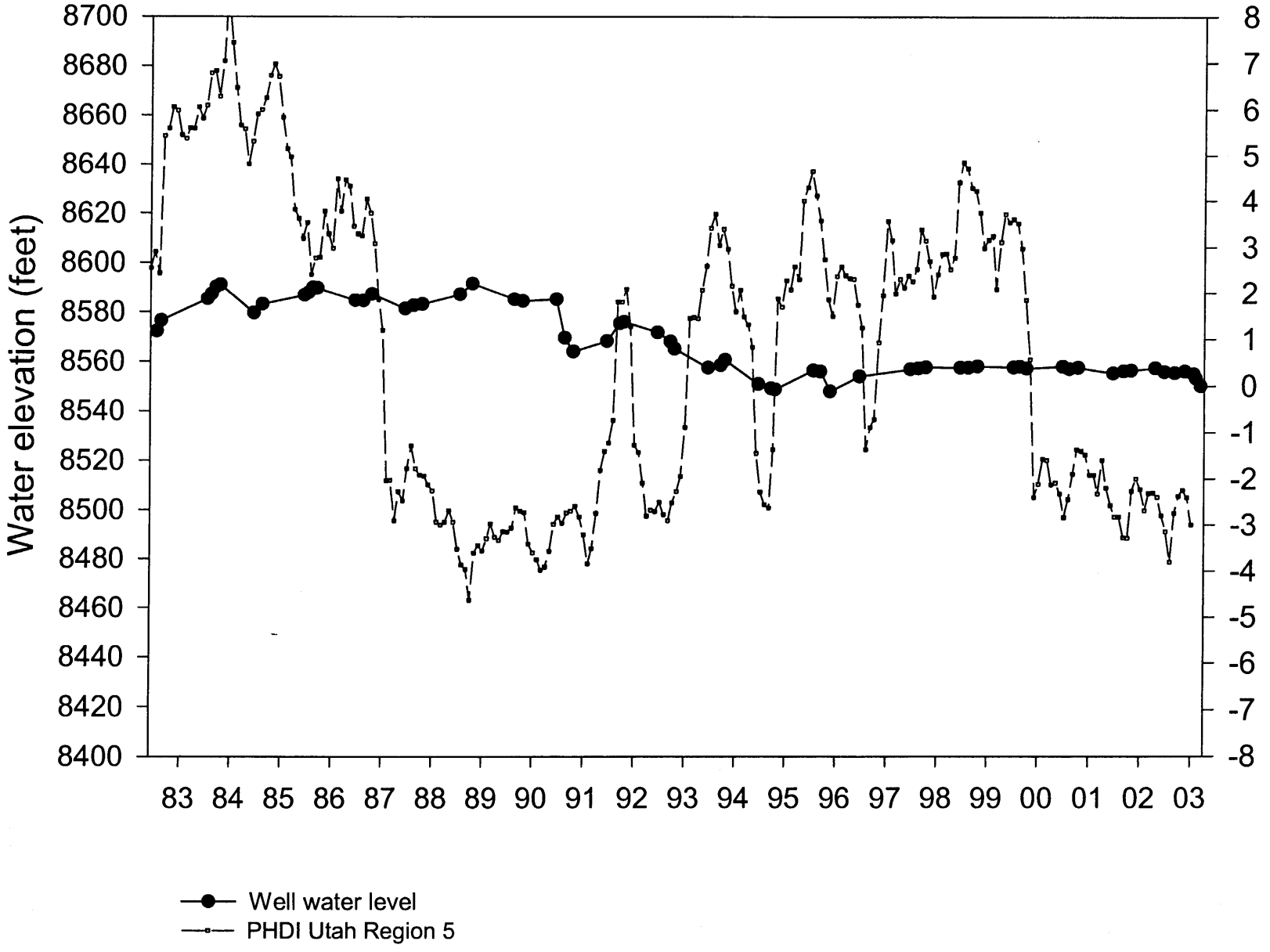
Well W79-35-1B



W79-35-1B

W79-35-1B is completed immediately adjacent to W79-35-1A in the Blackhawk Formation above the mined coal seams. Water levels in the well have remained stable over time. There is no indication of seasonal or climatic response in the well. It is important to note that, while well 35-1A is in communication with the sandstone rocks in connection with the mine, well 35-1B is not in hydraulic communication with the deeper sandstone horizons. This demonstrates the effectiveness of the relatively impermeable shales and mudstones of the Blackhawk Formation in prohibiting vertical fluid migration in the formation. It is for this reason that discharges from shallow groundwater systems occurring as springs or stream baseflow are not impacted by mining operations in the lower Blackhawk Formation.

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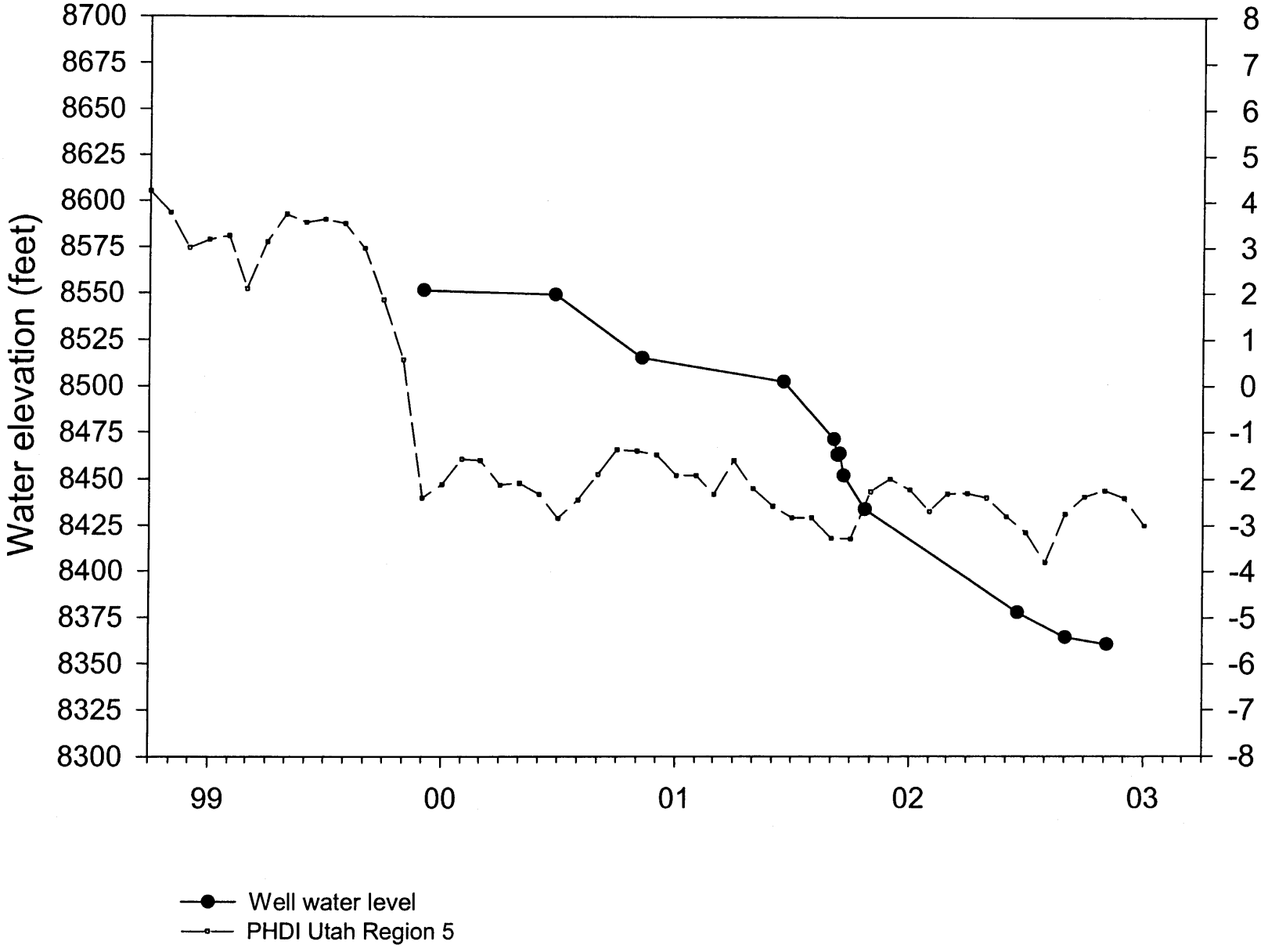
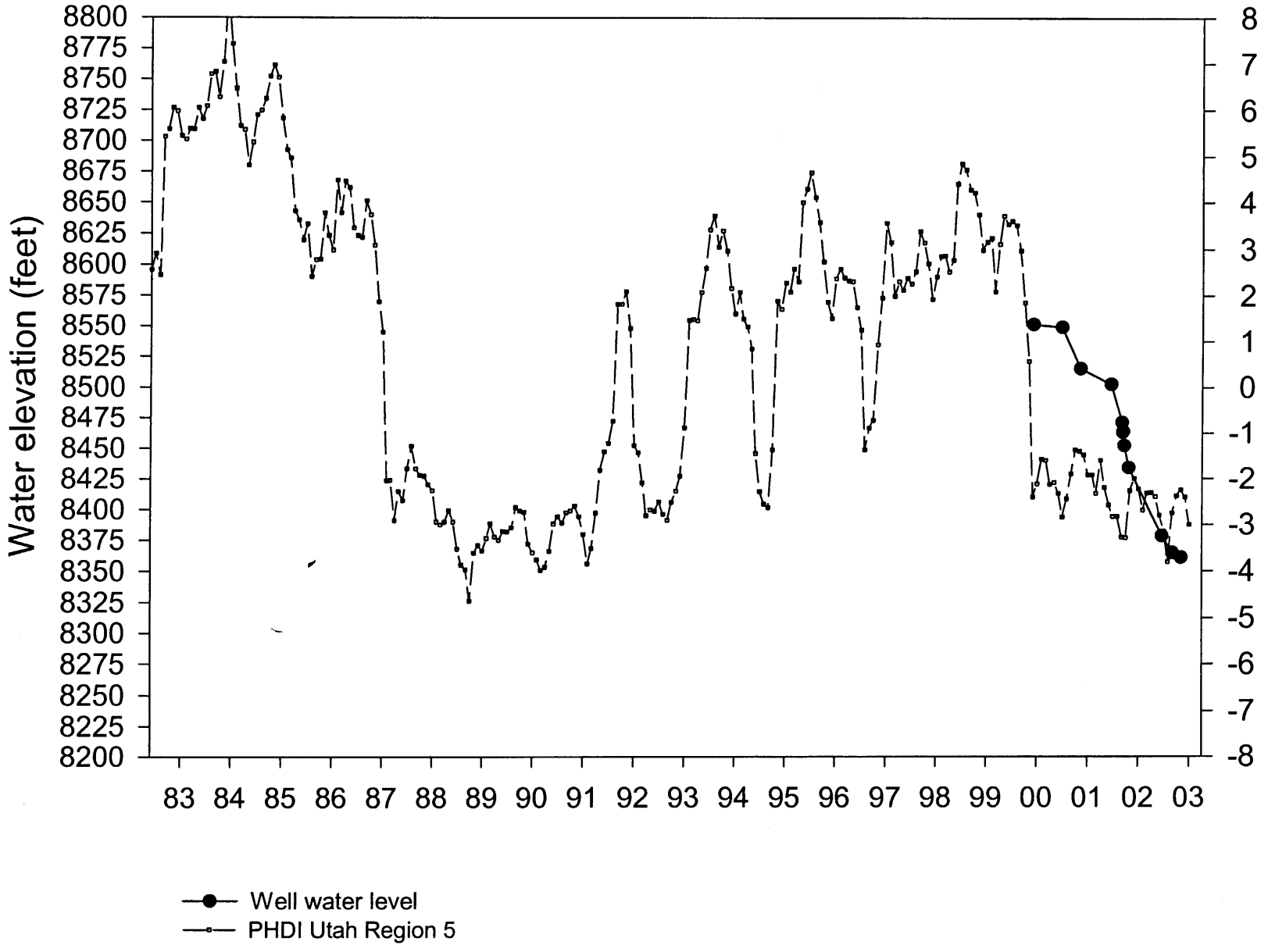
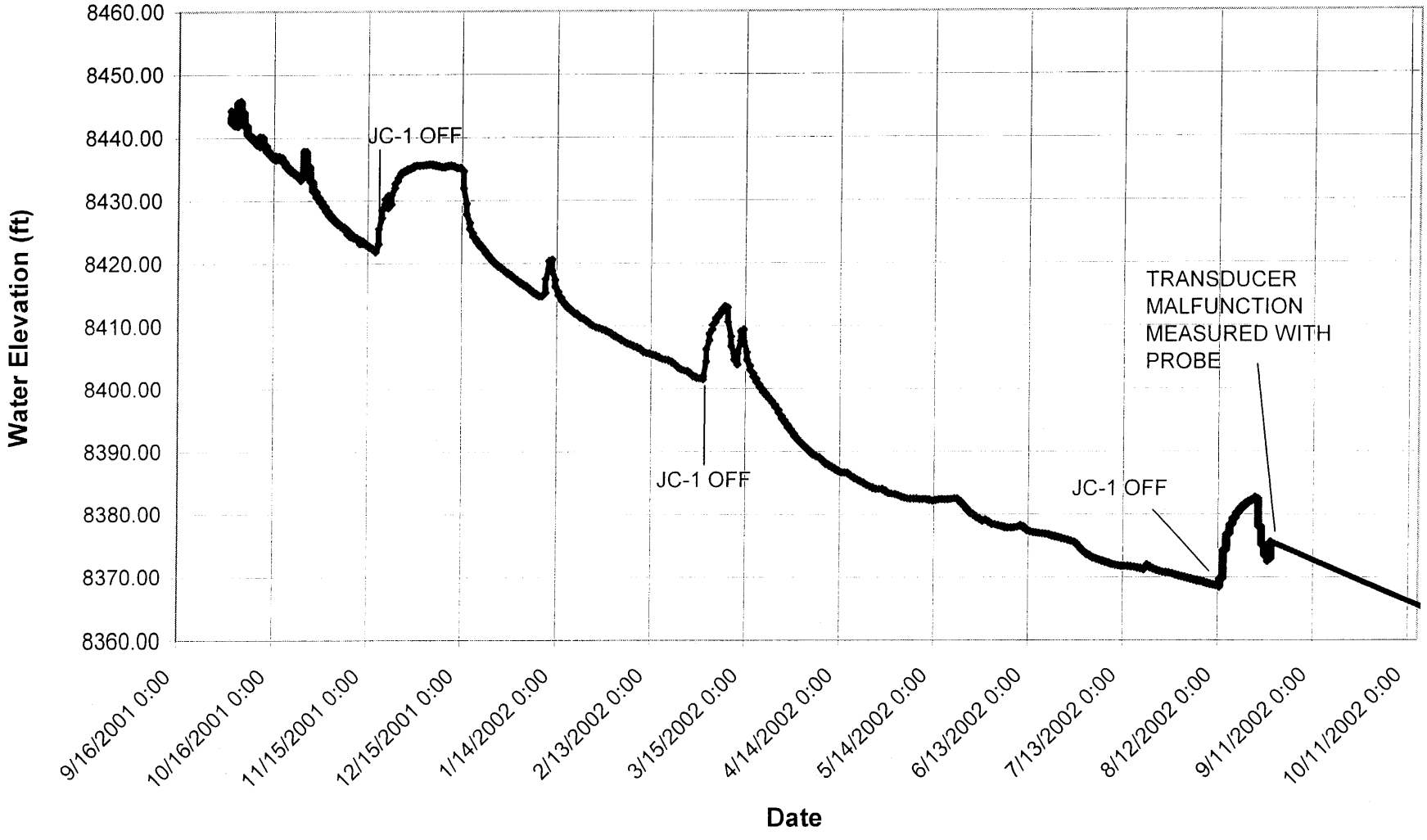
Well W2-1


Water elevation (feet)
8700
8675
8650
8625
8600
8575
8550
8525
8500
8475
8450
8425
8400
8375
8350
8325
8300
8
7
6
5
4
3
2
1
0
-1
-2
-3
-4
-5
-6
-7
-8
99
00
01
02
03
Well water level
PHDI Utah Region 5

Well W2-1


Water elevation (feet)
8800
8775
8750
8725
8700
8675
8650
8625
8600
8575
8550
8525
8500
8475
8450
8425
8400
8375
8350
8325
8300
8275
8250
8225
8200
8
7
6
5
4
3
2
1
0
-1
-2
-3
-4
-5
-6
-7
-8
83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 00 01 02 03
Well water level
PHDI Utah Region 5

W2-1 JAMES CANYON SOUTH RIDGE
Transducer Data



W2-1

Graphs illustrating the water levels of W2-1 are included on the attached figure; one graph illustrates the historic water level data and a second illustrates the most recent water level data as recorded by a downhole transducer. A plot of the PHDI for Utah Region 5 is included on the figure the first two graphs. Note the impacts of the periodic shutdown of JC-1 well. The responses to well shut down suggest W2-1 is completed in the same aquifer or fracture system as the JC-1 well. Well W79-35-1A exhibits similar responses to the JC-1 well suggesting the three wells are completed in the same aquifer or fracture system. The deep horizons monitored by well W2-1 are not in communication with the shallow subsurface and consequently, there is no seasonal or climatic variation apparent in the hydrograph.

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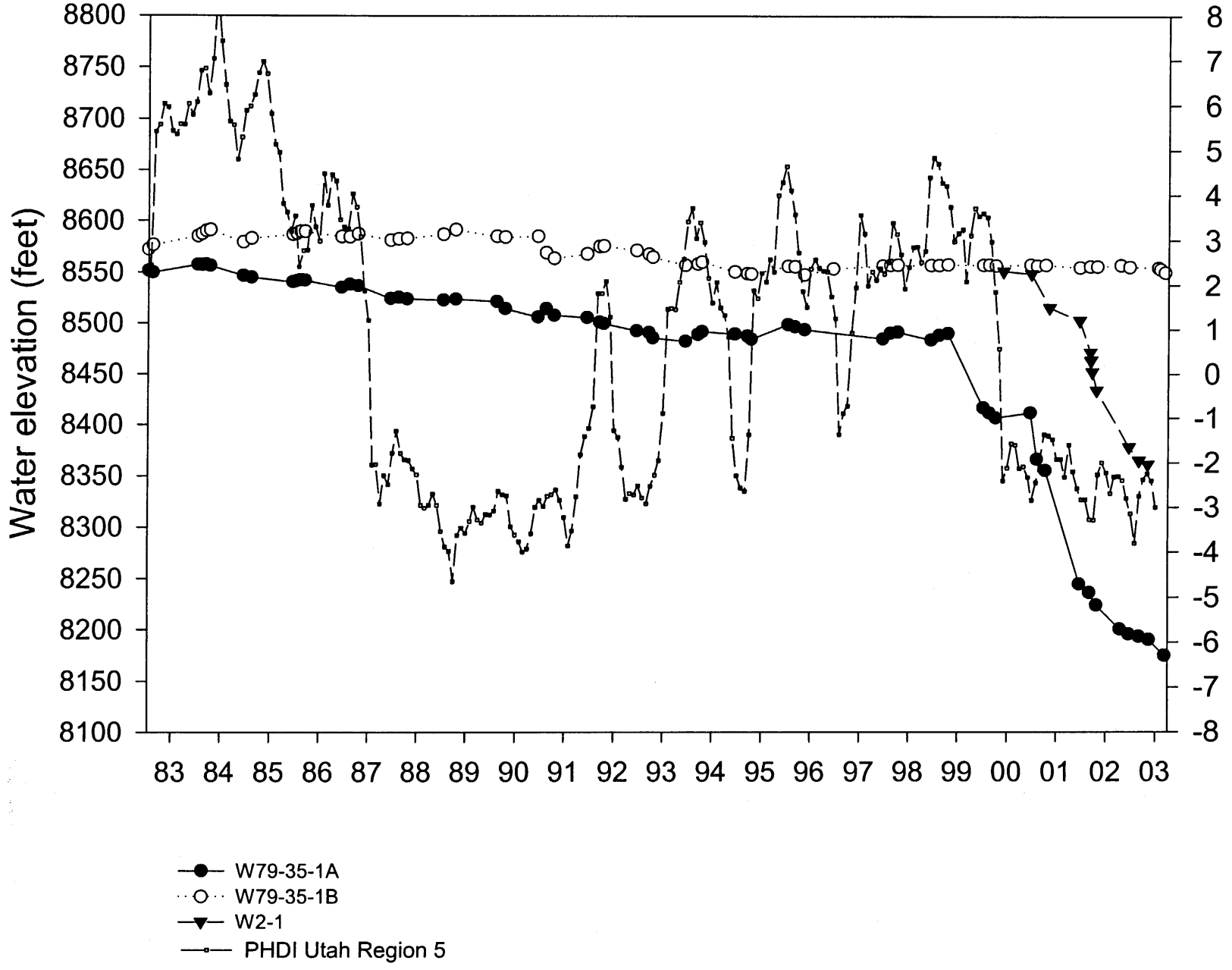
Wells W79-35-1A, B & W2-1



W35-1A, W35-1B, and W2-1

A graph showing the water levels in W35-1A, W35-1B, and W2-1 is included on the attached figure. A plot of the PHDI for Utah Region 5 is included on the figure. It is important to note that the water levels in W35-1A and W2-1 show the anticipated steady declines resulting from the dewatering activities in the sandstone horizons beneath the coal mine. In contrast, the water level in W35-1B, which is completed in the Blackhawk Formation above the mined coal seams, has remained relatively constant. This demonstrates the effectiveness of the Blackhawk Formation in impeding vertical migration of water across the formation.

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Historic Water Levels in Monitoring Wells in the Skyline Mine Area

W79-26-1			W79-35-1A			W79-35-1B			W79-10-1		
Date	Depth	Elevation	Date	Depth	Elevation	Date	Depth	Elevation	Date	Depth	Elevation
8/15/1982	58.30	8963.50	7/15/1982	177.50	8551.40	7/15/1982	154.70	8572.20	6/15/1996	480.30	8902.50
7/15/1983	52.20	8969.60	8/15/1982	179.00	8549.90	8/15/1982	150.40	8576.50	9/11/1996	482.19	8900.61
8/15/1983	52.50	8969.30	7/15/1983	171.50	8557.40	7/15/1983	141.70	8585.20	6/23/1997	477.20	8905.60
9/15/1983	52.80	8969.00	8/15/1983	171.70	8557.20	8/15/1983	139.60	8587.30	8/15/1997	480.70	8902.10
10/15/1983	52.20	8969.60	9/15/1983	171.20	8557.70	9/15/1983	136.80	8590.10	10/9/1997	491.10	8891.70
6/15/1984	51.60	8970.20	10/15/1983	172.40	8556.50	10/15/1983	135.90	8591.00	6/22/1998	476.30	8906.50
8/15/1984	51.20	8970.60	6/15/1984	182.20	8546.70	6/15/1984	147.40	8579.50	8/22/1998	476.20	8906.60
6/15/1985	51.20	8970.60	8/15/1984	183.70	8545.20	8/15/1984	143.80	8583.10	10/17/1998	476.00	8906.80
7/15/1985	51.00	8970.80	6/15/1985	188.30	8540.60	6/15/1985	140.10	8586.80	6/29/1999	475.30	8907.50
8/15/1985	50.90	8970.90	7/15/1985	187.20	8541.70	7/15/1985	139.10	8587.80	8/17/1999	475.10	8907.70
9/15/1985	50.70	8971.10	8/15/1985	186.20	8542.70	8/15/1985	137.10	8589.80	8/7/2000	473.70	8909.10
6/15/1986	50.70	8971.10	9/15/1985	186.70	8542.20	9/15/1985	137.30	8589.60	10/2/2000	472.80	8910.00
8/15/1986	50.80	8971.00	6/15/1986	193.70	8535.20	6/15/1986	142.30	8584.60	6/18/2001	470.70	8912.10
10/15/1986	50.90	8970.90	8/15/1986	190.70	8538.20	8/15/1986	142.40	8584.50	9/3/2001	359.70	9023.10
6/15/1987	51.90	8969.90	10/15/1986	192.20	8536.70	10/15/1986	139.70	8587.20	10/23/2001	357.10	9025.70
8/15/1987	52.30	8969.50	6/15/1987	204.80	8524.10	6/15/1987	145.60	8581.30	6/17/2002	348.20	9034.60
10/15/1987	52.80	8969.00	8/15/1987	203.60	8525.30	8/15/1987	144.30	8582.60			
7/15/1988	52.10	8969.70	10/15/1987	205.40	8523.50	10/15/1987	143.80	8583.10			
10/15/1988	50.40	8971.40	7/15/1988	206.20	8522.70	7/15/1988	139.80	8587.10			
8/15/1989	47.00	8974.80	10/15/1988	205.30	8523.60	10/15/1988	135.40	8591.50			
10/15/1989	45.30	8976.50	8/15/1989	207.60	8521.30	8/15/1989	141.80	8585.10			
6/15/1990	50.80	8971.00	10/15/1989	214.60	8514.30	10/15/1989	142.60	8584.30			
8/15/1990	51.20	8970.60	6/15/1990	222.90	8506.00	6/15/1990	141.80	8585.10			
10/15/1990	51.00	8970.80	8/15/1990	214.70	8514.20	8/15/1990	157.50	8569.40			
6/15/1991	52.80	8969.00	10/15/1990	221.20	8507.70	10/15/1990	163.00	8563.90			
9/15/1991	52.10	8969.70	6/15/1991	223.40	8505.50	6/15/1991	158.80	8568.10			
10/15/1991	52.80	8969.00	9/15/1991	228.00	8500.90	9/15/1991	151.60	8575.30			
6/15/1992	52.80	8969.00	10/15/1991	229.40	8499.50	10/15/1991	151.00	8575.90			
9/15/1992	54.40	8967.40	6/15/1992	236.50	8492.40	6/15/1992	155.30	8571.60			
10/15/1992	57.50	8964.30	9/15/1992	238.20	8490.70	9/15/1992	159.00	8567.90			
6/15/1993	58.20	8963.60	10/15/1992	243.30	8485.60	10/15/1992	161.90	8565.00			
9/15/1993	59.80	8962.00	6/15/1993	246.70	8482.20	6/15/1993	169.60	8557.30			
10/15/1993	61.60	8960.20	9/15/1993	239.90	8489.00	9/15/1993	168.50	8558.40			
6/15/1994	67.80	8954.00	10/15/1993	237.20	8491.70	10/15/1993	166.40	8560.50			
9/15/1994	68.60	8953.20	6/15/1994	239.70	8489.20	6/15/1994	176.10	8550.80			
10/15/1994	68.50	8953.30	9/15/1994	241.50	8487.40	9/15/1994	177.80	8549.10			
7/15/1995	67.90	8953.90	10/15/1994	244.70	8484.20	10/15/1994	178.20	8548.70			
9/5/1995	68.50	8953.30	7/15/1995	230.20	8498.70	7/15/1995	170.60	8556.30			
11/15/1995	68.70	8953.10	9/5/1995	232.40	8496.50	9/5/1995	171.10	8555.80			
6/15/1996	69.00	8952.80	11/15/1995	235.20	8493.70	11/15/1995	179.00	8547.90			
6/19/1997	118.50	8903.30	6/19/1997	244.20	8484.70	6/15/1996	173.00	8553.90			
8/13/1997	118.44	8903.36	8/15/1997	238.50	8490.40	6/19/1997	170.10	8556.80			
10/12/1997	118.44	8903.36	10/9/1997	237.70	8491.20	8/15/1997	169.80	8557.10			
6/15/1998	70.30	8951.50	6/15/1998	245.40	8483.50	10/9/1997	169.40	8557.50			
8/13/1998	71.00	8950.80	8/13/1998	240.70	8488.20	6/15/1998	169.60	8557.30			
10/17/1998	118.90	8902.90	10/17/1998	239.00	8489.90	8/13/1998	169.60	8557.30			
7/5/1999	71.90	8949.90	7/5/1999	312.20	8416.70	10/17/1998	169.00	8557.90			
9/19/1999	81.20	8940.60	8/19/1999	317.30	8411.60	7/5/1999	169.40	8557.50			
10/6/1999	91.80	8930.00	10/6/1999	322.30	8406.60	8/19/1999	169.10	8557.80			
6/20/2000	131.70	8890.10	6/20/2000	317.30	8411.60	10/6/1999	169.90	8557.00			
8/7/2000	129.00	8892.80	8/7/2000	363.00	8365.90	6/20/2000	169.10	8557.80			
10/9/2000	136.70	8885.10	10/9/2000	374.00	8354.90	8/7/2000	170.00	8556.90			
6/19/2001	89.00	8932.80	6/19/2001	484.90	8244.00	10/9/2000	169.50	8557.40			
9/3/2001	93.10	8928.70	9/3/2001	493.30	8235.60	6/19/2001	171.80	8555.10			
10/25/2001	95.50	8926.30	10/25/2001	505.50	8223.40	9/3/2001	170.90	8556.00			
6/19/2002	97.60	8924.20	4/15/2002	528.8	8200.15	10/25/2001	170.70	8556.20			
			6/19/2002	533.71	8195.19	4/15/2002	169.75	8557.15			
						6/19/2002	171.25	8555.65			

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Historic Water Levels in Monitoring Wells in the Skyline Mine Area

W79-14-2A			99-21-1			99-28-1			20-4-1		
Date	Depth	Elevation	Date	Depth	Elevation	Date	Depth	Elevation	Date	Depth	Elevation
9/5/1995	78.70	8973.00	12/9/1999	926.50	8419.50	12/9/1999	841.00	8510.00	1/29/2001	315.00	8559.00
6/15/1996	76.90	8974.80	6/26/2000	927.00	8419.00	6/26/2000	843.70	8507.30	6/18/2001	317.40	8556.60
9/12/1996	75.66	8976.04	1/29/2001	990.00	8356.00	11/8/2000	860.10	8490.90	9/3/2001	326.33	8547.67
6/27/1997	59.06	8992.64	6/18/2001	990.70	8355.30	1/29/2001	899.00	8452.00	10/8/2001	332.10	8541.90
8/15/1997	71.90	8979.80	9/3/2001	996.80	8349.20	6/18/2001	902.30	8448.70	1/3/2002	346.50	8527.50
10/12/1997	77.30	8974.40	10/8/2001	996.10	8349.90	9/3/2001	908.70	8442.30	6/12/2002	370.50	8503.50
6/22/1998	58.20	8993.50	4/15/2002	1005.8	8340.21	10/8/2001	911.70	8439.30			
8/22/1998	86.40	8965.30	6/12/2002	1010.3	8335.70	6/12/2002	926.25	8424.75			
10/17/1998	85.90	8965.80									
7/6/1999	84.70	8967.00									
8/19/1999	84.30	8967.40									
10/12/1999	88.60	8963.10									
6/27/2000	86.20	8965.50									
8/8/2000	86.90	8964.80									
10/2/2000	87.00	8964.70									
6/18/2001	85.30	8966.40									
9/5/2001	85.90	8965.80									
10/8/2001	87.50	8964.20									
6/18/2002	86.50	8965.20									

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Historic Water Levels in Monitoring Wells in the Skyline Mine Area

20-4-2			W2-1		
Date	Depth	Elevation	Date	Depth	Elevation
1/29/2001	1022.00	8532.00	12/3/1999	720.00	8551.40
6/18/2001	1026.50	8527.50	6/26/2000	722.20	8549.20
9/3/2001	1040.00	8514.00	11/8/2000	756.20	8515.20
10/8/2001	1056.90	8497.10	6/18/2001	768.90	8502.50
4/16/2002	1101.5	8452.54	9/5/2001	800.10	8471.30
6/13/2002	1110.95	8443.05	9/10/2001	808.40	8463.00
			9/14/2001	807.70	8463.70
			9/20/2001	819.40	8452.00
			10/23/2001	837.50	8433.90
			6/19/2002	893.55	8377.85

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November 21, 2001

CANYON FUEL CO., SKYLINE MINES
P.O. Box 719
Helper, Utah 84526

Sample identification by
Skyline

ID:JAMES CANYON WELLS

Kind of sample reported to us: Water

Sample taken at: Skyline

Sample taken by: C. Hansen

Date sampled: November 9, 2001

Date received: November 9, 2001

RECEIVED 1640
SAMPLED 1400
FIELD MEASUREMENTS
FLOW 2530 TEMP 16 C
COND 710 pH 7.53

NOTES
DIS.METALS
FILTERED @ LAB
PARTIAL REPORT
Page 1 of 1

Analysis report no. 59-21629

Parameter	Result	MRL	Units	Method	Analyzed Date/Time/Analyst
Alkalinity, Bicarbonate	236	5	mg/l as HCO3	EPA 310.1	11-12-2001 1225 CB
Alkalinity, Carbonate	<5	5	mg/l as CO3	EPA 310.1	11-12-2001 1225 CB
Alkalinity, Total	194	5	mg/l as CaCO3	EPA 310.1	11-12-2001 1225 CB
Anions	4.1		meq/l		11-21-2001 1100 CB
Calcium, Total	47	1	mg/l	EPA 215.1	11-12-2001 1443 MK
Calcium, Dissolved	47	1	mg/l	EPA 215.1	11-12-2001 1452 MK
Cations	4.0		meq/l		11-21-2001 1100 CB
Chloride	1.7	0.5	mg/l	EPA 300.0	11-19-2001 0011 CB
Conductivity	361		umhos/cm	SM2510-B	11-12-2001 1500 SC
Hardness, Total	187		mg/l as CaCO3	SM2340-B	11-21-2001 1100 CB
Iron, Total	0.2	0.1	mg/l	EPA 236.1	11-12-2001 1254 MK
Iron, Dissolved	<0.1	0.1	mg/l	EPA 236.1	11-12-2001 1301 MK
Magnesium, Total	17	1	mg/l	EPA 242.1	11-12-2001 1458 MK
Magnesium, Dissolved	17	1	mg/l	EPA 242.1	11-12-2001 1504 MK
Manganese, Total	<0.05	0.05	mg/l	EPA 243.1	11-12-2001 1308 MK
Manganese, Dissolved	<0.05	0.05	mg/l	EPA 243.1	11-12-2001 1315 MK
Potassium, Total	2	1	mg/l	EPA 258.1	11-12-2001 1327 MK
Potassium, Dissolved	2	1	mg/l	EPA 258.1	11-12-2001 1334 MK
Sodium, Total	4	1	mg/l	EPA 273.1	11-12-2001 1341 MK
Sodium, Dissolved	4	1	mg/l	EPA 273.1	11-12-2001 1348 MK
Solids, Total Dissolved	204	10	mg/l	EPA 160.1	11-12-2001 0915 SC
Sulfate	8.2	0.5	mg/l	EPA 300.0	11-19-2001 1100 CB
Cation/Anion Balance	-1.5		%		11-21-2001 1100 CB

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Respectfully submitted,
COMMERCIAL TESTING & ENGINEERING CO.

Huntington Laboratory

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February 5, 2002

CANYON FUEL CO., SKYLINE MINES
P.O. Box 719
Helper, Utah 84526

Sample identification by
Skyline

ID:JAMES CANYON WELLS

Kind of sample reported to us: Water

Sample taken at: Skyline

Sample taken by: Chris Hansen

Date sampled: January 23, 2002

Date received: January 28, 2002

RECEIVED 1720
SAMPLED 1500
FIELD MEASUREMENTS
FLOW 2300 TEMP 14
COND 242 pH 7.24

Analysis report no. 59-23753

Parameter	Result	MRL	Units	Method	Analyzed Date/Time/Analyst
Iron, Total	0.1	0.1	mg/l	EPA 236.1	02-01-2002 1139 MK
Oil & Grease	<2	2	mg/l	EPA 413.1	01-29-2002 0730 MK
Solids, Total Dissolved	198	10	mg/l	EPA 160.1	01-28-2002 1730 DI
Solids, Total Suspended	<5	5	mg/l	EPA 160.2	01-28-2002 1730 DI

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May 30, 2002

CANYON FUEL CO., SKYLINE MINES
P.O. Box 719
Helper, Utah 84526

Sample identification by
Skyline

ID:JC-1

Kind of sample reported to us Water

Sample taken at Skyline

Sample taken by C. HANSEN

Date sampled May 15, 2002

Date received May 16, 2002

RECEIVED 0645
SAMPLED 1215
FIELD MEASUREMENTS
FLOW 2100 TEMP 14.7
COND. 247 pH 7.0

NOTES:

Analysis report no. 59-23987

Parameter	Result	MRL	Units	Method	Analyzed Date/Time/Analyst
Iron, Total	0.5	0.1	mg/l	EPA 236.1	05-21-2002 1000 MK
Oil & Grease	<2	2	mg/l	EPA 413.1	05-28-2002 1230 DI
Solids, Total Dissolved	174	10	mg/l	EPA 160.1	05-20-2002 1130 DI
Solids, Total Suspended	<5	5	mg/l	EPA 160.2	05-20-2002 1130 DI

FAXED May 30 '02

RECEIVED
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Respectfully submitted,
COMMERCIAL TESTING & ENGINEERING CO.

Huntington Laboratory

MEMBER ACIL

	discharge (gpm)	T (C)	pH	Cond µS/cm	TDS mg/l	Ca^{2+} mg/l	Mg^{2+} mg/l	Na^{+} mg/l	K^{+} mg/l	HCO_3^{-} mg/l	CO_3^{2-} mg/l	SO_4^{2-} mg/l	Cl^{-} mg/l
Swens Canyon Creek (CS-16)													
10/20/1997	1.54	2.8	8.3	322	180	53	7	3	<1	210	<5	8	3
7/21/1998	300	13.1	8.5	230	200	52	5	1	<1	172	12	4	<1
10/12/1998	32	6.7	8.3	220	178	45	8	2	1	180	<5	7	2
7/7/1999	300	13.4	8.5	218	177	52	5	<1	<1	182	7	4	<1
10/19/1999	200	-0.5	8.2	306	213	59	7	2	<1	215	<5	8	<1
7/10/2000	329	11.3	8.39	304	163	53	7	1	<1	190	<5	15	<1
6/18/2001	429	18.3	8.67	270	170	47	6	2	<1	179		5	0.7
9/4/2001	117.4	15.8	8.35	325	234	42	7	2	<1	157	<5	7	0.8
10/23/2001	131	7.4	8.2	378	159	52	8	2	<1	195		8	1.4
6/12/2002	467	18	8.2	341									
average	**231**	**11**	**8**	**291**	**186**	**51**	**7**	**2**	**<1**	**187**	**<5**	**7**	**2**
Little Swens Canyon Creek (CS-17)													
7/21/1998	211	13.2	8.2	220	183	46	5	2	<1	145	11	6	2
10/12/1998	16	3.4	8.5	180	176	47	7	2	1	181	<5	9	3
7/7/1999	115	13.4	8.4	244	151	44	5	<1	<1	158	<5	4	<1
10/19/1999	21	-0.6	7.97	324	214	60	8	3	<1	216	<5	11	2
7/12/2000	89.9	11.4	7.96	287	176	50	7	<1	<1	174	<5	7	2
6/18/2001	176	17.6	8.65	226	147	40	5	2	<1	152		5	0.8
9/4/2001	40.7	13.1	8.61	261	158	43	7	1	<1	157	<5	9	1.7
10/23/2001	47.7	2.7	8.26	381	185	51	9	2	<1	180	<5	11.5	1.6
6/12/2002	267	18	8.3	282									
average	**109**	**10**	**8**	**267**	**174**	**48**	**7**	**2**	**<1**	**170**	**<5**	**8**	**2**
James Canyon Creek (F-10)													
6/20/2001	257												
7/20/2001	110												
7/31/2001	110	14	8.8	320	259	60	12	2	1			10	1
9/5/2001	118	9	8.4	390	212	68	12	2	0	255	<5.	10	1
10/23/2001	115	5	8.2	389	239	68	13	3	0	250		10	2
6/19/2002	350	12	8.5	371									
average	**177**	**10**	**8.5**	**368**	**237**	**65**	**12**	**2**	**0**	**253**	**<5**	**10**	**1**
Huntington Creek above Electric Lake (UPL-10)													
7/30/1981		13	8.2		167					171		18	3
10/22/1981		0	6.8		195					221		6	4
11/10/1981	494	3	8.0		196					162		38	3
12/8/1981		0	8.2		212					189		33	3
6/28/1982	5790	13	8.2	332									
7/21/1982	2715	13	7.9	339									
8/17/1982	1158	14	8.2	246	187					208		<3.	11
9/15/1982	1436	8	8.0	320									
10/15/1982	1616	4	8.6	247									
6/28/1983	28319	13	8.0	126									
7/19/1983	5094	12	8.0	270									
8/24/1983	2383	9	7.6	315	176					188		13	<0.1
9/27/1983	3478	10	6.6	263									
10/20/1983	2289	6	7.7	283									
5/24/1984		8	7.3	142									
6/26/1984	14003	11	6.8	227									
7/31/1984	2401	12	7.5	291									
8/24/1984	1391	10	7.7	353	225	60	22	10	1	220		<10.	20
9/27/1984	1293	4	7.6	311									
11/13/1984		0	7.5	243									
1/30/1985		0	8.1	545	442	96	37	3	2	334		107	7
5/21/1985	35455	6	7.4	154									
6/19/1985	3680	17	7.8	317									
7/17/1985	1279	15	7.9	406									
8/28/1985	803	14	7.9	291						181			2
9/24/1985	776	10	7.9	301									
10/15/1985	965	6	7.7	290									
5/27/1986		7	7.3	120									
6/19/1986	14003	14	7.8	191									
7/22/1986	1521	11	7.4	315									
8/19/1986	830	15	7.7	311	155					176		9	2

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	discharge (gpm)	T (C)	pH	Cond µS/cm	TDS mg/l	Ca^{2+} mg/l	Mg^{2+} mg/l	Na^{+} mg/l	K^{+} mg/l	HCO_3^{-} mg/l	CO_3^{2-} mg/l	SO_4^{2-} mg/l	Cl^{-} mg/l
9/24/1986	1055	5	7.6	297									
10/16/1986	925	1	7.8	267									
5/19/1987	7544	8	7.9	170									
6/16/1987	1310	16	8.0	233									
7/28/1987	898	14	8.1	265									
8/20/1987	269	17	8.4	265	162					196		8	1
9/22/1987	489	7	8.0	294									
10/19/1987	615	6	8.4	289									
8/17/1988	750	10	7.2	341	185					198		10	2
6/21/1989	1840	16	7.6	287	198					177		7	11
9/7/1989	426	8	6.8	383	188					178		24	3
10/17/1989	606	6	8.2	280	179	53	9	2	1	176		20	3
6/5/1990		8	7.3	183	104	34	4	5	0	124		6	3
9/11/1990	494	18	8.4	329	172	47	9	3	1	194		11	4
10/24/1990	570	9	7.3	342	186	51	8	2	1	184		14	5
6/19/1991	3379	14	8.3	210	116					108		8	5
9/5/1991	678	14	8.3	325	174	58	9	1	1	180		10	5
10/15/1991	467	12	8.0	322	204	53	9	2	0	177		13	5
6/9/1992	1230	17	8.3	288	194					143	1	8	7
9/2/1992	364	12	7.8	311	172					167	3	12	7
10/21/1992		3	7.9	389	186					198	2	15	6
6/28/1993	2343	17	8.8	206	112					118	3	6	5
8/26/1993		11	8.2	387	182					183	4	10	7
10/27/1993	619	3	8.2	382	188					181	2	15	8
6/19/1995	13958	14	8.1	216	80					95	10	1	4
9/4/1995	1355	16	8.6	343	130					175		9	9
10/18/1995	718	10	8.3	384	190					170		11	9
6/24/1996	8222	13	8.5	307	140	44	5	3	0	129		5	1
9/11/1996	1176	11	8.4	375	210					191	<5.	11	10
10/28/1996	1257	2	8.1	232	216	54	9	6	1	395			11
6/23/1997	12876	9	7.6	315	150	49	6	3	0	153			7
8/12/1997	1957	16	8.3	368	190	53	8	5	0	183	<5.	10	9
10/9/1997	1391	9	8.6	336	180	53	8	5	1	177			13
6/15/1998	19173	9	8.3	249	142	36	4	3	0	115			6
8/13/1998	911	10	7.5	382	198	56	7	4	0	208	<5.	9	10
10/8/1998	386	10	8.2	392	222	54	8	4	1	214			12
7/5/1999	1337	20	8.3	342	166	45	6	4	0	164			8
8/18/1999	283	18	8.3	391	181	50	8	2	0	178	<5.	9	10
10/6/1999	217	9	8.2	416									
10/6/1999					210	56	8	<1.	0	193			10
6/20/2000	270	19	8.3	349	197	45	7	5	0	142	6	8	13
8/7/2000	197	12	8.3	392	233	49	9	4	0	177	<5.	11	13
10/9/2000	196	9	8.2	432	259	54	9	5	0	184	<5.	14	12
6/19/2001	1641	19	8.8	274	165	41	7	5	0	149		10	16
9/3/2001		16	8.1	411	215	50	9	6	0	132	9	12	16
10/25/2001	711	0	7.6	443	216	58	10	6	1	196		16	15
6/19/2002	1212	19	8.1	365									
average	**3512**	**10**	**7.9**	**306**	**186**	**52**	**9**	**4**	**0**	**180**	**5**	**15**	**8**
James Canyon Well JC-1													
9/19/2001			7.6				18			227		9	2.6
9/21/2001			8				19			224		9	2.3
9/23/2001			7.9				19			222		9	2.7
9/25/2001		15	7.9	354		45	18	3	3	222		9	2.2
9/26/2001		15	7.65	354	---	45	17	3	3	220	<0.1	8	1.98
9/28/2001			7.6				17			229		9	3
10/3/2001			7.7				17			229		9	4
James Canyon Well JC-2													
10/5/2001						48	18	4	3	227		9	3

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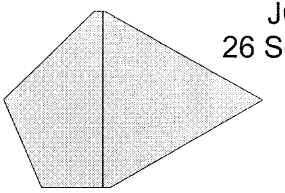
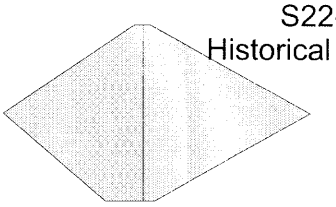
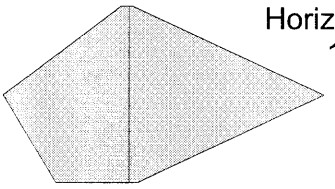


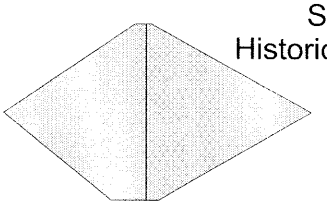
JC-1
26 Sep 01



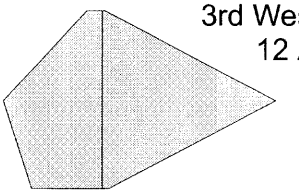
S22-11
Historical average



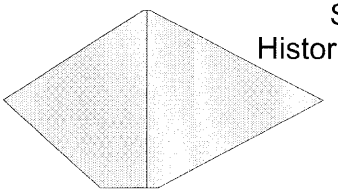
9 Left Headgate
Horizontal borehole
12 Aug 01



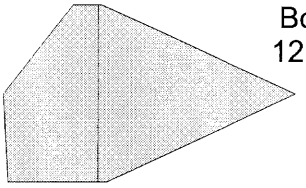
S26-13
Historical average



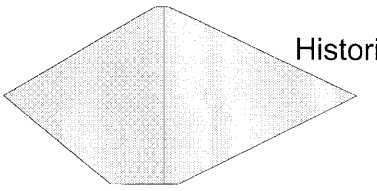
Fault Crossing
3rd West Submain
12 Aug 01



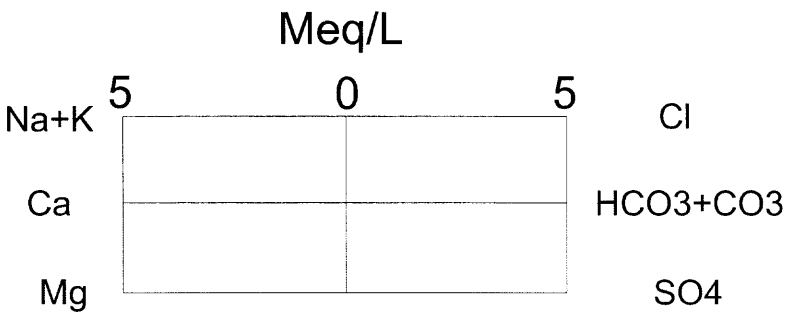
S34-12
Historical average

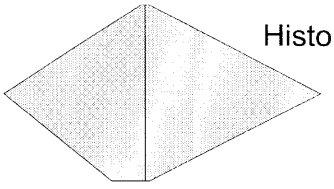


10 Left Entry #3
Borehole
12 Aug 01



S35-8
Historical average





2-413
Historical average

Stiff diagrams for springs and in-mine groundwaters from the Skyline Mine.

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Stiff Diagrams

Results of flow and chemical monitoring of selected springs in the area are presented in the attached table.

Stiff diagrams depicting water quality in selected springs and in-mine locations are shown on the attached figure. The shape of the stiff diagram is a function of the chemical type of the water, while the size of the Stiff diagram is a function of the total dissolved solids concentration of the water. Results of one-time water samplings were used for the construction of the in-mine groundwaters. Historical average chemical compositions were used in the construction of the spring Stiff diagrams. The use of historical averages is preferable to the use of a one-time sampling event in the construction of Stiff diagrams because the potential for the inclusion of non-representative data is minimized (i.e. such as would occur as a result of a single bad laboratory analysis or sampling error).

The Stiff diagrams for the selected springs indicate that the waters are of the calcium-bicarbonate chemical type. TDS concentrations are relatively low. This chemical composition is consistent with the dissolution of carbonate minerals in the presence of soil-zone CO_2

The chemical composition of the in-mine groundwaters is of the calcium-magnesium-bicarbonate type. The calcium/magnesium ratio of the in-mine groundwaters is significantly lower than it is in the shallow groundwater systems from which the springs discharge. TDS concentrations of the in-mine groundwaters are of a similar magnitude to those of the springs.

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November 21, 2001

CANYON FUEL CO., SKYLINE MINES
P.O. Box 719
Helper, Utah 84526

Sample identification by
Skyline

ID:JAMES CANYON WELLS

Kind of sample reported to us: Water

Sample taken at: Skyline

Sample taken by: C. Hansen

Date sampled: November 9, 2001

Date received: November 9, 2001

RECEIVED 1640
SAMPLED 1400
FIELD MEASUREMENTS
FLOW 2530 TEMP 16 C
COND 710 pH 7.53

NOTES
DIS.METALS
FILTERED @ LAB
PARTIAL REPORT
Page 1 of 1

Analysis report no. 59-2[illegible]629

Parameter	Result	MRL	Units	Method	Analyzed Date/Time/Analyst
Alkalinity, Bicarbonate	236	5	mg/l as HCO	EPA 310.1	11-12-2001 1225 CB
Alkalinity, Carbonate	<5	5	mg/l as CO	EPA 310.1	11-12-2001 1225 CB
[illegible]kalinity, Total	194	5	mg/l as CaCO	EPA 310.1	11-12-2001 1225 CB
[illegible]ions	4.1		meq/l		11-21-2001 1100 CB
Calcium, Total	47	1	mg/l	EPA 215.1	11-12-2001 1443 MK
Calcium, Dissolved	47	1	mg/l	EPA 215.1	11-12-2001 1452 MK
Cations	4.0		meq/l		11-21-2001 1100 CB
Chloride	1.7	0.5	mg/l	EPA 300.0	11-19-2001 0011 CB
Conductivity	361		umhos/cm	SM2510-B	11-12-2001 1500 SC
Hardness, Total	187		mg/l as CaCO	SM2340-B	11-21-2001 1100 CB
Iron, Total	0.2	0.1	mg/l	EPA 236.1	11-12-2001 1254 MK
Iron, Dissolved	<0.1	0.1	mg/l	EPA 236.1	11-12-2001 1301 MK
Magnesium, Total	17	1	mg/l	EPA 242.1	11-12-2001 1458 MK
Magnesium, Dissolved	17	1	mg/l	EPA 242.1	11-12-2001 1504 MK
Manganese, Total	<0.05	0.05	mg/l	EPA 243.1	11-12-2001 1308 MK
Manganese, Dissolved	<0.05	0.05	mg/l	EPA 243.1	11-12-2001 1315 MK
Potassium, Total	2	1	mg/l	EPA 258.1	11-12-2001 1327 MK
Potassium, Dissolved	2	1	mg/l	EPA 258.1	11-12-2001 1334 MK
Sodium, Total	4	1	mg/l	EPA 273.1	11-12-2001 1341 MK
Sodium, Dissolved	4	1	mg/l	EPA 273.1	11-12-2001 1348 MK
Solids, Total Dissolved	204	10	mg/l	EPA 160.1	11-12-2001 0815 SC
Sulfate	8.2	0.5	mg/l	EPA 300.0	11-19-2001 1100 CB
Cation/Anion Balance	-1.5		%		11-21-2001 1100 CB

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Respectfully submitted,
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Huntington Laboratory

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February 5, 2002

CANYON FUEL CO., SKYLINE MINES
P.O. Box 719
Helper, Utah 84526

Sample identification by
Skyline

ID:JAMES CANYON WELLS

Kind of sample reported to us: Water

Sample taken at: Skyline

Sample taken by: Chris Hansen

Date sampled: January 23, 2002

Date received: January 28, 2002

RECEIVED 1720
SAMPLED 1500
FIELD MEASUREMENTS
FLOW 2300 TEMP 14
COND 242 pH 7.24

Analysis report no. 59-23753

Parameter	Result	MRL	Units	Method	Analyzed Date/Time/Analyst
Iron, Total	0.1	0.1	mg/l	EPA 236.1	02-01-2002 1139 MK
Oil & Grease	<2	2	mg/l	EPA 413.1	01-29-2002 0730 MK
Solids, Total Dissolved	198	10	mg/l	EPA 160.1	01-28-2002 1730 DI
Solids, Total Suspended	<5	5	mg/l	EPA 160.2	01-28-2002 1730 DI

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May 30, 2002

CANYON FUEL CO., SKYLINE MINES
P.O. Box 719
Helper, Utah 84526

Sample identification by
Skyline

ID:JC-1

Kind of sample reported to us Water

Sample taken at Skyline

Sample taken by C. HANSEN

Date sampled May 15, 2002

Date received May 16, 2002

RECEIVED 0645
SAMPLED 1215
FIELD MEASUREMENTS
FLOW 2100 TEMP 14.7
COND. 247 pH 7.0

NOTES:

Analysis report no. 59-23987

Parameter	Result	MRL	Units	Method	Analyzed Date/Time/Analyst
Iron, Total	0.5	0.1	mg/l	EPA 236.1	05-21-2002 1000 MK
Oil & Grease	<2	2	mg/l	EPA 413.1	05-28-2002 1230 DI
Solids, Total Dissolved	174	10	mg/l	EPA 160.1	05-20-2002 1130 DI
Solids, Total Suspended	<5	5	mg/l	EPA 160.2	05-20-2002 1130 DI

FAXED May 30 '02

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Groundwater mean residence times in the Skyline Mine area.

Site	Date	$\delta^{13}C$	^{14}C	Tritium	Mean residence time
Springs, Flat Canyon Tract					
2-413	10/8/1997	-13.8	95.71	14.9	modern
	7/22/1998	-12.4	91.68	15	modern
7-242	10/9/1997	-13.1	73.52	10.5	modern
29-138	10/8/1997	-12.3	88.58	12.9	modern
	7/21/1998	-13.5	90.96	14	modern
8-253	10/9/1997	-16.0	84.39	29.7	modern
	7/21/1998	-16.1	79.06	30	modern
32-279	10/9/1997	-12.3	68.62	14	modern
	7/21/1998	-12.5	71.67	15	modern
MST-3	9/11/1997			13.1	modern
	7/21/1998	-12.1	71.35	10.3	modern
Springs, Existing Permit Area					
S13-2	10/17/1995	-12.0	80.1	18.8	modern
S15-3	10/18/1995	-13.2	62.4	17.1	modern
S22-11	10/18/1995	-13.3	75.5	21.6	modern
S34-12	10/18/1995	-13.0	78.3	20.4	modern
S36-12	10/17/1995	-13.3	85.2	18.1	modern
Fault Related					
S17-2	10/17/1995	-10.5	39.6	1.6	3,000 mixed w/modern
Wells, Existing Permit Area					
W17-3	6/6/1996	-10.8	37.3	4.56	3,500 mixed w/modern
W24-1	6/6/1996	-11.2	45.9	2.83	2,000 mixed w/modern
Skyline Mine (roof drips, floor seeps)					
Roof Drip 1-03D	10/6/1993	-10.7	15.4	5.6*	10,500
Roof Drip 1-05D	5/8/1996			0.28	
Roof Drip 1-14D	5/8/1996	-8.7	21.4	0.16	7,500
Roof Drip 1-15D	5/8/1996	-10.3	28.7	0.16	5,500
Floor Water 1-01S	10/6/1993	-13.8	5.6	0	18,500
Roof Drip 3-07D	10/6/1993	-10.8	14.1	6.7*	10,500
	5/8/1996			0.12	
Roof Drip 3-08D	5/8/1996	-10.9	41.5	0.26	2,500
Skyline Mine Fault Inflows					
14LHGE1C35 Roof	3/22/1999	-10.3	10.85	-0.01	13,300
14LHGE1C35 Floor	3/22/1999	-9.7	9.63	0.11	14,400
14LHGE1C37 Rib Water	4/12/1999	-9.9	6.91	0.02	16,700
5LTGE1C39	12/18/1999	-9.8	19.05	-0.06	8,000
16LE2XC11.5	12/15/1999	-10.7	17.25	0.14	9,500
14LE1XC36	12/15/1999	-10.1	17.66	0.02	9,200
14LHGE1C35	9/22/2000	-10.2	12.98	-0.02	11,500
E6XC22 West Submains	9/22/2000	-10.3	21.15	0.00	7,400
16LXC12	4/18/2001	-9.9	16.02	-0.02	9,250
14LE1XC36	4/18/2001	-10.3	18.65	0.12	8,500
9LE3XC40 Borehole	4/19/2001	-11.2	23.53	0.06	7,250
Diagonal Submains E3XC12	4/19/2001	-10.3	23.98	0.05	6,250
8LE3XC62 Borehole	4/18/2001	-11.9	29.11	0.78	6,000
8L Bleeder XC51 Borehole	4/18/2001	-12.3	13.66	0.51	12,500
8LE2XC62 Borehole (uncased)	4/18/2001	-11.9	8.15	0.06	16,500
9L Borehole XC59	4/10/2002	-10.4	16.91	0.16	9,300
Diagonal Fault	4/10/2002	-10.3	11.91	0.01	12,100
11L Headgate E1 XC62	4/10/2002	-10.5	25.57	0.31	5,900
East Submains E1 XC5 Fault	4/10/2002	-10.7	15.17	0.01	10,200
East Submains E3 XC14 Fault	4/10/2002	-10.3	17.35	0.88	9,000
11L Headgate E1 XC39 Fault	4/10/2002	-10.9	2.29	0.01	25,800
11L Headgate XC54	4/25/2002	-10.1	7.26	0.06	16,300
Mine Dewatering Wells					
JC-1	9/26/2001	-11.8	30.42	0.17	4,600
Electric Lake					
Upper Electric Lake	9/26/2001	-8.3	72.44	13	modern

* Likely analytical error, samples analyzed using less accurate direct counting technique, verified on subsequent resampling at 3-07D

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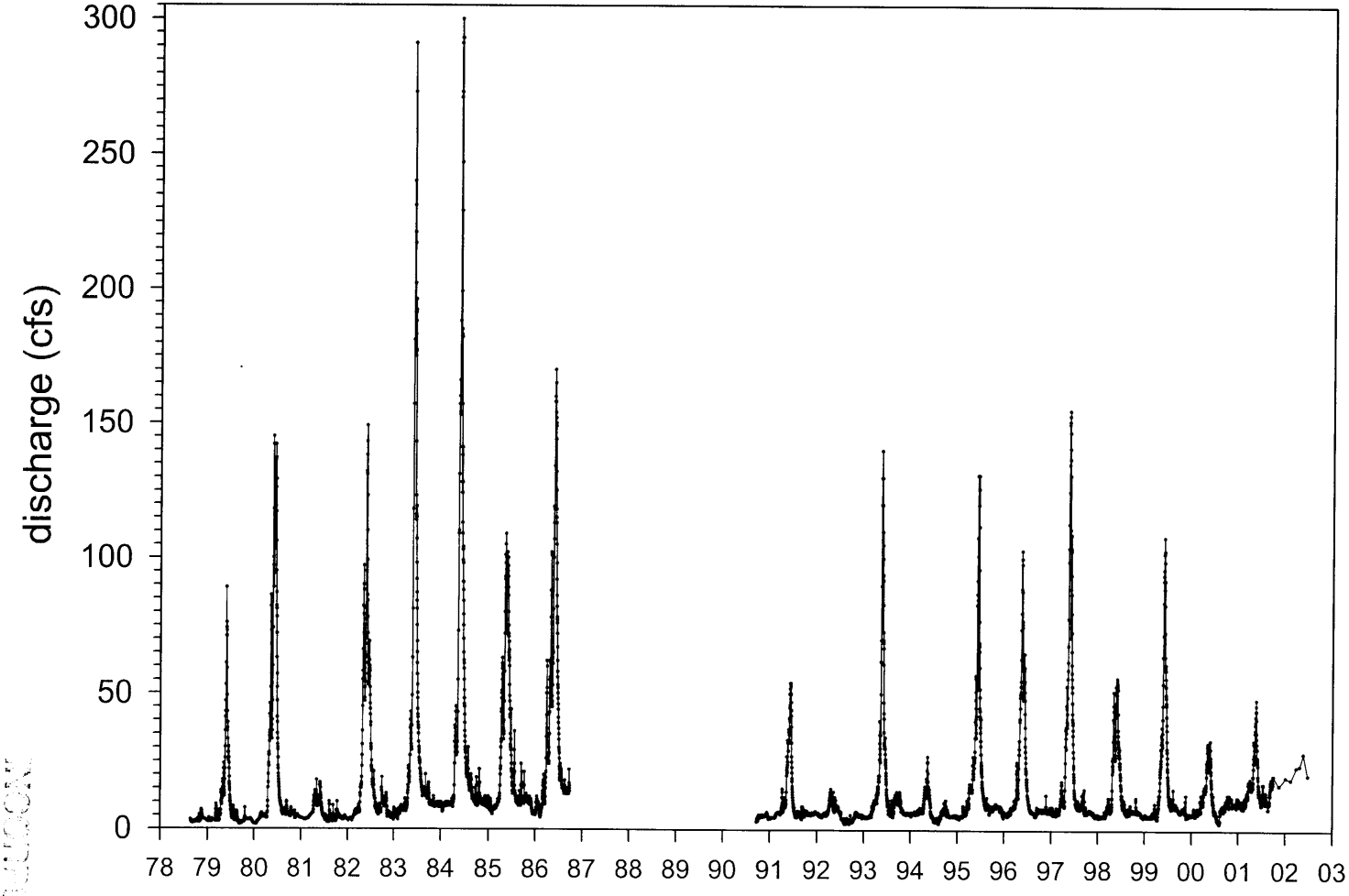
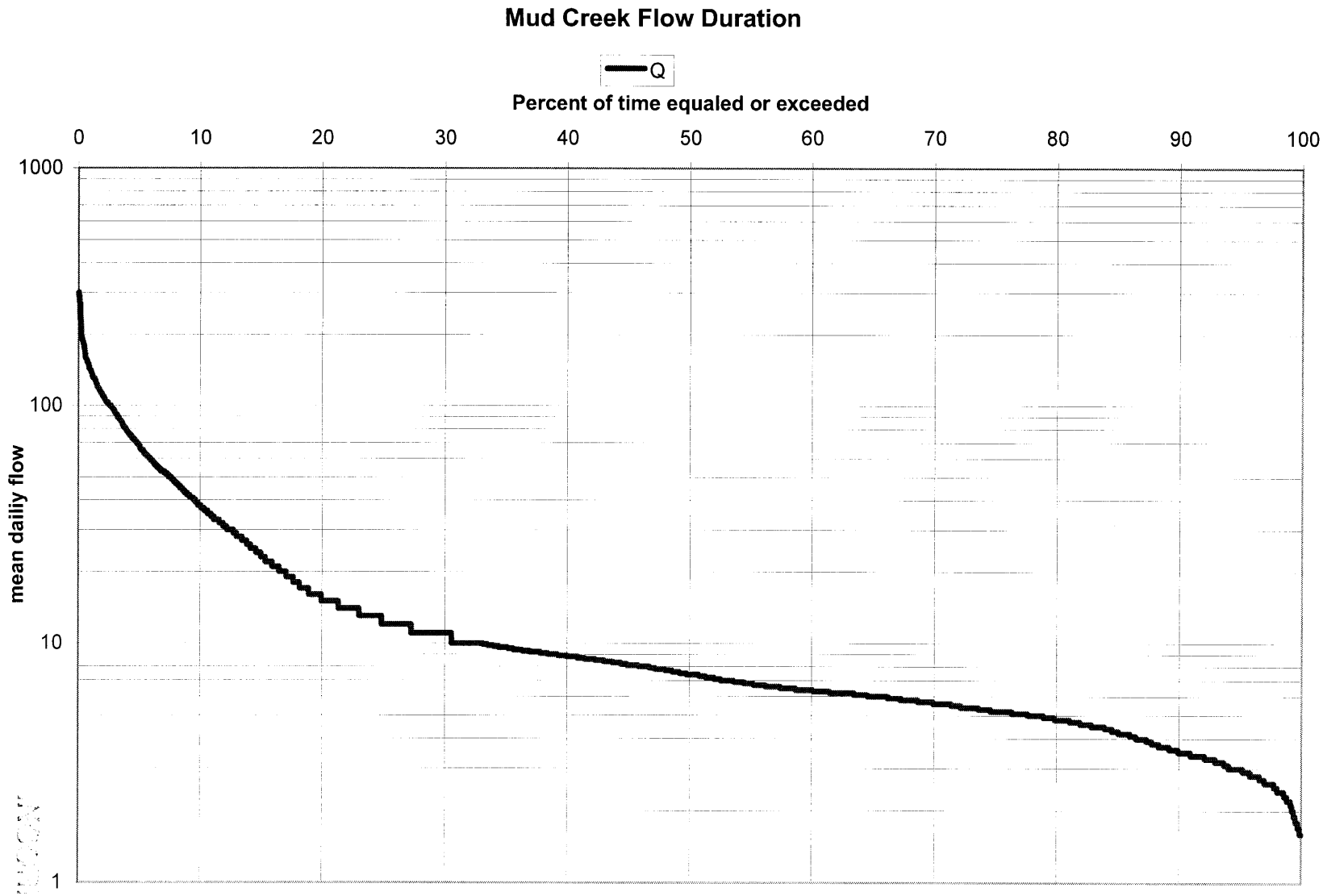
Mud Creek discharge





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Flows in Mud Creek

Discharge in Mud Creek has been monitored by the USGS since 1978 (Site number 09310700). Discharge in Mud Creek is plotted versus time on the attached figure. A flow duration curve is also attached. This curve indicates the frequency of flows of representative magnitude including low flows and floods.

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Water Discharged to Eccles Creek/Scofield Reservoir

Storage capacity of Scofield Reservoir = 73,600 ac-ft

Day	Hrs	GPM	CFS	Daily Gallons	Cumulative Gallons	Daily Acre-Feet	Cumulative Acre-Feet
8/16/2001	24	4,500	10.0	6,480,000	6,480,000	19.9	20
8/17/2001	24	4,500	10.0	6,480,000	12,960,000	19.9	40
8/18/2001	24	4,500	10.0	6,480,000	19,440,000	19.9	60
8/19/2001	24	4,500	10.0	6,480,000	25,920,000	19.9	80
8/20/2001	24	4,500	10.0	6,480,000	32,400,000	19.9	99
8/21/2001	24	4,500	10.0	6,480,000	38,880,000	19.9	119
8/22/2001	24	4,500	10.0	6,480,000	45,360,000	19.9	139
8/23/2001	24	4,500	10.0	6,480,000	51,840,000	19.9	159
8/24/2001	24	4,500	10.0	6,480,000	58,320,000	19.9	179
8/25/2001	24	4,500	10.0	6,480,000	64,800,000	19.9	199
8/26/2001	24	4,500	10.0	6,480,000	71,280,000	19.9	219
8/27/2001	24	4,500	10.0	6,480,000	77,760,000	19.9	239
8/28/2001	24	4,500	10.0	6,480,000	84,240,000	19.9	259
8/29/2001	24	4,500	10.0	6,480,000	90,720,000	19.9	278
8/30/2001	24	6,000	13.4	8,640,000	99,360,000	26.5	305
8/31/2001	24	6,000	13.4	8,640,000	108,000,000	26.5	331
9/1/2001	24	6,000	13.4	8,640,000	116,640,000	26.5	358
9/2/2001	24	6,000	13.4	8,640,000	125,280,000	26.5	385
9/3/2001	24	6,000	13.4	8,640,000	133,920,000	26.5	411
9/4/2001	24	6,000	13.4	8,640,000	142,560,000	26.5	438
9/5/2001	24	6,000	13.4	8,640,000	151,200,000	26.5	464
9/6/2001	24	6,000	13.4	8,640,000	159,840,000	26.5	491
9/7/2001	24	6,000	13.4	8,640,000	168,480,000	26.5	517
9/8/2001	24	6,000	13.4	8,640,000	177,120,000	26.5	544
9/9/2001	24	6,000	13.4	8,640,000	185,760,000	26.5	570
9/10/2001	24	8,000	17.8	11,520,000	197,280,000	35.4	606
9/11/2001	24	8,000	17.8	11,520,000	208,800,000	35.4	641
9/12/2001	24	8,000	17.8	11,520,000	220,320,000	35.4	676
9/13/2001	24	8,500	18.9	12,240,000	232,560,000	37.6	714
9/14/2001	24	8,500	18.9	12,240,000	244,800,000	37.6	751
9/15/2001	24	8,500	18.9	12,240,000	257,040,000	37.6	789
9/16/2001	24	8,500	18.9	12,240,000	269,280,000	37.6	827
9/17/2001	24	8,763	19.5	12,618,720	281,898,720	38.7	865
9/18/2001	24	8,850	19.7	12,744,000	294,642,720	39.1	904
9/19/2001	24	8,850	19.7	12,744,000	307,386,720	39.1	943
9/20/2001	24	8,952	19.9	12,890,880	320,277,600	39.6	983
9/21/2001	24	7,595	16.9	10,936,800	331,214,400	33.6	1,017
9/22/2001	24	8,315	18.5	11,973,600	343,188,000	36.8	1,053
9/23/2001	24	8,685	19.4	12,506,400	355,694,400	38.4	1,092
9/24/2001	24	8,893	19.8	12,805,920	368,500,320	39.3	1,131
9/25/2001	24	8,030	17.9	11,563,200	380,063,520	35.5	1,167
9/26/2001	24	8,812	19.6	12,689,280	392,752,800	38.9	1,205
9/27/2001	24	9,114	20.3	13,124,160	405,876,960	40.3	1,246
9/28/2001	24	9,000	20.1	12,960,000	418,836,960	39.8	1,286
9/29/2001	24	9,000	20.1	12,960,000	431,796,960	39.8	1,325
9/30/2001	24	9,000	20.1	12,960,000	444,756,960	39.8	1,365
10/1/2001	24	9,000	20.1	12,960,000	457,716,960	39.8	1,405
10/2/2001	24	9,000	20.1	12,960,000	470,676,960	39.8	1,445
10/3/2001	24	9,000	20.1	12,960,000	483,636,960	39.8	1,484
10/4/2001	24	9,000	20.1	12,960,000	496,596,960	39.8	1,524
10/5/2001	24	9,000	20.1	12,960,000	509,556,960	39.8	1,564
10/6/2001	24	9,000	20.1	12,960,000	522,516,960	39.8	1,604
10/7/2001	24	9,000	20.1	12,960,000	535,476,960	39.8	1,644
10/8/2001	24	9,000	20.1	12,960,000	548,436,960	39.8	1,683
10/9/2001	24	9,000	20.1	12,960,000	561,396,960	39.8	1,723
10/10/2001	24	9,000	20.1	12,960,000	574,356,960	39.8	1,763
10/11/2001	24	9,000	20.1	12,960,000	587,316,960	39.8	1,803
10/12/2001	24	9,000	20.1	12,960,000	600,276,960	39.8	1,842
10/13/2001	24	9,000	20.1	12,960,000	613,236,960	39.8	1,882
10/14/2001	24	9,000	20.1	12,960,000	626,196,960	39.8	1,922
10/15/2001	24	9,000	20.1	12,960,000	639,156,960	39.8	1,962
10/16/2001	24	9,000	20.1	12,960,000	652,116,960	39.8	2,002
10/17/2001	24	9,000	20.1	12,960,000	665,076,960	39.8	2,041

Water Discharged to Eccles Creek/Scofield Reservoir

Storage capacity of Scofield Reservoir = 73,600 ac-ft

Day	Hrs	GPM	CFS	Daily Gallons	Cumulative Gallons	Daily Acre-Feet	Cumulative Acre-Feet
10/18/2001	24	9,000	20.1	12,960,000	678,036,960	39.8	2,081
10/19/2001	24	9,000	20.1	12,960,000	690,996,960	39.8	2,121
10/20/2001	24	9,000	20.1	12,960,000	703,956,960	39.8	2,161
10/21/2001	24	9,000	20.1	12,960,000	716,916,960	39.8	2,200
10/22/2001	24	9,000	20.1	12,960,000	729,876,960	39.8	2,240
10/23/2001	24	9,000	20.1	12,960,000	742,836,960	39.8	2,280
10/24/2001	24	9,000	20.1	12,960,000	755,796,960	39.8	2,320
10/25/2001	24	9,000	20.1	12,960,000	768,756,960	39.8	2,360
10/26/2001	24	9,000	20.1	12,960,000	781,716,960	39.8	2,399
10/27/2001	24	9,000	20.1	12,960,000	794,676,960	39.8	2,439
10/28/2001	24	9,000	20.1	12,960,000	807,636,960	39.8	2,479
10/29/2001	24	9,000	20.1	12,960,000	820,596,960	39.8	2,519
10/30/2001	24	9,000	20.1	12,960,000	833,556,960	39.8	2,558
10/31/2001	24	9,000	20.1	12,960,000	846,516,960	39.8	2,598
11/1/2001	24	9,000	20.1	12,960,000	859,476,960	39.8	2,638
11/2/2001	24	9,000	20.1	12,960,000	872,436,960	39.8	2,678
11/3/2001	24	9,000	20.1	12,960,000	885,396,960	39.8	2,718
11/4/2001	24	9,000	20.1	12,960,000	898,356,960	39.8	2,757
11/5/2001	24	9,000	20.1	12,960,000	911,316,960	39.8	2,797
11/6/2001	24	9,000	20.1	12,960,000	924,276,960	39.8	2,837
11/7/2001	20	9,000	20.1	10,800,000	935,076,960	33.1	2,870
11/8/2001	24	9,000	20.1	12,960,000	948,036,960	39.8	2,910
11/9/2001	24	9,000	20.1	12,960,000	960,996,960	39.8	2,950
11/10/2001	24	9,000	20.1	12,960,000	973,956,960	39.8	2,989
11/11/2001	24	9,000	20.1	12,960,000	986,916,960	39.8	3,029
11/12/2001	24	9,000	20.1	12,960,000	999,876,960	39.8	3,069
11/13/2001	12	9,000	20.1	6,480,000	1,006,356,960	19.9	3,089
11/14/2001	24	9,000	20.1	12,960,000	1,019,316,960	39.8	3,129
11/15/2001	24	9,200	20.5	13,248,000	1,032,564,960	40.7	3,169
11/16/2001	24	9,200	20.5	13,248,000	1,045,812,960	40.7	3,210
11/17/2001	24	9,200	20.5	13,248,000	1,059,060,960	40.7	3,251
11/18/2001	24	9,200	20.5	13,248,000	1,072,308,960	40.7	3,291
11/19/2001	24	9,200	20.5	13,248,000	1,085,556,960	40.7	3,332
11/20/2001	24	9,200	20.5	13,248,000	1,098,804,960	40.7	3,373
11/21/2001	24	9,200	20.5	13,248,000	1,112,052,960	40.7	3,413
11/22/2001	24	9,200	20.5	13,248,000	1,125,300,960	40.7	3,454
11/23/2001	24	9,200	20.5	13,248,000	1,138,548,960	40.7	3,495
11/24/2001	24	9,200	20.5	13,248,000	1,151,796,960	40.7	3,535
11/25/2001	24	9,200	20.5	13,248,000	1,165,044,960	40.7	3,576
11/26/2001	24	9,200	20.5	13,248,000	1,178,292,960	40.7	3,617
11/27/2001	24	9,200	20.5	13,248,000	1,191,540,960	40.7	3,657
11/28/2001	24	9,200	20.5	13,248,000	1,204,788,960	40.7	3,698
11/29/2001	24	9,200	20.5	13,248,000	1,218,036,960	40.7	3,739
11/30/2001	24	9,200	20.5	13,248,000	1,231,284,960	40.7	3,779
12/1/2001	24	8,500	18.9	12,240,000	1,243,524,960	37.6	3,817
12/2/2001	24	8,500	18.9	12,240,000	1,255,764,960	37.6	3,854
12/3/2001	24	8,500	18.9	12,240,000	1,268,004,960	37.6	3,892
12/4/2001	24	8,500	18.9	12,240,000	1,280,244,960	37.6	3,929
12/5/2001	24	8,500	18.9	12,240,000	1,292,484,960	37.6	3,967
12/6/2001	24	8,500	18.9	12,240,000	1,304,724,960	37.6	4,005
12/7/2001	24	8,500	18.9	12,240,000	1,316,964,960	37.6	4,042
12/8/2001	24	8,500	18.9	12,240,000	1,329,204,960	37.6	4,080
12/9/2001	24	8,500	18.9	12,240,000	1,341,444,960	37.6	4,117
12/10/2001	24	8,000	17.8	11,520,000	1,352,964,960	35.4	4,153
12/11/2001	24	8,000	17.8	11,520,000	1,364,484,960	35.4	4,188
12/12/2001	24	8,000	17.8	11,520,000	1,376,004,960	35.4	4,223
12/13/2001	24	7,700	17.2	11,088,000	1,387,092,960	34.0	4,257
12/14/2001	24	7,700	17.2	11,088,000	1,398,180,960	34.0	4,291
12/15/2001	24	7,700	17.2	11,088,000	1,409,268,960	34.0	4,326
12/16/2001	24	7,700	17.2	11,088,000	1,420,356,960	34.0	4,360
12/17/2001	24	7,687	17.1	11,069,280	1,431,426,240	34.0	4,394
12/18/2001	24	7,674	17.1	11,050,560	1,442,476,800	33.9	4,427
12/19/2001	24	7,661	17.1	11,031,840	1,453,508,640	33.9	4,461

Water Discharged to Eccles Creek/Scofield Reservoir

Storage capacity of Scofield Reservoir = 73,600 ac-ft

Day	Hrs	GPM	CFS	Daily Gallons	Cumulative Gallons	Daily Acre-Feet	Cumulative Acre-Feet
12/20/2001	24	7,648	17.0	11,013,120	1,464,521,760	33.8	4,495
12/21/2001	24	7,635	17.0	10,994,400	1,475,516,160	33.7	4,529
12/22/2001	24	7,622	17.0	10,975,680	1,486,491,840	33.7	4,563
12/23/2001	24	7,609	17.0	10,956,960	1,497,448,800	33.6	4,596
12/24/2001	24	7,596	16.9	10,938,240	1,508,387,040	33.6	4,630
12/25/2001	24	7,583	16.9	10,919,520	1,519,306,560	33.5	4,663
12/26/2001	24	7,570	16.9	10,900,800	1,530,207,360	33.5	4,697
12/27/2001	24	7,557	16.8	10,882,080	1,541,089,440	33.4	4,730
12/28/2001	24	7,544	16.8	10,863,360	1,551,952,800	33.3	4,763
12/29/2001	24	7,531	16.8	10,844,640	1,562,797,440	33.3	4,797
12/30/2001	24	7,518	16.8	10,825,920	1,573,623,360	33.2	4,830
12/31/2001	24	7,505	16.7	10,807,200	1,584,430,560	33.2	4,863
1/1/2002	24	7,492	16.7	10,788,480	1,595,219,040	33.1	4,896
1/2/2002	24	7,479	16.7	10,769,760	1,605,988,800	33.1	4,929
1/3/2002	24	7,466	16.6	10,751,040	1,616,739,840	33.0	4,962
1/4/2002	24	7,453	16.6	10,732,320	1,627,472,160	32.9	4,995
1/5/2002	24	7,440	16.6	10,713,600	1,638,185,760	32.9	5,028
1/6/2002	24	7,427	16.5	10,694,880	1,648,880,640	32.8	5,061
1/7/2002	24	7,414	16.5	10,676,160	1,659,556,800	32.8	5,094
1/8/2002	24	7,401	16.5	10,657,440	1,670,214,240	32.7	5,126
1/9/2002	24	7,388	16.5	10,638,720	1,680,852,960	32.7	5,159
1/10/2002	24	7,375	16.4	10,620,000	1,691,472,960	32.6	5,192
1/11/2002	24	7,362	16.4	10,601,280	1,702,074,240	32.5	5,224
1/12/2002	24	7,349	16.4	10,582,560	1,712,656,800	32.5	5,257
1/13/2002	24	7,336	16.3	10,563,840	1,723,220,640	32.4	5,289
1/14/2002	24	7,323	16.3	10,545,120	1,733,765,760	32.4	5,321
1/15/2002	24	7,310	16.3	10,526,400	1,744,292,160	32.3	5,354
1/16/2002	24	7,297	16.3	10,507,680	1,754,799,840	32.3	5,386
1/17/2002	24	7,284	16.2	10,488,960	1,765,288,800	32.2	5,418
1/18/2002	24	7,271	16.2	10,470,240	1,775,759,040	32.1	5,450
1/19/2002	24	7,258	16.2	10,451,520	1,786,210,560	32.1	5,482
1/20/2002	24	7,245	16.1	10,432,800	1,796,643,360	32.0	5,514
1/21/2002	24	7,232	16.1	10,414,080	1,807,057,440	32.0	5,546
1/22/2002	24	7,219	16.1	10,395,360	1,817,452,800	31.9	5,578
1/23/2002	24	7,206	16.1	10,376,640	1,827,829,440	31.8	5,610
1/24/2002	24	7,193	16.0	10,357,920	1,838,187,360	31.8	5,642
1/25/2002	24	7,180	16.0	10,339,200	1,848,526,560	31.7	5,674
1/26/2002	24	7,167	16.0	10,320,480	1,858,847,040	31.7	5,705
1/27/2002	24	7,154	15.9	10,301,760	1,869,148,800	31.6	5,737
1/28/2002	24	7,141	15.9	10,283,040	1,879,431,840	31.6	5,769
1/29/2002	24	7,128	15.9	10,264,320	1,889,696,160	31.5	5,800
1/30/2002	24	7,115	15.9	10,245,600	1,899,941,760	31.4	5,832
1/31/2002	24	7,102	15.8	10,226,880	1,910,168,640	31.4	5,863
2/1/2002	24	7,089	15.8	10,208,160	1,920,376,800	31.3	5,894
2/2/2002	24	7,076	15.8	10,189,440	1,930,566,240	31.3	5,926
2/3/2002	24	7,063	15.7	10,170,720	1,940,736,960	31.2	5,957
2/4/2002	24	7,050	15.7	10,152,000	1,950,888,960	31.2	5,988
2/5/2002	24	7,037	15.7	10,133,280	1,961,022,240	31.1	6,019
2/6/2002	24	7,024	15.6	10,114,560	1,971,136,800	31.0	6,050
2/7/2002	24	7,000	15.6	10,080,000	1,981,216,800	30.9	6,081
2/8/2002	24	7,000	15.6	10,080,000	1,991,296,800	30.9	6,112
2/9/2002	24	7,000	15.6	10,080,000	2,001,376,800	30.9	6,143
2/10/2002	24	7,000	15.6	10,080,000	2,011,456,800	30.9	6,174
2/11/2002	24	7,000	15.6	10,080,000	2,021,536,800	30.9	6,205
2/12/2002	24	7,000	15.6	10,080,000	2,031,616,800	30.9	6,236
2/13/2002	24	7,000	15.6	10,080,000	2,041,696,800	30.9	6,267
2/14/2002	24	7,000	15.6	10,080,000	2,051,776,800	30.9	6,298
2/15/2002	24	7,000	15.6	10,080,000	2,061,856,800	30.9	6,329
2/16/2002	24	7,000	15.6	10,080,000	2,071,936,800	30.9	6,359
2/17/2002	24	7,000	15.6	10,080,000	2,082,016,800	30.9	6,390
2/18/2002	24	7,000	15.6	10,080,000	2,092,096,800	30.9	6,421
2/19/2002	24	7,000	15.6	10,080,000	2,102,176,800	30.9	6,452
2/20/2002	24	7,000	15.6	10,080,000	2,112,256,800	30.9	6,483

Water Discharged to Eccles Creek/Scofield Reservoir

Storage capacity of Scofield Reservoir = 73,600 ac-ft

Day	Hrs	GPM	CFS	Daily Gallons	Cumulative Gallons	Daily Acre-Feet	Cumulative Acre-Feet
2/21/2002	24	7,000	15.6	10,080,000	2,122,336,800	30.9	6,514
2/22/2002	24	7,000	15.6	10,080,000	2,132,416,800	30.9	6,545
2/23/2002	24	7,000	15.6	10,080,000	2,142,496,800	30.9	6,576
2/24/2002	24	7,000	15.6	10,080,000	2,152,576,800	30.9	6,607
2/25/2002	24	7,000	15.6	10,080,000	2,162,656,800	30.9	6,638
2/26/2002	24	7,000	15.6	10,080,000	2,172,736,800	30.9	6,669
2/27/2002	24	7,000	15.6	10,080,000	2,182,816,800	30.9	6,700
2/28/2002	24	7,000	15.6	10,080,000	2,192,896,800	30.9	6,731
3/1/2002	24	7,000	15.6	10,080,000	2,202,976,800	30.9	6,762
3/2/2002	24	7,000	15.6	10,080,000	2,213,056,800	30.9	6,793
3/3/2002	24	7,000	15.6	10,080,000	2,223,136,800	30.9	6,824
3/4/2002	24	7,000	15.6	10,080,000	2,233,216,800	30.9	6,854
3/5/2002	24	7,000	15.6	10,080,000	2,243,296,800	30.9	6,885
3/6/2002	24	7,000	15.6	10,080,000	2,253,376,800	30.9	6,916
3/7/2002	24	7,000	15.6	10,080,000	2,263,456,800	30.9	6,947
3/8/2002	20	7,000	15.6	8,400,000	2,271,856,800	25.8	6,973
3/9/2002	24	7,000	15.6	10,080,000	2,281,936,800	30.9	7,004
3/10/2002	24	7,000	15.6	10,080,000	2,292,016,800	30.9	7,035
3/11/2002	20	7,000	15.6	8,400,000	2,300,416,800	25.8	7,061
3/12/2002	24	7,000	15.6	10,080,000	2,310,496,800	30.9	7,092
3/13/2002	24	7,000	15.6	10,080,000	2,320,576,800	30.9	7,123
3/14/2002	24	7,000	15.6	10,080,000	2,330,656,800	30.9	7,154
3/15/2002	24	7,000	15.6	10,080,000	2,340,736,800	30.9	7,184
3/16/2002	24	7,000	15.6	10,080,000	2,350,816,800	30.9	7,215
3/17/2002	24	7,000	15.6	10,080,000	2,360,896,800	30.9	7,246
3/18/2002	24	7,000	15.6	10,080,000	2,370,976,800	30.9	7,277
3/19/2002	24	7,000	15.6	10,080,000	2,381,056,800	30.9	7,308
3/20/2002	24	7,000	15.6	10,080,000	2,391,136,800	30.9	7,339
3/21/2002	24	7,000	15.6	10,080,000	2,401,216,800	30.9	7,370
3/22/2002	24	7,000	15.6	10,080,000	2,411,296,800	30.9	7,401
3/23/2002	24	7,000	15.6	10,080,000	2,421,376,800	30.9	7,432
3/24/2002	24	7,000	15.6	10,080,000	2,431,456,800	30.9	7,463
3/25/2002	24	8,200	18.3	11,808,000	2,443,264,800	36.2	7,499
3/26/2002	24	8,200	18.3	11,808,000	2,455,072,800	36.2	7,535
3/27/2002	24	8,200	18.3	11,808,000	2,466,880,800	36.2	7,572
3/28/2002	24	8,200	18.3	11,808,000	2,478,688,800	36.2	7,608
3/29/2002	24	8,200	18.3	11,808,000	2,490,496,800	36.2	7,644
3/30/2002	24	8,200	18.3	11,808,000	2,502,304,800	36.2	7,680
3/31/2002	24	8,200	18.3	11,808,000	2,514,112,800	36.2	7,717
4/1/2002	24	8,200	18.3	11,808,000	2,525,920,800	36.2	7,753
4/2/2002	24	8,200	18.3	11,808,000	2,537,728,800	36.2	7,789
4/3/2002	24	8,200	18.3	11,808,000	2,549,536,800	36.2	7,825
4/4/2002	24	8,200	18.3	11,808,000	2,561,344,800	36.2	7,862
4/5/2002	24	8,200	18.3	11,808,000	2,573,152,800	36.2	7,898
4/6/2002	24	8,200	18.3	11,808,000	2,584,960,800	36.2	7,934
4/7/2002	24	8,200	18.3	11,808,000	2,596,768,800	36.2	7,970
4/8/2002	24	8,200	18.3	11,808,000	2,608,576,800	36.2	8,007
4/9/2002	24	8,200	18.3	11,808,000	2,620,384,800	36.2	8,043
4/10/2002	24	8,200	18.3	11,808,000	2,632,192,800	36.2	8,079
4/11/2002	24	8,200	18.3	11,808,000	2,644,000,800	36.2	8,115
4/12/2002	24	8,200	18.3	11,808,000	2,655,808,800	36.2	8,152
4/13/2002	24	8,200	18.3	11,808,000	2,667,616,800	36.2	8,188
4/14/2002	24	8,200	18.3	11,808,000	2,679,424,800	36.2	8,224
4/15/2002	24	8,200	18.3	11,808,000	2,691,232,800	36.2	8,260
4/16/2002	24	8,200	18.3	11,808,000	2,703,040,800	36.2	8,297
4/17/2002	24	8,200	18.3	11,808,000	2,714,848,800	36.2	8,333
4/18/2002	24	8,200	18.3	11,808,000	2,726,656,800	36.2	8,369
4/19/2002	24	8,200	18.3	11,808,000	2,738,464,800	36.2	8,405
4/20/2002	24	8,200	18.3	11,808,000	2,750,272,800	36.2	8,441
4/21/2002	24	8,200	18.3	11,808,000	2,762,080,800	36.2	8,478
4/22/2002	24	8,200	18.3	11,808,000	2,773,888,800	36.2	8,514
4/23/2002	24	8,200	18.3	11,808,000	2,785,696,800	36.2	8,550
4/24/2002	24	8,200	18.3	11,808,000	2,797,504,800	36.2	8,586

Water Discharged to Eccles Creek/Scofield Reservoir

Storage capacity of Scofield Reservoir = 73,600 ac-ft

Day	Hrs	GPM	CFS	Daily Gallons	Cumulative Gallons	Daily Acre-Feet	Cumulative Acre-Feet
4/25/2002	24	8,200	18.3	11,808,000	2,809,312,800	36.2	8,623
4/26/2002	24	8,200	18.3	11,808,000	2,821,120,800	36.2	8,659
4/27/2002	24	8,200	18.3	11,808,000	2,832,928,800	36.2	8,695
4/28/2002	24	8,200	18.3	11,808,000	2,844,736,800	36.2	8,731
4/29/2002	24	8,200	18.3	11,808,000	2,856,544,800	36.2	8,768
4/30/2002	24	8,200	18.3	11,808,000	2,868,352,800	36.2	8,804
5/1/2002	24	7,740	17.2	11,145,600	2,879,498,400	34.2	8,838
5/2/2002	24	7,740	17.2	11,145,600	2,890,644,000	34.2	8,872
5/3/2002	24	7,740	17.2	11,145,600	2,901,789,600	34.2	8,907
5/4/2002	24	7,740	17.2	11,145,600	2,912,935,200	34.2	8,941
5/5/2002	24	7,740	17.2	11,145,600	2,924,080,800	34.2	8,975
5/6/2002	24	7,740	17.2	11,145,600	2,935,226,400	34.2	9,009
5/7/2002	24	7,740	17.2	11,145,600	2,946,372,000	34.2	9,043
5/8/2002	24	7,740	17.2	11,145,600	2,957,517,600	34.2	9,078
5/9/2002	24	7,740	17.2	11,145,600	2,968,663,200	34.2	9,112
5/10/2002	24	7,740	17.2	11,145,600	2,979,808,800	34.2	9,146
5/11/2002	24	7,740	17.2	11,145,600	2,990,954,400	34.2	9,180
5/12/2002	24	7,740	17.2	11,145,600	3,002,100,000	34.2	9,214
5/13/2002	24	7,740	17.2	11,145,600	3,013,245,600	34.2	9,249
5/14/2002	24	7,740	17.2	11,145,600	3,024,391,200	34.2	9,283
5/15/2002	24	7,740	17.2	11,145,600	3,035,536,800	34.2	9,317
5/16/2002	24	7,740	17.2	11,145,600	3,046,682,400	34.2	9,351
5/17/2002	24	7,740	17.2	11,145,600	3,057,828,000	34.2	9,385
5/18/2002	24	7,740	17.2	11,145,600	3,068,973,600	34.2	9,420
5/19/2002	24	7,740	17.2	11,145,600	3,080,119,200	34.2	9,454
5/20/2002	24	7,740	17.2	11,145,600	3,091,264,800	34.2	9,488
5/21/2002	24	7,740	17.2	11,145,600	3,102,410,400	34.2	9,522
5/22/2002	24	7,740	17.2	11,145,600	3,113,556,000	34.2	9,557
5/23/2002	24	7,740	17.2	11,145,600	3,124,701,600	34.2	9,591
5/24/2002	24	7,740	17.2	11,145,600	3,135,847,200	34.2	9,625
5/25/2002	24	7,740	17.2	11,145,600	3,146,992,800	34.2	9,659
5/26/2002	24	7,740	17.2	11,145,600	3,158,138,400	34.2	9,693
5/27/2002	24	7,740	17.2	11,145,600	3,169,284,000	34.2	9,728
5/28/2002	24	7,740	17.2	11,145,600	3,180,429,600	34.2	9,762
5/29/2002	24	7,740	17.2	11,145,600	3,191,575,200	34.2	9,796
5/30/2002	24	7,740	17.2	11,145,600	3,202,720,800	34.2	9,830
5/31/2002	24	7,740	17.2	11,145,600	3,213,866,400	34.2	9,864
6/1/2002	24	7,077	15.8	10,190,880	3,224,057,280	31.3	9,896
6/2/2002	24	7,077	15.8	10,190,880	3,234,248,160	31.3	9,927
6/3/2002	24	7,077	15.8	10,190,880	3,244,439,040	31.3	9,958
6/4/2002	24	7,077	15.8	10,190,880	3,254,629,920	31.3	9,990
6/5/2002	24	7,077	15.8	10,190,880	3,264,820,800	31.3	10,021
6/6/2002	24	7,077	15.8	10,190,880	3,275,011,680	31.3	10,052
6/7/2002	24	7,077	15.8	10,190,880	3,285,202,560	31.3	10,083
6/8/2002	24	7,077	15.8	10,190,880	3,295,393,440	31.3	10,115
6/9/2002	24	7,077	15.8	10,190,880	3,305,584,320	31.3	10,146
6/10/2002	24	7,077	15.8	10,190,880	3,315,775,200	31.3	10,177
6/11/2002	24	7,077	15.8	10,190,880	3,325,966,080	31.3	10,208
6/12/2002	24	8,681	19.3	12,500,640	3,338,466,720	38.4	10,247
6/13/2002	24	8,681	19.3	12,500,640	3,350,967,360	38.4	10,285
6/14/2002	24	8,681	19.3	12,500,640	3,363,468,000	38.4	10,324
6/15/2002	24	8,681	19.3	12,500,640	3,375,968,640	38.4	10,362
6/16/2002	24	8,681	19.3	12,500,640	3,388,469,280	38.4	10,400
6/17/2002	24	8,681	19.3	12,500,640	3,400,969,920	38.4	10,439
6/18/2002	24	8,681	19.3	12,500,640	3,413,470,560	38.4	10,477
6/19/2002	24	8,681	19.3	12,500,640	3,425,971,200	38.4	10,515
6/20/2002	24	8,681	19.3	12,500,640	3,438,471,840	38.4	10,554
6/21/2002	24	8,681	19.3	12,500,640	3,450,972,480	38.4	10,592
6/22/2002	24	8,681	19.3	12,500,640	3,463,473,120	38.4	10,631
6/23/2002	24	8,681	19.3	12,500,640	3,475,973,760	38.4	10,669
6/24/2002	24	8,681	19.3	12,500,640	3,488,474,400	38.4	10,707
6/25/2002	24	8,681	19.3	12,500,640	3,500,975,040	38.4	10,746
6/26/2002	24	9,250	20.6	13,320,000	3,514,295,040	40.9	10,787

Water Discharged to Eccles Creek/Scofield Reservoir

Storage capacity of Scofield Reservoir = 73,600 ac-ft

Day	Hrs	GPM	CFS	Daily Gallons	Cumulative Gallons	Daily Acre-Feet	Cumulative Acre-Feet
6/27/2002	24	9,250	20.6	13,320,000	3,527,615,040	40.9	10,827
6/28/2002	24	9,250	20.6	13,320,000	3,540,935,040	40.9	10,868
6/29/2002	24	9,250	20.6	13,320,000	3,554,255,040	40.9	10,909
6/30/2002	24	9,250	20.6	13,320,000	3,567,575,040	40.9	10,950
7/1/2002	24	9,245	20.6	13,312,800	3,580,887,840	40.9	10,991
7/2/2002	24	9,245	20.6	13,312,800	3,594,200,640	40.9	11,032
7/3/2002	24	9,245	20.6	13,312,800	3,607,513,440	40.9	11,073
7/4/2002	24	9,245	20.6	13,312,800	3,620,826,240	40.9	11,114
7/5/2002	24	9,245	20.6	13,312,800	3,634,139,040	40.9	11,154
7/6/2002	24	9,245	20.6	13,312,800	3,647,451,840	40.9	11,195
7/7/2002	24	9,245	20.6	13,312,800	3,660,764,640	40.9	11,236
7/8/2002	24	9,245	20.6	13,312,800	3,674,077,440	40.9	11,277
7/9/2002	24	9,245	20.6	13,312,800	3,687,390,240	40.9	11,318
7/10/2002	24	9,245	20.6	13,312,800	3,700,703,040	40.9	11,359
7/11/2002	24	8,645	19.3	12,448,800	3,713,151,840	38.2	11,397
7/12/2002	24	8,645	19.3	12,448,800	3,725,600,640	38.2	11,435
7/13/2002	24	8,645	19.3	12,448,800	3,738,049,440	38.2	11,473
7/14/2002	24	8,645	19.3	12,448,800	3,750,498,240	38.2	11,512
7/15/2002	24	8,645	19.3	12,448,800	3,762,947,040	38.2	11,550
7/16/2002	24	8,645	19.3	12,448,800	3,775,395,840	38.2	11,588
7/17/2002	24	8,645	19.3	12,448,800	3,787,844,640	38.2	11,626
7/18/2002	24	8,820	19.7	12,700,800	3,800,545,440	39.0	11,665
7/19/2002	24	8,820	19.7	12,700,800	3,813,246,240	39.0	11,704
7/20/2002	24	8,820	19.7	12,700,800	3,825,947,040	39.0	11,743
7/21/2002	24	8,820	19.7	12,700,800	3,838,647,840	39.0	11,782
7/22/2002	24	8,849	19.7	12,742,560	3,851,390,400	39.1	11,821
7/23/2002	24	8,849	19.7	12,742,560	3,864,132,960	39.1	11,860
7/24/2002	24	8,849	19.7	12,742,560	3,876,875,520	39.1	11,899
7/25/2002	24	8,849	19.7	12,742,560	3,889,618,080	39.1	11,939
7/26/2002	24	8,849	19.7	12,742,560	3,902,360,640	39.1	11,978
7/27/2002	24	8,849	19.7	12,742,560	3,915,103,200	39.1	12,017
7/28/2002	24	8,849	19.7	12,742,560	3,927,845,760	39.1	12,056
7/29/2002	24	8,849	19.7	12,742,560	3,940,588,320	39.1	12,095
7/30/2002	24	8,849	19.7	12,742,560	3,953,330,880	39.1	12,134
7/31/2002	24	8,849	19.7	12,742,560	3,966,073,440	39.1	12,173
8/1/2002	24	8,710	19.4	12,542,400	3,978,615,840	38.5	12,212
8/2/2002	24	8,710	19.4	12,542,400	3,991,158,240	38.5	12,250
8/3/2002	24	8,710	19.4	12,542,400	4,003,700,640	38.5	12,289
8/4/2002	24	8,710	19.4	12,542,400	4,016,243,040	38.5	12,327
8/5/2002	24	8,710	19.4	12,542,400	4,028,785,440	38.5	12,366
8/6/2002	24	8,710	19.4	12,542,400	4,041,327,840	38.5	12,404
8/7/2002	24	8,471	18.9	12,198,240	4,053,526,080	37.4	12,442
8/8/2002	24	8,471	18.9	12,198,240	4,065,724,320	37.4	12,479
8/9/2002	24	8,471	18.9	12,198,240	4,077,922,560	37.4	12,516
8/10/2002	24	8,471	18.9	12,198,240	4,090,120,800	37.4	12,554
8/11/2002	24	8,471	18.9	12,198,240	4,102,319,040	37.4	12,591
8/12/2002	24	8,471	18.9	12,198,240	4,114,517,280	37.4	12,629
8/13/2002	24	8,471	18.9	12,198,240	4,126,715,520	37.4	12,666
8/14/2002	24	8,471	18.9	12,198,240	4,138,913,760	37.4	12,704
8/15/2002	24	8,627	19.2	12,422,880	4,151,336,640	38.1	12,742
8/16/2002	24	8,627	19.2	12,422,880	4,163,759,520	38.1	12,780
8/17/2002	24	8,627	19.2	12,422,880	4,176,182,400	38.1	12,818
8/18/2002	24	8,627	19.2	12,422,880	4,188,605,280	38.1	12,856
8/19/2002	24	8,627	19.2	12,422,880	4,201,028,160	38.1	12,894
8/20/2002	24	8,627	19.2	12,422,880	4,213,451,040	38.1	12,932
8/21/2002	24	9,119	20.3	13,131,360	4,226,582,400	40.3	12,973
8/22/2002	24	9,119	20.3	13,131,360	4,239,713,760	40.3	13,013
8/23/2002	24	9,119	20.3	13,131,360	4,252,845,120	40.3	13,053
8/24/2002	24	9,119	20.3	13,131,360	4,265,976,480	40.3	13,094
8/25/2002	24	9,119	20.3	13,131,360	4,279,107,840	40.3	13,134
8/26/2002	24	9,119	20.3	13,131,360	4,292,239,200	40.3	13,174
8/27/2002	24	9,119	20.3	13,131,360	4,305,370,560	40.3	13,215
8/28/2002	24	9,119	20.3	13,131,360	4,318,501,920	40.3	13,255

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Water Discharged to Eccles Creek/Scofield Reservoir

Storage capacity of Scofield Reservoir = 73,600 ac-ft

Day	Hrs	GPM	CFS	Daily Gallons	Cumulative Gallons	Daily Acre-Feet	Cumulative Acre-Feet
8/29/2002	24	9,078	20.2	13,072,320	4,331,574,240	40.1	13,295
8/30/2002	24	9,078	20.2	13,072,320	4,344,646,560	40.1	13,335
8/31/2002	24	9,078	20.2	13,072,320	4,357,718,880	40.1	13,375
9/1/2002	24	9,078	20.2	13,072,320	4,370,791,200	40.1	13,415
9/2/2002	24	9,078	20.2	13,072,320	4,383,863,520	40.1	13,456
9/3/2002	24	9,078	20.2	13,072,320	4,396,935,840	40.1	13,496
9/4/2002	24	9,078	20.2	13,072,320	4,410,008,160	40.1	13,536
9/5/2002	24	9,174	20.4	13,210,560	4,423,218,720	40.5	13,576
9/6/2002	24	9,174	20.4	13,210,560	4,436,429,280	40.5	13,617
9/7/2002	24	9,174	20.4	13,210,560	4,449,639,840	40.5	13,657
9/8/2002	24	9,174	20.4	13,210,560	4,462,850,400	40.5	13,698
9/9/2002	24	9,174	20.4	13,210,560	4,476,060,960	40.5	13,739
9/10/2002	24	9,174	20.4	13,210,560	4,489,271,520	40.5	13,779
9/11/2002	24	9,174	20.4	13,210,560	4,502,482,080	40.5	13,820
9/12/2002	24	9,321	20.8	13,422,240	4,515,904,320	41.2	13,861
9/13/2002	24	9,321	20.8	13,422,240	4,529,326,560	41.2	13,902
9/14/2002	24	9,321	20.8	13,422,240	4,542,748,800	41.2	13,943
9/15/2002	24	9,321	20.8	13,422,240	4,556,171,040	41.2	13,984
9/16/2002	24	9,321	20.8	13,422,240	4,569,593,280	41.2	14,026
9/17/2002	24	9,321	20.8	13,422,240	4,583,015,520	41.2	14,067
9/18/2002	24	9,321	20.8	13,422,240	4,596,437,760	41.2	14,108
9/19/2002	24	8,954	19.9	12,893,760	4,609,331,520	39.6	14,148
9/20/2002	24	8,954	19.9	12,893,760	4,622,225,280	39.6	14,187
9/21/2002	24	8,954	19.9	12,893,760	4,635,119,040	39.6	14,227
9/22/2002	24	8,954	19.9	12,893,760	4,648,012,800	39.6	14,266
9/23/2002	24	8,954	19.9	12,893,760	4,660,906,560	39.6	14,306
9/24/2002	24	8,954	19.9	12,893,760	4,673,800,320	39.6	14,345
9/25/2002	24	9,827	21.9	14,150,880	4,687,951,200	43.4	14,389
9/26/2002	24	9,827	21.9	14,150,880	4,702,102,080	43.4	14,432
9/27/2002	24	9,827	21.9	14,150,880	4,716,252,960	43.4	14,476
9/28/2002	24	9,827	21.9	14,150,880	4,730,403,840	43.4	14,519
9/29/2002	24	9,827	21.9	14,150,880	4,744,554,720	43.4	14,563
9/30/2002	24	9,827	21.9	14,150,880	4,758,705,600	43.4	14,606
10/1/2002	24	9,827	21.9	14,150,880	4,772,856,480	43.4	14,649
10/2/2002	24	6,247	13.9	8,995,680	4,781,852,160	27.6	14,677
10/3/2002	24	6,247	13.9	8,995,680	4,790,847,840	27.6	14,705
10/4/2002	24	6,247	13.9	8,995,680	4,799,843,520	27.6	14,732
10/5/2002	24	6,247	13.9	8,995,680	4,808,839,200	27.6	14,760
10/6/2002	24	6,247	13.9	8,995,680	4,817,834,880	27.6	14,788
10/7/2002	24	6,247	13.9	8,995,680	4,826,830,560	27.6	14,815
10/8/2002	24	6,247	13.9	8,995,680	4,835,826,240	27.6	14,843
10/9/2002	24	4,883	10.9	7,031,520	4,842,857,760	21.6	14,864
10/10/2002	24	4,883	10.9	7,031,520	4,849,889,280	21.6	14,886
10/11/2002	24	4,883	10.9	7,031,520	4,856,920,800	21.6	14,907
10/12/2002	24	4,883	10.9	7,031,520	4,863,952,320	21.6	14,929
10/13/2002	24	4,883	10.9	7,031,520	4,870,983,840	21.6	14,951
10/14/2002	24	4,883	10.9	7,031,520	4,878,015,360	21.6	14,972
10/15/2002	24	4,883	10.9	7,031,520	4,885,046,880	21.6	14,994
10/16/2002	24	4,883	10.9	7,031,520	4,892,078,400	21.6	15,015
10/17/2002	24	6,500	14.5	9,360,000	4,901,438,400	28.7	15,044
10/18/2002	24	6,500	14.5	9,360,000	4,910,798,400	28.7	15,073
10/19/2002	24	6,500	14.5	9,360,000	4,920,158,400	28.7	15,102
10/20/2002	24	6,500	14.5	9,360,000	4,929,518,400	28.7	15,130
10/21/2002	24	6,500	14.5	9,360,000	4,938,878,400	28.7	15,159
10/22/2002	24	6,637	14.8	9,557,280	4,948,435,680	29.3	15,188
10/23/2002	24	6,637	14.8	9,557,280	4,957,992,960	29.3	15,218
10/24/2002	24	6,637	14.8	9,557,280	4,967,550,240	29.3	15,247
10/25/2002	24	10,500	23.4	15,120,000	4,982,670,240	46.4	15,293
10/26/2002	24	10,500	23.4	15,120,000	4,997,790,240	46.4	15,340
10/27/2002	24	10,500	23.4	15,120,000	5,012,910,240	46.4	15,386
10/28/2002	24	10,500	23.4	15,120,000	5,028,030,240	46.4	15,433
10/29/2002	24	10,500	23.4	15,120,000	5,043,150,240	46.4	15,479
10/30/2002	24	10,098	22.5	14,541,120	5,057,691,360	44.6	15,524

Water Discharged to Eccles Creek/Scofield Reservoir

Storage capacity of Scofield Reservoir = 73,600 ac-ft

Day	Hrs	GPM	CFS	Daily Gallons	Cumulative Gallons	Daily Acre-Feet	Cumulative Acre-Feet
10/31/2002	24	10,098	22.5	14,541,120	5,072,232,480	44.6	15,568
11/1/2002	24	10,098	22.5	14,541,120	5,086,773,600	44.6	15,613
11/2/2002	24	10,098	22.5	14,541,120	5,101,314,720	44.6	15,658
11/3/2002	24	10,098	22.5	14,541,120	5,115,855,840	44.6	15,702
11/4/2002	24	10,098	22.5	14,541,120	5,130,396,960	44.6	15,747
11/5/2002	24	10,098	22.5	14,541,120	5,144,938,080	44.6	15,792
11/6/2002	24	10,200	22.7	14,688,000	5,159,626,080	45.1	15,837
11/7/2002	24	10,200	22.7	14,688,000	5,174,314,080	45.1	15,882
11/8/2002	24	10,200	22.7	14,688,000	5,189,002,080	45.1	15,927
11/9/2002	24	10,200	22.7	14,688,000	5,203,690,080	45.1	15,972
11/10/2002	24	10,200	22.7	14,688,000	5,218,378,080	45.1	16,017
11/11/2002	24	10,200	22.7	14,688,000	5,233,066,080	45.1	16,062
11/12/2002	24	10,200	22.7	14,688,000	5,247,754,080	45.1	16,107
11/13/2002	24	9,054	20.2	13,037,760	5,260,791,840	40.0	16,147
11/14/2002	24	9,054	20.2	13,037,760	5,273,829,600	40.0	16,187
11/15/2002	24	9,054	20.2	13,037,760	5,286,867,360	40.0	16,227
11/16/2002	24	9,054	20.2	13,037,760	5,299,905,120	40.0	16,267
11/17/2002	24	9,054	20.2	13,037,760	5,312,942,880	40.0	16,307
11/18/2002	24	9,054	20.2	13,037,760	5,325,980,640	40.0	16,347
11/19/2002	24	9,054	20.2	13,037,760	5,339,018,400	40.0	16,387
11/20/2002	24	10,028	22.3	14,440,320	5,353,458,720	44.3	16,432
11/21/2002	24	10,028	22.3	14,440,320	5,367,899,040	44.3	16,476
11/22/2002	24	10,028	22.3	14,440,320	5,382,339,360	44.3	16,520
11/23/2002	24	10,028	22.3	14,440,320	5,396,779,680	44.3	16,564
11/24/2002	24	10,028	22.3	14,440,320	5,411,220,000	44.3	16,609
11/25/2002	24	10,028	22.3	14,440,320	5,425,660,320	44.3	16,653
11/26/2002	24	10,028	22.3	14,440,320	5,440,100,640	44.3	16,697
11/27/2002	24	10,028	22.3	14,440,320	5,454,540,960	44.3	16,742
11/28/2002	24	9,962	22.2	14,345,280	5,468,886,240	44.0	16,786
11/29/2002	24	9,962	22.2	14,345,280	5,483,231,520	44.0	16,830
11/30/2002	24	9,962	22.2	14,345,280	5,497,576,800	44.0	16,874
12/1/2002	24	9,962	22.2	14,345,280	5,511,922,080	44.0	16,918
12/2/2002	24	9,962	22.2	14,345,280	5,526,267,360	44.0	16,962
12/3/2002	24	9,962	22.2	14,345,280	5,540,612,640	44.0	17,006
12/4/2002	24	9,962	22.2	14,345,280	5,554,957,920	44.0	17,050
12/5/2002	24	9,308	20.7	13,403,520	5,568,361,440	41.1	17,091
12/6/2002	24	9,308	20.7	13,403,520	5,581,764,960	41.1	17,132
12/7/2002	24	9,308	20.7	13,403,520	5,595,168,480	41.1	17,173
12/8/2002	24	9,308	20.7	13,403,520	5,608,572,000	41.1	17,215
12/9/2002	24	9,308	20.7	13,403,520	5,621,975,520	41.1	17,256
12/10/2002	24	9,308	20.7	13,403,520	5,635,379,040	41.1	17,297
12/11/2002	24	9,617	21.4	13,848,480	5,649,227,520	42.5	17,339
12/12/2002	24	9,617	21.4	13,848,480	5,663,076,000	42.5	17,382
12/13/2002	24	9,617	21.4	13,848,480	5,676,924,480	42.5	17,424
12/14/2002	24	9,617	21.4	13,848,480	5,690,772,960	42.5	17,467
12/15/2002	24	9,617	21.4	13,848,480	5,704,621,440	42.5	17,509
12/16/2002	24	9,403	20.9	13,540,320	5,718,161,760	41.6	17,551
12/17/2002	24	9,403	20.9	13,540,320	5,731,702,080	41.6	17,592
12/18/2002	24	9,403	20.9	13,540,320	5,745,242,400	41.6	17,634
12/19/2002	24	9,403	20.9	13,540,320	5,758,782,720	41.6	17,676
12/20/2002	24	9,403	20.9	13,540,320	5,772,323,040	41.6	17,717
12/21/2002	24	9,403	20.9	13,540,320	5,785,863,360	41.6	17,759
12/22/2002	24	9,403	20.9	13,540,320	5,799,403,680	41.6	17,800
12/23/2002	24	9,403	20.9	13,540,320	5,812,944,000	41.6	17,842
12/24/2002	24	9,403	20.9	13,540,320	5,826,484,320	41.6	17,883
12/25/2002	24	9,403	20.9	13,540,320	5,840,024,640	41.6	17,925
12/26/2002	24	10,232	22.8	14,734,080	5,854,758,720	45.2	17,970
12/27/2002	24	10,232	22.8	14,734,080	5,869,492,800	45.2	18,015
12/28/2002	24	10,232	22.8	14,734,080	5,884,226,880	45.2	18,061
12/29/2002	24	10,232	22.8	14,734,080	5,898,960,960	45.2	18,106
12/30/2002	24	10,232	22.8	14,734,080	5,913,695,040	45.2	18,151
12/31/2002	24	10,232	22.8	14,734,080	5,928,429,120	45.2	18,196
1/1/2003	24	9,153	20.4	13,180,320	5,941,609,440	40.5	18,237

Water Discharged to Eccles Creek/Scofield Reservoir

Storage capacity of Scofield Reservoir = 73,600 ac-ft

Day	Hrs	GPM	CFS	Daily Gallons	Cumulative Gallons	Daily Acre-Feet	Cumulative Acre-Feet
1/2/2003	24	9,153	20.4	13,180,320	5,954,789,760	40.5	18,277
1/3/2003	24	9,153	20.4	13,180,320	5,967,970,080	40.5	18,318
1/4/2003	24	9,153	20.4	13,180,320	5,981,150,400	40.5	18,358
1/5/2003	24	9,153	20.4	13,180,320	5,994,330,720	40.5	18,399
1/6/2003	24	9,153	20.4	13,180,320	6,007,511,040	40.5	18,439
1/7/2003	24	9,153	20.4	13,180,320	6,020,691,360	40.5	18,479
1/8/2003	24	9,153	20.4	13,180,320	6,033,871,680	40.5	18,520
1/9/2003	24	10,046	22.4	14,466,240	6,048,337,920	44.4	18,564
1/10/2003	24	10,046	22.4	14,466,240	6,062,804,160	44.4	18,609
1/11/2003	24	10,046	22.4	14,466,240	6,077,270,400	44.4	18,653
1/12/2003	24	10,046	22.4	14,466,240	6,091,736,640	44.4	18,698
1/13/2003	24	10,046	22.4	14,466,240	6,106,202,880	44.4	18,742
1/14/2003	24	10,046	22.4	14,466,240	6,120,669,120	44.4	18,786
1/15/2003	24	8,920	19.9	12,844,800	6,133,513,920	39.4	18,826
1/16/2003	24	8,920	19.9	12,844,800	6,146,358,720	39.4	18,865
1/17/2003	24	8,920	19.9	12,844,800	6,159,203,520	39.4	18,905
1/18/2003	24	8,920	19.9	12,844,800	6,172,048,320	39.4	18,944
1/19/2003	24	8,920	19.9	12,844,800	6,184,893,120	39.4	18,983
1/20/2003	24	8,920	19.9	12,844,800	6,197,737,920	39.4	19,023
1/21/2003	24	8,998	20.0	12,957,120	6,210,695,040	39.8	19,063
1/22/2003	24	8,998	20.0	12,957,120	6,223,652,160	39.8	19,102
1/23/2003	24	8,998	20.0	12,957,120	6,236,609,280	39.8	19,142
1/24/2003	24	8,998	20.0	12,957,120	6,249,566,400	39.8	19,182
1/25/2003	24	8,998	20.0	12,957,120	6,262,523,520	39.8	19,222
1/26/2003	24	8,998	20.0	12,957,120	6,275,480,640	39.8	19,262
1/27/2003	24	8,998	20.0	12,957,120	6,288,437,760	39.8	19,301
1/28/2003	24	8,998	20.0	12,957,120	6,301,394,880	39.8	19,341
1/29/2003	24	9,050	20.2	13,032,000	6,314,426,880	40.0	19,381
1/30/2003	24	9,050	20.2	13,032,000	6,327,458,880	40.0	19,421
1/31/2003	24	9,050	20.2	13,032,000	6,340,490,880	40.0	19,461
2/1/2003	24	9,050	20.2	13,032,000	6,353,522,880	40.0	19,501
2/2/2003	24	9,050	20.2	13,032,000	6,366,554,880	40.0	19,541
2/3/2003	24	9,050	20.2	13,032,000	6,379,586,880	40.0	19,581
2/4/2003	24	9,050	20.2	13,032,000	6,392,618,880	40.0	19,621
2/5/2003	24	9,050	20.2	13,032,000	6,405,650,880	40.0	19,661
2/6/2003	24	9,050	20.2	13,032,000	6,418,682,880	40.0	19,701
2/7/2003	24	9,528	21.2	13,720,320	6,432,403,200	42.1	19,743
2/8/2003	24	9,528	21.2	13,720,320	6,446,123,520	42.1	19,785
2/9/2003	24	9,528	21.2	13,720,320	6,459,843,840	42.1	19,827
2/10/2003	24	9,528	21.2	13,720,320	6,473,564,160	42.1	19,870
2/11/2003	24	9,528	21.2	13,720,320	6,487,284,480	42.1	19,912
2/12/2003	24	9,158	20.4	13,187,520	6,500,472,000	40.5	19,952
2/13/2003	24	9,158	20.4	13,187,520	6,513,659,520	40.5	19,993
2/14/2003	24	9,158	20.4	13,187,520	6,526,847,040	40.5	20,033
2/15/2003	24	9,158	20.4	13,187,520	6,540,034,560	40.5	20,074
2/16/2003	24	9,158	20.4	13,187,520	6,553,222,080	40.5	20,114
2/17/2003	24	9,158	20.4	13,187,520	6,566,409,600	40.5	20,154
2/18/2003	24	9,158	20.4	13,187,520	6,579,597,120	40.5	20,195
2/19/2003	24	9,381	20.9	13,508,640	6,593,105,760	41.5	20,236
2/20/2003	24	9,381	20.9	13,508,640	6,606,614,400	41.5	20,278
2/21/2003	24	9,381	20.9	13,508,640	6,620,123,040	41.5	20,319
2/22/2003	24	9,381	20.9	13,508,640	6,633,631,680	41.5	20,361
2/23/2003	24	9,381	20.9	13,508,640	6,647,140,320	41.5	20,402
2/24/2003	24	9,381	20.9	13,508,640	6,660,648,960	41.5	20,444
2/25/2003	24	9,381	20.9	13,508,640	6,674,157,600	41.5	20,485
2/26/2003	24	9,250	20.6	13,320,000	6,687,477,600	40.9	20,526
2/27/2003	24	9,250	20.6	13,320,000	6,700,797,600	40.9	20,567
2/28/2003	24	9,250	20.6	13,320,000	6,714,117,600	40.9	20,608
3/1/2003	24	9,580	21.3	13,795,200	6,727,912,800	42.3	20,650
3/2/2003	24	9,580	21.3	13,795,200	6,741,708,000	42.3	20,693
3/3/2003	24	9,580	21.3	13,795,200	6,755,503,200	42.3	20,735
3/4/2003	24	9,580	21.3	13,795,200	6,769,298,400	42.3	20,777
3/5/2003	24	9,580	21.3	13,795,200	6,783,093,600	42.3	20,820

Water Discharged to Eccles Creek/Scofield Reservoir

Storage capacity of Scofield Reservoir = 73,600 ac-ft

Day	Hrs	GPM	CFS	Daily Gallons	Cumulative Gallons	Daily Acre-Feet	Cumulative Acre-Feet
3/6/2003	24	9,537	21.2	13,733,280	6,796,826,880	42.2	20,862
3/7/2003	24	9,537	21.2	13,733,280	6,810,560,160	42.2	20,904
3/8/2003	24	9,537	21.2	13,733,280	6,824,293,440	42.2	20,946
3/9/2003	24	9,537	21.2	13,733,280	6,838,026,720	42.2	20,988
3/10/2003	24	9,537	21.2	13,733,280	6,851,760,000	42.2	21,030
3/11/2003	24	9,537	21.2	13,733,280	6,865,493,280	42.2	21,072
3/12/2003	24	9,537	21.2	13,733,280	6,879,226,560	42.2	21,115
3/13/2003	24	10,220	22.8	14,716,800	6,893,943,360	45.2	21,160
3/14/2003	24	10,220	22.8	14,716,800	6,908,660,160	45.2	21,205
3/15/2003	24	10,220	22.8	14,716,800	6,923,376,960	45.2	21,250
3/16/2003	24	10,220	22.8	14,716,800	6,938,093,760	45.2	21,295
3/17/2003	24	10,220	22.8	14,716,800	6,952,810,560	45.2	21,340
3/18/2003	24	10,220	22.8	14,716,800	6,967,527,360	45.2	21,386
3/19/2003	24	9,527	21.2	13,718,880	6,981,246,240	42.1	21,428
3/20/2003	24	9,527	21.2	13,718,880	6,994,965,120	42.1	21,470
3/21/2003	24	9,527	21.2	13,718,880	7,008,684,000	42.1	21,512
3/22/2003	24	9,527	21.2	13,718,880	7,022,402,880	42.1	21,554
3/23/2003	24	9,527	21.2	13,718,880	7,036,121,760	42.1	21,596
3/24/2003	24	9,527	21.2	13,718,880	7,049,840,640	42.1	21,638
3/25/2003	24	9,527	21.2	13,718,880	7,063,559,520	42.1	21,680
3/26/2003	24	10,427	23.2	15,014,880	7,078,574,400	46.1	21,726
3/27/2003	24	10,427	23.2	15,014,880	7,093,589,280	46.1	21,773
3/28/2003	24	10,427	23.2	15,014,880	7,108,604,160	46.1	21,819
3/29/2003	24	10,427	23.2	15,014,880	7,123,619,040	46.1	21,865
3/30/2003	24	10,427	23.2	15,014,880	7,138,633,920	46.1	21,911
3/31/2003	24	10,427	23.2	15,014,880	7,153,648,800	46.1	21,957

Water Discharged to Electric Lake

Storage capacity of Electric Lake = 31,500 ac-ft

JC-1 / JC-2 Operation

Day	Hrs	GPM	CFS	Daily Gallons	Cumulative Gallons	Daily Acre-Feet	Cumulative Acre-Feet
9/16/2001	12.5	2,150	4.8	1,612,500	1,612,500	4.9	5
9/17/2001	24	2,150	4.8	3,096,000	4,708,500	9.5	14
9/18/2001	24	2,150	4.8	3,096,000	7,804,500	9.5	24
9/19/2001	24	2,150	4.8	3,096,000	10,900,500	9.5	33
9/20/2001	24	2,150	4.8	3,096,000	13,996,500	9.5	43
9/21/2001	24	2,150	4.8	3,096,000	17,092,500	9.5	52
9/22/2001	24	2,150	4.8	3,096,000	20,188,500	9.5	62
9/23/2001	24	2,150	4.8	3,096,000	23,284,500	9.5	71
9/24/2001	24	2,150	4.8	3,096,000	26,380,500	9.5	81
9/25/2001	24	2,150	4.8	3,096,000	29,476,500	9.5	90
9/26/2001	24	2,150	4.8	3,096,000	32,572,500	9.5	100
9/27/2001	0	2,150	4.8	-	32,572,500	-	100
9/28/2001	24	2,150	4.8	3,096,000	35,668,500	9.5	109
9/29/2001	24	2,150	4.8	3,096,000	38,764,500	9.5	119
9/30/2001	24	2,150	4.8	3,096,000	41,860,500	9.5	128
10/1/2001	24	2,150	4.8	3,096,000	44,956,500	9.5	138
10/2/2001	24	2,150	4.8	3,096,000	48,052,500	9.5	147
10/3/2001	24	2,150	4.8	3,096,000	51,148,500	9.5	157
10/4/2001	24	2,150	4.8	3,096,000	54,244,500	9.5	166
10/5/2001	24	2,150	4.8	3,096,000	57,340,500	9.5	176
10/6/2001	24	2,150	4.8	3,096,000	60,436,500	9.5	185
10/7/2001	24	2,150	4.8	3,096,000	63,532,500	9.5	195
10/8/2001	24	2,150	4.8	3,096,000	66,628,500	9.5	205
10/9/2001	24	2,150	4.8	3,096,000	69,724,500	9.5	214
10/10/2001	24	2,150	4.8	3,096,000	72,820,500	9.5	224
10/11/2001	24	2,150	4.8	3,096,000	75,916,500	9.5	233
10/12/2001	24	2,150	4.8	3,096,000	79,012,500	9.5	243
10/13/2001	24	2,150	4.8	3,096,000	82,108,500	9.5	252
10/14/2001	24	2,150	4.8	3,096,000	85,204,500	9.5	262
10/15/2001	24	2,150	4.8	3,096,000	88,300,500	9.5	271
10/16/2001	24	2,150	4.8	3,096,000	91,396,500	9.5	281
10/17/2001	24	2,150	4.8	3,096,000	94,492,500	9.5	290
10/18/2001	24	2,150	4.8	3,096,000	97,588,500	9.5	300
10/19/2001	24	2,150	4.8	3,096,000	100,684,500	9.5	309
10/20/2001	24	2,150	4.8	3,096,000	103,780,500	9.5	319
10/21/2001	24	2,150	4.8	3,096,000	106,876,500	9.5	328
10/22/2001	24	2,150	4.8	3,096,000	109,972,500	9.5	338
10/23/2001	24	2,150	4.8	3,096,000	113,068,500	9.5	347
10/24/2001	24	2,150	4.8	3,096,000	116,164,500	9.5	357
10/25/2001	24	-	-	-	116,164,500	-	357
10/26/2001	16	2,150	4.8	2,064,000	118,228,500	6.3	363
10/26/2001	8	2,470	5.5	1,185,600	119,414,100	3.6	367
10/27/2001	24	2,470	5.5	3,556,800	122,970,900	10.9	377
10/28/2001	24	2,470	5.5	3,556,800	126,527,700	10.9	388
10/29/2001	24	2,470	5.5	3,556,800	130,084,500	10.9	399
10/30/2001	24	2,470	5.5	3,556,800	133,641,300	10.9	410

Water Discharged to Electric Lake

Storage capacity of Electric Lake = 31,500 ac-ft

JC-1 / JC-2 Operation

Day	Hrs	GPM	CFS	Daily Gallons	Cumulative Gallons	Daily Acre-Feet	Cumulative Acre-Feet
10/31/2001	24	2,470	5.5	3,556,800	137,198,100	10.9	421
11/1/2001	24	2,470	5.5	3,556,800	140,754,900	10.9	432
11/2/2001	24	2,470	5.5	3,556,800	144,311,700	10.9	443
11/3/2001	24	2,470	5.5	3,556,800	147,868,500	10.9	454
11/4/2001	24	2,470	5.5	3,556,800	151,425,300	10.9	465
11/5/2001	24	2,470	5.5	3,556,800	154,982,100	10.9	476
11/6/2001	24	2,470	5.5	3,556,800	158,538,900	10.9	487
11/7/2001	24	2,470	5.5	3,556,800	162,095,700	10.9	498
11/8/2001	24	2,470	5.5	3,556,800	165,652,500	10.9	508
11/9/2001	24	2,470	5.5	3,556,800	169,209,300	10.9	519
11/10/2001	24	2,470	5.5	3,556,800	172,766,100	10.9	530
11/11/2001	24	2,470	5.5	3,556,800	176,322,900	10.9	541
11/12/2001	24	2,470	5.5	3,556,800	179,879,700	10.9	552
11/13/2001	24	2,470	5.5	3,556,800	183,436,500	10.9	563
11/14/2001	24	2,470	5.5	3,556,800	186,993,300	10.9	574
11/15/2001	24	2,470	5.5	3,556,800	190,550,100	10.9	585
11/16/2001	24	2,470	5.5	3,556,800	194,106,900	10.9	596
11/17/2001	24	2,470	5.5	3,556,800	197,663,700	10.9	607
11/18/2001	8	2,470	5.5	1,185,600	198,849,300	3.6	610
11/19/2001	16	2,470	5.5	2,371,200	201,220,500	7.3	618
11/20/2001	8	2,470	5.5	1,185,600	202,406,100	3.6	621
11/21/2001	0		-	-	202,406,100	-	621
11/22/2001	0		-	-	202,406,100	-	621
11/23/2001	0		-	-	202,406,100	-	621
11/24/2001	0		-	-	202,406,100	-	621
11/25/2001	0		-	-	202,406,100	-	621
11/26/2001	0		-	-	202,406,100	-	621
11/27/2001	0		-	-	202,406,100	-	621
11/28/2001	0		-	-	202,406,100	-	621
11/29/2001	0		-	-	202,406,100	-	621
11/30/2001	0		-	-	202,406,100	-	621
12/1/2001	0		-	-	202,406,100	-	621
12/2/2001	0		-	-	202,406,100	-	621
12/3/2001	0		-	-	202,406,100	-	621
12/4/2001	0		-	-	202,406,100	-	621
12/5/2001	0		-	-	202,406,100	-	621
12/6/2001	0		-	-	202,406,100	-	621
12/7/2001	0		-	-	202,406,100	-	621
12/8/2001	0		-	-	202,406,100	-	621
12/9/2001	0		-	-	202,406,100	-	621
12/10/2001	0		-	-	202,406,100	-	621
12/11/2001	0		-	-	202,406,100	-	621
12/12/2001	0		-	-	202,406,100	-	621
12/13/2001	0		-	-	202,406,100	-	621
12/14/2001	12	2,250	5.0	1,620,000	204,026,100	5.0	626
12/15/2001	24	2,250	5.0	3,240,000	207,266,100	9.9	636

Water Discharged to Electric Lake

Storage capacity of Electric Lake = 31,500 ac-ft

JC-1 / JC-2 Operation

Day	Hrs	GPM	CFS	Daily Gallons	Cumulative Gallons	Daily Acre-Feet	Cumulative Acre-Feet
12/16/2001	24	2,250	5.0	3,240,000	210,506,100	9.9	646
12/17/2001	24	2,250	5.0	3,240,000	213,746,100	9.9	656
12/18/2001	24	2,250	5.0	3,240,000	216,986,100	9.9	666
12/19/2001	24	2,250	5.0	3,240,000	220,226,100	9.9	676
12/20/2001	24	2,250	5.0	3,240,000	223,466,100	9.9	686
12/21/2001	24	2,250	5.0	3,240,000	226,706,100	9.9	696
12/22/2001	24	2,250	5.0	3,240,000	229,946,100	9.9	706
12/23/2001	24	2,250	5.0	3,240,000	233,186,100	9.9	716
12/24/2001	24	2,250	5.0	3,240,000	236,426,100	9.9	726
12/25/2001	24	2,250	5.0	3,240,000	239,666,100	9.9	736
12/26/2001	24	2,250	5.0	3,240,000	242,906,100	9.9	746
12/27/2001	24	2,250	5.0	3,240,000	246,146,100	9.9	756
12/28/2001	24	2,250	5.0	3,240,000	249,386,100	9.9	765
12/29/2001	24	2,250	5.0	3,240,000	252,626,100	9.9	775
12/30/2001	24	2,250	5.0	3,240,000	255,866,100	9.9	785
12/31/2001	24	2,250	5.0	3,240,000	259,106,100	9.9	795
1/1/2002	24	2,250	5.0	3,240,000	262,346,100	9.9	805
1/2/2002	24	2,250	5.0	3,240,000	265,586,100	9.9	815
1/3/2002	24	2,250	5.0	3,240,000	268,826,100	9.9	825
1/4/2002	24	2,250	5.0	3,240,000	272,066,100	9.9	835
1/5/2002	24	2,250	5.0	3,240,000	275,306,100	9.9	845
1/6/2002	24	2,250	5.0	3,240,000	278,546,100	9.9	855
1/7/2002	24	2,250	5.0	3,240,000	281,786,100	9.9	865
1/8/2002	24	2,250	5.0	3,240,000	285,026,100	9.9	875
1/9/2002	24	2,250	5.0	3,240,000	288,266,100	9.9	885
1/10/2002	24	2,250	5.0	3,240,000	291,506,100	9.9	895
1/11/2002	24	2,250	5.0	3,240,000	294,746,100	9.9	905
1/12/2002	24	2,250	5.0	3,240,000	297,986,100	9.9	915
1/13/2002	24	2,250	5.0	3,240,000	301,226,100	9.9	925
1/14/2002	24	2,250	5.0	3,240,000	304,466,100	9.9	935
1/15/2002	24	2,250	5.0	3,240,000	307,706,100	9.9	944
1/16/2002	24	2,250	5.0	3,240,000	310,946,100	9.9	954
1/17/2002	24	2,250	5.0	3,240,000	314,186,100	9.9	964
1/18/2002	24	2,250	5.0	3,240,000	317,426,100	9.9	974
1/19/2002	24	2,250	5.0	3,240,000	320,666,100	9.9	984
1/20/2002	24	2,250	5.0	3,240,000	323,906,100	9.9	994
1/21/2002	24	2,250	5.0	3,240,000	327,146,100	9.9	1,004
1/22/2002	24	2,250	5.0	3,240,000	330,386,100	9.9	1,014
1/23/2002	24	2,250	5.0	3,240,000	333,626,100	9.9	1,024
1/24/2002	24	2,250	5.0	3,240,000	336,866,100	9.9	1,034
1/25/2002	24	2,250	5.0	3,240,000	340,106,100	9.9	1,044
1/26/2002	24	2,250	5.0	3,240,000	343,346,100	9.9	1,054
1/27/2002	24	2,250	5.0	3,240,000	346,586,100	9.9	1,064
1/28/2002	24	2,250	5.0	3,240,000	349,826,100	9.9	1,074
1/29/2002	24	2,250	5.0	3,240,000	353,066,100	9.9	1,084
1/30/2002	24	2,250	5.0	3,240,000	356,306,100	9.9	1,094

Water Discharged to Electric Lake

Storage capacity of Electric Lake = 31,500 ac-ft

JC-1 / JC-2 Operation

Day	Hrs	GPM	CFS	Daily Gallons	Cumulative Gallons	Daily Acre-Feet	Cumulative Acre-Feet
1/31/2002	24	2,250	5.0	3,240,000	359,546,100	9.9	1,104
2/1/2002	24	2,250	5.0	3,240,000	362,786,100	9.9	1,114
2/2/2002	24	2,250	5.0	3,240,000	366,026,100	9.9	1,123
2/3/2002	24	2,250	5.0	3,240,000	369,266,100	9.9	1,133
2/4/2002	24	2,250	5.0	3,240,000	372,506,100	9.9	1,143
2/5/2002	24	2,250	5.0	3,240,000	375,746,100	9.9	1,153
2/6/2002	24	2,250	5.0	3,240,000	378,986,100	9.9	1,163
2/7/2002	24	2,250	5.0	3,240,000	382,226,100	9.9	1,173
2/8/2002	24	2,250	5.0	3,240,000	385,466,100	9.9	1,183
2/9/2002	24	2,250	5.0	3,240,000	388,706,100	9.9	1,193
2/10/2002	24	2,250	5.0	3,240,000	391,946,100	9.9	1,203
2/11/2002	24	2,250	5.0	3,240,000	395,186,100	9.9	1,213
2/12/2002	24	2,250	5.0	3,240,000	398,426,100	9.9	1,223
2/13/2002	24	2,250	5.0	3,240,000	401,666,100	9.9	1,233
2/14/2002	24	2,250	5.0	3,240,000	404,906,100	9.9	1,243
2/15/2002	24	2,250	5.0	3,240,000	408,146,100	9.9	1,253
2/16/2002	24	2,250	5.0	3,240,000	411,386,100	9.9	1,263
2/17/2002	24	2,250	5.0	3,240,000	414,626,100	9.9	1,273
2/18/2002	24	2,250	5.0	3,240,000	417,866,100	9.9	1,283
2/19/2002	24	2,250	5.0	3,240,000	421,106,100	9.9	1,293
2/20/2002	24	2,250	5.0	3,240,000	424,346,100	9.9	1,302
2/21/2002	24	2,250	5.0	3,240,000	427,586,100	9.9	1,312
2/22/2002	24	2,250	5.0	3,240,000	430,826,100	9.9	1,322
2/23/2002	24	2,250	5.0	3,240,000	434,066,100	9.9	1,332
2/24/2002	24	2,250	5.0	3,240,000	437,306,100	9.9	1,342
2/25/2002	24	2,250	5.0	3,240,000	440,546,100	9.9	1,352
2/26/2002	24	2,250	5.0	3,240,000	443,786,100	9.9	1,362
2/27/2002	24	2,250	5.0	3,240,000	447,026,100	9.9	1,372
2/28/2002	24	2,250	5.0	3,240,000	450,266,100	9.9	1,382
3/1/2002	24	2,250	5.0	3,240,000	453,506,100	9.9	1,392
3/2/2002	24	2,250	5.0	3,240,000	456,746,100	9.9	1,402
3/3/2002	24	2,250	5.0	3,240,000	459,986,100	9.9	1,412
3/4/2002	24	2,250	5.0	3,240,000	463,226,100	9.9	1,422
3/5/2002	24	2,250	5.0	3,240,000	466,466,100	9.9	1,432
3/6/2002	24	2,250	5.0	3,240,000	469,706,100	9.9	1,442
3/7/2002	24	2,250	5.0	3,240,000	472,946,100	9.9	1,452
3/8/2002	24	2,250	5.0	3,240,000	476,186,100	9.9	1,462
3/9/2002	24	2,250	5.0	3,240,000	479,426,100	9.9	1,472
3/10/2002	24	2,250	5.0	3,240,000	482,666,100	9.9	1,481
3/11/2002	16	2,250	5.0	2,160,000	484,826,100	6.6	1,488
3/12/2002	0	2,250	5.0	-	484,826,100	-	1,488
3/13/2002	0	2,250	5.0	-	484,826,100	-	1,488
3/14/2002	12	2,250	5.0	1,620,000	486,446,100	5.0	1,493
3/15/2002	24	2,250	5.0	3,240,000	489,686,100	9.9	1,503
3/16/2002	24	2,250	5.0	3,240,000	492,926,100	9.9	1,513
3/17/2002	24	2,250	5.0	3,240,000	496,166,100	9.9	1,523

Water Discharged to Electric Lake

Storage capacity of Electric Lake = 31,500 ac-ft

JC-1 / JC-2 Operation

Day	Hrs	GPM	CFS	Daily Gallons	Cumulative Gallons	Daily Acre-Feet	Cumulative Acre-Feet
3/18/2002	24	2,250	5.0	3,240,000	499,406,100	9.9	1,533
3/19/2002	24	2,250	5.0	3,240,000	502,646,100	9.9	1,543
3/20/2002	24	2,250	5.0	3,240,000	505,886,100	9.9	1,553
3/21/2002	24	2,250	5.0	3,240,000	509,126,100	9.9	1,563
3/22/2002	24	2,250	5.0	3,240,000	512,366,100	9.9	1,573
3/23/2002	24	2,250	5.0	3,240,000	515,606,100	9.9	1,583
3/24/2002	24	2,250	5.0	3,240,000	518,846,100	9.9	1,593
3/25/2002	24	2,250	5.0	3,240,000	522,086,100	9.9	1,602
3/26/2002	24	2,250	5.0	3,240,000	525,326,100	9.9	1,612
3/27/2002	24	2,250	5.0	3,240,000	528,566,100	9.9	1,622
3/28/2002	24	2,250	5.0	3,240,000	531,806,100	9.9	1,632
3/29/2002	24	2,250	5.0	3,240,000	535,046,100	9.9	1,642
3/30/2002	24	2,250	5.0	3,240,000	538,286,100	9.9	1,652
3/31/2002	24	2,250	5.0	3,240,000	541,526,100	9.9	1,662
4/1/2002	24	2,250	5.0	3,240,000	544,766,100	9.9	1,672
4/2/2002	24	2,250	5.0	3,240,000	548,006,100	9.9	1,682
4/3/2002	24	2,250	5.0	3,240,000	551,246,100	9.9	1,692
4/4/2002	24	2,250	5.0	3,240,000	554,486,100	9.9	1,702
4/5/2002	24	2,250	5.0	3,240,000	557,726,100	9.9	1,712
4/6/2002	24	2,250	5.0	3,240,000	560,966,100	9.9	1,722
4/7/2002	24	2,250	5.0	3,240,000	564,206,100	9.9	1,732
4/8/2002	24	2,250	5.0	3,240,000	567,446,100	9.9	1,742
4/9/2002	24	2,250	5.0	3,240,000	570,686,100	9.9	1,752
4/10/2002	24	2,250	5.0	3,240,000	573,926,100	9.9	1,762
4/11/2002	24	2,250	5.0	3,240,000	577,166,100	9.9	1,772
4/12/2002	24	2,250	5.0	3,240,000	580,406,100	9.9	1,781
4/13/2002	24	2,250	5.0	3,240,000	583,646,100	9.9	1,791
4/14/2002	24	2,250	5.0	3,240,000	586,886,100	9.9	1,801
4/15/2002	24	2,250	5.0	3,240,000	590,126,100	9.9	1,811
4/16/2002	24	2,250	5.0	3,240,000	593,366,100	9.9	1,821
4/17/2002	24	2,250	5.0	3,240,000	596,606,100	9.9	1,831
4/18/2002	24	2,250	5.0	3,240,000	599,846,100	9.9	1,841
4/19/2002	24	2,250	5.0	3,240,000	603,086,100	9.9	1,851
4/20/2002	24	2,250	5.0	3,240,000	606,326,100	9.9	1,861
4/21/2002	24	2,250	5.0	3,240,000	609,566,100	9.9	1,871
4/22/2002	24	2,250	5.0	3,240,000	612,806,100	9.9	1,881
4/23/2002	24	2,250	5.0	3,240,000	616,046,100	9.9	1,891
4/24/2002	24	2,250	5.0	3,240,000	619,286,100	9.9	1,901
4/25/2002	24	2,250	5.0	3,240,000	622,526,100	9.9	1,911
4/26/2002	24	2,250	5.0	3,240,000	625,766,100	9.9	1,921
4/27/2002	24	2,250	5.0	3,240,000	629,006,100	9.9	1,931
4/28/2002	24	2,250	5.0	3,240,000	632,246,100	9.9	1,941
4/29/2002	24	2,250	5.0	3,240,000	635,486,100	9.9	1,951
4/30/2002	24	2,250	5.0	3,240,000	638,726,100	9.9	1,960
5/1/2002	24	2,250	5.0	3,240,000	641,966,100	9.9	1,970
5/2/2002	24	2,250	5.0	3,240,000	645,206,100	9.9	1,980

Water Discharged to Electric Lake

Storage capacity of Electric Lake = 31,500 ac-ft

JC-1 / JC-2 Operation

Day	Hrs	GPM	CFS	Daily Gallons	Cumulative Gallons	Daily Acre-Feet	Cumulative Acre-Feet
5/3/2002	24	2,250	5.0	3,240,000	648,446,100	9.9	1,990
5/4/2002	24	2,250	5.0	3,240,000	651,686,100	9.9	2,000
5/5/2002	24	2,250	5.0	3,240,000	654,926,100	9.9	2,010
5/6/2002	24	2,250	5.0	3,240,000	658,166,100	9.9	2,020
5/7/2002	24	2,250	5.0	3,240,000	661,406,100	9.9	2,030
5/8/2002	24	2,250	5.0	3,240,000	664,646,100	9.9	2,040
5/9/2002	24	2,250	5.0	3,240,000	667,886,100	9.9	2,050
5/10/2002	24	2,250	5.0	3,240,000	671,126,100	9.9	2,060
5/11/2002	24	2,250	5.0	3,240,000	674,366,100	9.9	2,070
5/12/2002	24	2,100	4.7	3,024,000	677,390,100	9.3	2,079
5/13/2002	24	2,100	4.7	3,024,000	680,414,100	9.3	2,088
5/14/2002	24	2,100	4.7	3,024,000	683,438,100	9.3	2,098
5/15/2002	24	2,100	4.7	3,024,000	686,462,100	9.3	2,107
5/16/2002	24	2,100	4.7	3,024,000	689,486,100	9.3	2,116
5/17/2002	24	2,100	4.7	3,024,000	692,510,100	9.3	2,126
5/18/2002	24	2,100	4.7	3,024,000	695,534,100	9.3	2,135
5/19/2002	24	2,100	4.7	3,024,000	698,558,100	9.3	2,144
5/20/2002	24	2,100	4.7	3,024,000	701,582,100	9.3	2,153
5/21/2002	24	2,100	4.7	3,024,000	704,606,100	9.3	2,163
5/22/2002	24	2,100	4.7	3,024,000	707,630,100	9.3	2,172
5/23/2002	24	2,100	4.7	3,024,000	710,654,100	9.3	2,181
5/24/2002	24	2,100	4.7	3,024,000	713,678,100	9.3	2,191
5/25/2002	24	2,100	4.7	3,024,000	716,702,100	9.3	2,200
5/26/2002	24	2,100	4.7	3,024,000	719,726,100	9.3	2,209
5/27/2002	24	2,100	4.7	3,024,000	722,750,100	9.3	2,218
5/28/2002	24	2,100	4.7	3,024,000	725,774,100	9.3	2,228
5/29/2002	21	2,100	4.7	2,646,000	728,420,100	8.1	2,236
5/30/2002	24	2,100	4.7	3,024,000	731,444,100	9.3	2,245
5/31/2002	24	2,100	4.7	3,024,000	734,468,100	9.3	2,254
6/1/2002	24	2,080	4.6	2,995,200	737,463,300	9.2	2,264
6/2/2002	24	2,080	4.6	2,995,200	740,458,500	9.2	2,273
6/3/2002	24	2,080	4.6	2,995,200	743,453,700	9.2	2,282
6/4/2002	24	2,080	4.6	2,995,200	746,448,900	9.2	2,291
6/5/2002	24	2,080	4.6	2,995,200	749,444,100	9.2	2,300
6/6/2002	24	2,080	4.6	2,995,200	752,439,300	9.2	2,309
6/7/2002	24	2,080	4.6	2,995,200	755,434,500	9.2	2,319
6/8/2002	24	2,080	4.6	2,995,200	758,429,700	9.2	2,328
6/9/2002	24	2,080	4.6	2,995,200	761,424,900	9.2	2,337
6/10/2002	24	2,080	4.6	2,995,200	764,420,100	9.2	2,346
6/11/2002	24	2,080	4.6	2,995,200	767,415,300	9.2	2,355
6/12/2002	24	2,080	4.6	2,995,200	770,410,500	9.2	2,365
6/13/2002	24	2,080	4.6	2,995,200	773,405,700	9.2	2,374
6/14/2002	24	2,080	4.6	2,995,200	776,400,900	9.2	2,383
6/15/2002	24	2,080	4.6	2,995,200	779,396,100	9.2	2,392
6/16/2002	24	2,080	4.6	2,995,200	782,391,300	9.2	2,401
6/17/2002	24	2,080	4.6	2,995,200	785,386,500	9.2	2,411

Water Discharged to Electric Lake

Storage capacity of Electric Lake = 31,500 ac-ft

JC-1 / JC-2 Operation

Day	Hrs	GPM	CFS	Daily Gallons	Cumulative Gallons	Daily Acre-Feet	Cumulative Acre-Feet
6/18/2002	24	2,080	4.6	2,995,200	788,381,700	9.2	2,420
6/19/2002	24	2,080	4.6	2,995,200	791,376,900	9.2	2,429
6/20/2002	24	2,080	4.6	2,995,200	794,372,100	9.2	2,438
6/21/2002	24	2,080	4.6	2,995,200	797,367,300	9.2	2,447
6/22/2002	24	2,080	4.6	2,995,200	800,362,500	9.2	2,457
6/23/2002	24	2,080	4.6	2,995,200	803,357,700	9.2	2,466
6/24/2002	24	2,080	4.6	2,995,200	806,352,900	9.2	2,475
6/25/2002	24	2,080	4.6	2,995,200	809,348,100	9.2	2,484
6/26/2002	24	2,080	4.6	2,995,200	812,343,300	9.2	2,493
6/27/2002	24	2,080	4.6	2,995,200	815,338,500	9.2	2,503
6/28/2002	24	2,080	4.6	2,995,200	818,333,700	9.2	2,512
6/29/2002	24	2,080	4.6	2,995,200	821,328,900	9.2	2,521
6/30/2002	24	2,080	4.6	2,995,200	824,324,100	9.2	2,530
7/1/2002	24	2,080	4.6	2,995,200	827,319,300	9.2	2,539
7/2/2002	24	2,080	4.6	2,995,200	830,314,500	9.2	2,549
7/3/2002	24	2,080	4.6	2,995,200	833,309,700	9.2	2,558
7/4/2002	24	2,080	4.6	2,995,200	836,304,900	9.2	2,567
7/5/2002	24	2,080	4.6	2,995,200	839,300,100	9.2	2,576
7/6/2002	24	2,080	4.6	2,995,200	842,295,300	9.2	2,585
7/7/2002	24	2,080	4.6	2,995,200	845,290,500	9.2	2,594
7/8/2002	24	2,080	4.6	2,995,200	848,285,700	9.2	2,604
7/9/2002	24	2,080	4.6	2,995,200	851,280,900	9.2	2,613
7/10/2002	24	2,080	4.6	2,995,200	854,276,100	9.2	2,622
7/11/2002	24	2,080	4.6	2,995,200	857,271,300	9.2	2,631
7/12/2002	24	2,080	4.6	2,995,200	860,266,500	9.2	2,640
7/13/2002	24	2,080	4.6	2,995,200	863,261,700	9.2	2,650
7/14/2002	24	2,080	4.6	2,995,200	866,256,900	9.2	2,659
7/15/2002	24	2,080	4.6	2,995,200	869,252,100	9.2	2,668
7/16/2002	24	2,080	4.6	2,995,200	872,247,300	9.2	2,677
7/17/2002	24	2,080	4.6	2,995,200	875,242,500	9.2	2,686
7/18/2002	24	2,080	4.6	2,995,200	878,237,700	9.2	2,696
7/19/2002	24	2,080	4.6	2,995,200	881,232,900	9.2	2,705
7/20/2002	24	2,080	4.6	2,995,200	884,228,100	9.2	2,714
7/21/2002	24	2,080	4.6	2,995,200	887,223,300	9.2	2,723
7/22/2002	24	2,080	4.6	2,995,200	890,218,500	9.2	2,732
7/23/2002	24	2,080	4.6	2,995,200	893,213,700	9.2	2,742
7/24/2002	24	2,080	4.6	2,995,200	896,208,900	9.2	2,751
7/25/2002	24	2,080	4.6	2,995,200	899,204,100	9.2	2,760
7/26/2002	24	2,080	4.6	2,995,200	902,199,300	9.2	2,769
7/27/2002	24	2,080	4.6	2,995,200	905,194,500	9.2	2,778
7/28/2002	24	2,080	4.6	2,995,200	908,189,700	9.2	2,788
7/29/2002	24	2,080	4.6	2,995,200	911,184,900	9.2	2,797
7/30/2002	24	2,080	4.6	2,995,200	914,180,100	9.2	2,806
7/31/2002	24	2,080	4.6	2,995,200	917,175,300	9.2	2,815
8/1/2002	24	2,080	4.6	2,995,200	920,170,500	9.2	2,824
8/2/2002	24	2,080	4.6	2,995,200	923,165,700	9.2	2,833

Water Discharged to Electric Lake

Storage capacity of Electric Lake = 31,500 ac-ft

JC-1 / JC-2 Operation

Day	Hrs	GPM	CFS	Daily Gallons	Cumulative Gallons	Daily Acre-Feet	Cumulative Acre-Feet
8/3/2002	24	2,080	4.6	2,995,200	926,160,900	9.2	2,843
8/4/2002	24	2,080	4.6	2,995,200	929,156,100	9.2	2,852
8/5/2002	24	2,080	4.6	2,995,200	932,151,300	9.2	2,861
8/6/2002	24	2,080	4.6	2,995,200	935,146,500	9.2	2,870
8/7/2002	24	2,080	4.6	2,995,200	938,141,700	9.2	2,879
8/8/2002	24	2,080	4.6	2,995,200	941,136,900	9.2	2,889
8/9/2002	24	2,080	4.6	2,995,200	944,132,100	9.2	2,898
8/10/2002	24	2,080	4.6	2,995,200	947,127,300	9.2	2,907
8/11/2002	24	2,080	4.6	2,995,200	950,122,500	9.2	2,916
8/12/2002	9	2,080	4.6	1,123,200	951,245,700	3.4	2,920
8/13/2002	0	-	-	-	951,245,700	-	2,920
8/14/2002	0	-	-	-	951,245,700	-	2,920
8/15/2002	0	-	-	-	951,245,700	-	2,920
8/16/2002	0	-	-	-	951,245,700	-	2,920
8/17/2002	0	-	-	-	951,245,700	-	2,920
8/18/2002	0	-	-	-	951,245,700	-	2,920
8/19/2002	0	-	-	-	951,245,700	-	2,920
8/20/2002	0	-	-	-	951,245,700	-	2,920
8/21/2002	0	-	-	-	951,245,700	-	2,920
8/22/2002	0	-	-	-	951,245,700	-	2,920
8/23/2002	8.7	2,100	4.7	1,092,420	952,338,120	3.4	2,923
8/24/2002	24	2,100	4.7	3,024,000	955,362,120	9.3	2,932
8/25/2002	24	2,100	4.7	3,024,000	958,386,120	9.3	2,942
8/26/2002	24	2,100	4.7	3,024,000	961,410,120	9.3	2,951
8/27/2002	12.5	2,100	4.7	1,575,000	962,985,120	4.8	2,956
8/28/2002	0	-	-	-	962,985,120	-	2,956
8/29/2002	7.7	2,100	4.7	968,100	963,953,220	3.0	2,959
8/30/2002	24	2,100	4.7	3,024,000	966,977,220	9.3	2,968
8/31/2002	24	2,100	4.7	3,024,000	970,001,220	9.3	2,977
9/1/2002	24	2,100	4.7	3,024,000	973,025,220	9.3	2,987
9/2/2002	24	2,100	4.7	3,024,000	976,049,220	9.3	2,996
9/3/2002	24	2,100	4.7	3,024,000	979,073,220	9.3	3,005
9/4/2002	24	2,100	4.7	3,024,000	982,097,220	9.3	3,014
9/5/2002	24	2,100	4.7	3,024,000	985,121,220	9.3	3,024
9/6/2002	24	2,100	4.7	3,024,000	988,145,220	9.3	3,033
9/7/2002	24	2,100	4.7	3,024,000	991,169,220	9.3	3,042
9/8/2002	24	2,100	4.7	3,024,000	994,193,220	9.3	3,052
9/9/2002	24	2,100	4.7	3,024,000	997,217,220	9.3	3,061
9/10/2002	24	2,100	4.7	3,024,000	1,000,241,220	9.3	3,070
9/11/2002	24	2,100	4.7	3,024,000	1,003,265,220	9.3	3,079
9/12/2002	24	2,100	4.7	3,024,000	1,006,289,220	9.3	3,089
9/13/2002	24	2,100	4.7	3,024,000	1,009,313,220	9.3	3,098
9/14/2002	24	2,100	4.7	3,024,000	1,012,337,220	9.3	3,107
9/15/2002	24	2,100	4.7	3,024,000	1,015,361,220	9.3	3,116
9/16/2002	24	2,100	4.7	3,024,000	1,018,385,220	9.3	3,126
9/17/2002	24	2,100	4.7	3,024,000	1,021,409,220	9.3	3,135

Water Discharged to Electric Lake

Storage capacity of Electric Lake = 31,500 ac-ft

JC-1 / JC-2 Operation

Day	Hrs	GPM	CFS	Daily Gallons	Cumulative Gallons	Daily Acre-Feet	Cumulative Acre-Feet
9/18/2002	24	2,100	4.7	3,024,000	1,024,433,220	9.3	3,144
9/19/2002	24	2,100	4.7	3,024,000	1,027,457,220	9.3	3,154
9/20/2002	24	2,100	4.7	3,024,000	1,030,481,220	9.3	3,163
9/21/2002	24	2,100	4.7	3,024,000	1,033,505,220	9.3	3,172
9/22/2002	24	2,100	4.7	3,024,000	1,036,529,220	9.3	3,181
9/23/2002	24	2,100	4.7	3,024,000	1,039,553,220	9.3	3,191
9/24/2002	24	2,100	4.7	3,024,000	1,042,577,220	9.3	3,200
9/25/2002	24	2,100	4.7	3,024,000	1,045,601,220	9.3	3,209
9/26/2002	24	2,100	4.7	3,024,000	1,048,625,220	9.3	3,219
9/27/2002	24	2,100	4.7	3,024,000	1,051,649,220	9.3	3,228
9/28/2002	24	2,100	4.7	3,024,000	1,054,673,220	9.3	3,237
9/29/2002	24	2,100	4.7	3,024,000	1,057,697,220	9.3	3,246
9/30/2002	24	2,100	4.7	3,024,000	1,060,721,220	9.3	3,256
10/1/2002	24	2,100	4.7	3,024,000	1,063,745,220	9.3	3,265
10/2/2002	10	2,100	4.7	1,260,000	1,065,005,220	3.9	3,269
10/3/2002	0		-	-	1,065,005,220	-	3,269
10/4/2002	0		-	-	1,065,005,220	-	3,269
10/5/2002	0		-	-	1,065,005,220	-	3,269
10/6/2002	0		-	-	1,065,005,220	-	3,269
10/7/2002	0		-	-	1,065,005,220	-	3,269
10/8/2002	0		-	-	1,065,005,220	-	3,269
10/9/2002	0		-	-	1,065,005,220	-	3,269
10/10/2002	0		-	-	1,065,005,220	-	3,269
10/11/2002	0		-	-	1,065,005,220	-	3,269
10/12/2002	0		-	-	1,065,005,220	-	3,269
10/13/2002	0		-	-	1,065,005,220	-	3,269
10/14/2002	11	4,200	9.4	2,772,000	1,067,777,220	8.5	3,277
10/15/2002	24	4,200	9.4	6,048,000	1,073,825,220	18.6	3,296
10/16/2002	24	4,200	9.4	6,048,000	1,079,873,220	18.6	3,314
10/17/2002	24	4,200	9.4	6,048,000	1,085,921,220	18.6	3,333
10/18/2002	24	4,200	9.4	6,048,000	1,091,969,220	18.6	3,352
10/19/2002	24	4,200	9.4	6,048,000	1,098,017,220	18.6	3,370
10/20/2002	24	4,200	9.4	6,048,000	1,104,065,220	18.6	3,389
10/21/2002	24	4,200	9.4	6,048,000	1,110,113,220	18.6	3,407
10/22/2002	24	4,200	9.4	6,048,000	1,116,161,220	18.6	3,426
10/23/2002	24	4,200	9.4	6,048,000	1,122,209,220	18.6	3,444
10/24/2002	24	4,200	9.4	6,048,000	1,128,257,220	18.6	3,463
10/25/2002	24	4,200	9.4	6,048,000	1,134,305,220	18.6	3,482
10/26/2002	24	4,200	9.4	6,048,000	1,140,353,220	18.6	3,500
10/27/2002	24	4,200	9.4	6,048,000	1,146,401,220	18.6	3,519
10/28/2002	24	4,200	9.4	6,048,000	1,152,449,220	18.6	3,537
10/29/2002	24	4,200	9.4	6,048,000	1,158,497,220	18.6	3,556
10/30/2002	24	4,200	9.4	6,048,000	1,164,545,220	18.6	3,574
10/31/2002	10	4,200	9.4	2,520,000	1,167,065,220	7.7	3,582
11/1/2002	0	4,200	9.4	-	1,167,065,220	-	3,582
11/2/2002	0	4,200	9.4	-	1,167,065,220	-	3,582

Water Discharged to Electric Lake

Storage capacity of Electric Lake = 31,500 ac-ft

JC-1 / JC-2 Operation

Day	Hrs	GPM	CFS	Daily Gallons	Cumulative Gallons	Daily Acre-Feet	Cumulative Acre-Feet
11/3/2002	0	4,200	9.4	-	1,167,065,220	-	3,582
11/4/2002	0	4,200	9.4	-	1,167,065,220	-	3,582
11/5/2002	0	4,200	9.4	-	1,167,065,220	-	3,582
11/6/2002	0		-	-	1,167,065,220	-	3,582
11/7/2002	0		-	-	1,167,065,220	-	3,582
11/8/2002	0		-	-	1,167,065,220	-	3,582
11/9/2002	0		-	-	1,167,065,220	-	3,582
11/10/2002	0		-	-	1,167,065,220	-	3,582
11/11/2002	0		-	-	1,167,065,220	-	3,582
11/12/2002	14	4,100	9.1	3,444,000	1,170,509,220	10.6	3,593
11/13/2002	24	4,100	9.1	5,904,000	1,176,413,220	18.1	3,611
11/14/2002	24	4,100	9.1	5,904,000	1,182,317,220	18.1	3,629
11/15/2002	24	4,100	9.1	5,904,000	1,188,221,220	18.1	3,647
11/16/2002	24	4,100	9.1	5,904,000	1,194,125,220	18.1	3,665
11/17/2002	24	4,100	9.1	5,904,000	1,200,029,220	18.1	3,683
11/18/2002	24	4,100	9.1	5,904,000	1,205,933,220	18.1	3,701
11/19/2002	24	4,100	9.1	5,904,000	1,211,837,220	18.1	3,720
11/20/2002	24	4,100	9.1	5,904,000	1,217,741,220	18.1	3,738
11/21/2002	24	4,100	9.1	5,904,000	1,223,645,220	18.1	3,756
11/22/2002	24	4,100	9.1	5,904,000	1,229,549,220	18.1	3,774
11/23/2002	24	4,100	9.1	5,904,000	1,235,453,220	18.1	3,792
11/24/2002	24	4,100	9.1	5,904,000	1,241,357,220	18.1	3,810
11/25/2002	24	4,100	9.1	5,904,000	1,247,261,220	18.1	3,828
11/26/2002	24	4,100	9.1	5,904,000	1,253,165,220	18.1	3,846
11/27/2002	24	4,100	9.1	5,904,000	1,259,069,220	18.1	3,864
11/28/2002	24	4,100	9.1	5,904,000	1,264,973,220	18.1	3,883
11/29/2002	24	4,100	9.1	5,904,000	1,270,877,220	18.1	3,901
11/30/2002	24	4,100	9.1	5,904,000	1,276,781,220	18.1	3,919
12/1/2002	24	4,100	9.1	5,904,000	1,282,685,220	18.1	3,937
12/2/2002	24	4,100	9.1	5,904,000	1,288,589,220	18.1	3,955
12/3/2002	24	4,100	9.1	5,904,000	1,294,493,220	18.1	3,973
12/4/2002	24	4,100	9.1	5,904,000	1,300,397,220	18.1	3,991
12/5/2002	24	4,100	9.1	5,904,000	1,306,301,220	18.1	4,009
12/6/2002	24	4,100	9.1	5,904,000	1,312,205,220	18.1	4,028
12/7/2002	24	4,100	9.1	5,904,000	1,318,109,220	18.1	4,046
12/8/2002	24	4,100	9.1	5,904,000	1,324,013,220	18.1	4,064
12/9/2002	24	4,100	9.1	5,904,000	1,329,917,220	18.1	4,082
12/10/2002	24	4,100	9.1	5,904,000	1,335,821,220	18.1	4,100
12/11/2002	24	4,100	9.1	5,904,000	1,341,725,220	18.1	4,118
12/12/2002	24	4,100	9.1	5,904,000	1,347,629,220	18.1	4,136
12/13/2002	24	4,100	9.1	5,904,000	1,353,533,220	18.1	4,154
12/14/2002	24	4,100	9.1	5,904,000	1,359,437,220	18.1	4,173
12/15/2002	24	4,100	9.1	5,904,000	1,365,341,220	18.1	4,191
12/16/2002	24	4,100	9.1	5,904,000	1,371,245,220	18.1	4,209
12/17/2002	24	4,100	9.1	5,904,000	1,377,149,220	18.1	4,227
12/18/2002	24	4,100	9.1	5,904,000	1,383,053,220	18.1	4,245

Water Discharged to Electric Lake

Storage capacity of Electric Lake = 31,500 ac-ft

JC-1 / JC-2 Operation

Day	Hrs	GPM	CFS	Daily Gallons	Cumulative Gallons	Daily Acre-Feet	Cumulative Acre-Feet
12/19/2002	24	4,100	9.1	5,904,000	1,388,957,220	18.1	4,263
12/20/2002	24	4,100	9.1	5,904,000	1,394,861,220	18.1	4,281
12/21/2002	24	4,100	9.1	5,904,000	1,400,765,220	18.1	4,299
12/22/2002	24	4,100	9.1	5,904,000	1,406,669,220	18.1	4,318
12/23/2002	24	4,100	9.1	5,904,000	1,412,573,220	18.1	4,336
12/24/2002	24	4,100	9.1	5,904,000	1,418,477,220	18.1	4,354
12/25/2002	24	4,100	9.1	5,904,000	1,424,381,220	18.1	4,372
12/26/2002	24	4,100	9.1	5,904,000	1,430,285,220	18.1	4,390
12/27/2002	24	4,100	9.1	5,904,000	1,436,189,220	18.1	4,408
12/28/2002	24	4,100	9.1	5,904,000	1,442,093,220	18.1	4,426
12/29/2002	24	4,100	9.1	5,904,000	1,447,997,220	18.1	4,444
12/30/2002	24	4,100	9.1	5,904,000	1,453,901,220	18.1	4,463
12/31/2002	24	4,100	9.1	5,904,000	1,459,805,220	18.1	4,481
1/1/2003	24	4,100	9.1	5,904,000	1,465,709,220	18.1	4,499
1/2/2003	24	4,100	9.1	5,904,000	1,471,613,220	18.1	4,517
1/3/2003	24	4,100	9.1	5,904,000	1,477,517,220	18.1	4,535
1/4/2003	24	4,100	9.1	5,904,000	1,483,421,220	18.1	4,553
1/5/2003	24	4,100	9.1	5,904,000	1,489,325,220	18.1	4,571
1/6/2003	24	4,100	9.1	5,904,000	1,495,229,220	18.1	4,589
1/7/2003	24	4,100	9.1	5,904,000	1,501,133,220	18.1	4,607
1/8/2003	24	4,100	9.1	5,904,000	1,507,037,220	18.1	4,626
1/9/2003	24	4,100	9.1	5,904,000	1,512,941,220	18.1	4,644
1/10/2003	24	4,100	9.1	5,904,000	1,518,845,220	18.1	4,662
1/11/2003	24	4,100	9.1	5,904,000	1,524,749,220	18.1	4,680
1/12/2003	24	4,100	9.1	5,904,000	1,530,653,220	18.1	4,698
1/13/2003	24	4,100	9.1	5,904,000	1,536,557,220	18.1	4,716
1/14/2003	24	4,100	9.1	5,904,000	1,542,461,220	18.1	4,734
1/15/2003	24	4,100	9.1	5,904,000	1,548,365,220	18.1	4,752
1/16/2003	24	4,100	9.1	5,904,000	1,554,269,220	18.1	4,771
1/17/2003	24	4,100	9.1	5,904,000	1,560,173,220	18.1	4,789
1/18/2003	24	4,100	9.1	5,904,000	1,566,077,220	18.1	4,807
1/19/2003	24	4,100	9.1	5,904,000	1,571,981,220	18.1	4,825
1/20/2003	24	4,100	9.1	5,904,000	1,577,885,220	18.1	4,843
1/21/2003	24	4,100	9.1	5,904,000	1,583,789,220	18.1	4,861
1/22/2003	24	4,100	9.1	5,904,000	1,589,693,220	18.1	4,879
1/23/2003	24	4,100	9.1	5,904,000	1,595,597,220	18.1	4,897
1/24/2003	24	4,100	9.1	5,904,000	1,601,501,220	18.1	4,916
1/25/2003	24	4,100	9.1	5,904,000	1,607,405,220	18.1	4,934
1/26/2003	24	4,100	9.1	5,904,000	1,613,309,220	18.1	4,952
1/27/2003	24	4,100	9.1	5,904,000	1,619,213,220	18.1	4,970
1/28/2003	24	4,100	9.1	5,904,000	1,625,117,220	18.1	4,988
1/29/2003	24	4,100	9.1	5,904,000	1,631,021,220	18.1	5,006
1/30/2003	24	4,100	9.1	5,904,000	1,636,925,220	18.1	5,024
1/31/2003	24	4,100	9.1	5,904,000	1,642,829,220	18.1	5,042
2/1/2003	24	4,100	9.1	5,904,000	1,648,733,220	18.1	5,061
2/2/2003	24	4,100	9.1	5,904,000	1,654,637,220	18.1	5,079

Water Discharged to Electric Lake

Storage capacity of Electric Lake = 31,500 ac-ft

JC-1 / JC-2 Operation

Day	Hrs	GPM	CFS	Daily Gallons	Cumulative Gallons	Daily Acre-Feet	Cumulative Acre-Feet
2/3/2003	24	4,100	9.1	5,904,000	1,660,541,220	18.1	5,097
2/4/2003	24	4,100	9.1	5,904,000	1,666,445,220	18.1	5,115
2/5/2003	24	4,100	9.1	5,904,000	1,672,349,220	18.1	5,133
2/6/2003	24	4,100	9.1	5,904,000	1,678,253,220	18.1	5,151
2/7/2003	24	4,100	9.1	5,904,000	1,684,157,220	18.1	5,169
2/8/2003	24	4,100	9.1	5,904,000	1,690,061,220	18.1	5,187
2/9/2003	24	4,100	9.1	5,904,000	1,695,965,220	18.1	5,205
2/10/2003	24	4,100	9.1	5,904,000	1,701,869,220	18.1	5,224
2/11/2003	24	4,100	9.1	5,904,000	1,707,773,220	18.1	5,242
2/12/2003	24	4,100	9.1	5,904,000	1,713,677,220	18.1	5,260
2/13/2003	24	4,100	9.1	5,904,000	1,719,581,220	18.1	5,278
2/14/2003	24	4,100	9.1	5,904,000	1,725,485,220	18.1	5,296
2/15/2003	24	4,100	9.1	5,904,000	1,731,389,220	18.1	5,314
2/16/2003	24	4,100	9.1	5,904,000	1,737,293,220	18.1	5,332
2/17/2003	24	4,100	9.1	5,904,000	1,743,197,220	18.1	5,350
2/18/2003	24	4,100	9.1	5,904,000	1,749,101,220	18.1	5,369
2/19/2003	24	4,100	9.1	5,904,000	1,755,005,220	18.1	5,387
2/20/2003	24	4,100	9.1	5,904,000	1,760,909,220	18.1	5,405
2/21/2003	24	4,100	9.1	5,904,000	1,766,813,220	18.1	5,423
2/22/2003	24	4,100	9.1	5,904,000	1,772,717,220	18.1	5,441
2/23/2003	24	4,100	9.1	5,904,000	1,778,621,220	18.1	5,459
2/24/2003	24	4,000	8.9	5,760,000	1,784,381,220	17.7	5,477
2/25/2003	24	4,000	8.9	5,760,000	1,790,141,220	17.7	5,495
2/26/2003	24	4,000	8.9	5,760,000	1,795,901,220	17.7	5,512
2/27/2003	24	4,000	8.9	5,760,000	1,801,661,220	17.7	5,530
2/28/2003	24	4,000	8.9	5,760,000	1,807,421,220	17.7	5,548
3/1/2003	24	4,000	8.9	5,760,000	1,813,181,220	17.7	5,565
3/2/2003	24	4,000	8.9	5,760,000	1,818,941,220	17.7	5,583
3/3/2003	24	4,000	8.9	5,760,000	1,824,701,220	17.7	5,601
3/4/2003	24	4,000	8.9	5,760,000	1,830,461,220	17.7	5,618
3/5/2003	24	4,000	8.9	5,760,000	1,836,221,220	17.7	5,636
3/6/2003	24	4,000	8.9	5,760,000	1,841,981,220	17.7	5,654
3/7/2003	24	3,900	8.7	5,616,000	1,847,597,220	17.2	5,671
3/8/2003	24	3,900	8.7	5,616,000	1,853,213,220	17.2	5,688
3/9/2003	24	3,900	8.7	5,616,000	1,858,829,220	17.2	5,705
3/10/2003	24	3,900	8.7	5,616,000	1,864,445,220	17.2	5,723
3/11/2003	24	3,900	8.7	5,616,000	1,870,061,220	17.2	5,740
3/12/2003	24	3,900	8.7	5,616,000	1,875,677,220	17.2	5,757
3/13/2003	24	3,900	8.7	5,616,000	1,881,293,220	17.2	5,774
3/14/2003	24	3,900	8.7	5,616,000	1,886,909,220	17.2	5,792
3/15/2003	24	3,900	8.7	5,616,000	1,892,525,220	17.2	5,809
3/16/2003	24	3,900	8.7	5,616,000	1,898,141,220	17.2	5,826
3/17/2003	24	3,900	8.7	5,616,000	1,903,757,220	17.2	5,843
3/18/2003	24	3,900	8.7	5,616,000	1,909,373,220	17.2	5,860
3/19/2003	24	3,900	8.7	5,616,000	1,914,989,220	17.2	5,878
3/20/2003	24	3,900	8.7	5,616,000	1,920,605,220	17.2	5,895

Water Discharged to Electric Lake

Storage capacity of Electric Lake = 31,500 ac-ft

JC-1 / JC-2 Operation

Day	Hrs	GPM	CFS	Daily Gallons	Cumulative Gallons	Daily Acre-Feet	Cumulative Acre-Feet
3/21/2003	24	3,900	8.7	5,616,000	1,926,221,220	17.2	5,912
3/22/2003	24	3,900	8.7	5,616,000	1,931,837,220	17.2	5,929
3/23/2003	24	3,900	8.7	5,616,000	1,937,453,220	17.2	5,947
3/24/2003	21	3,900	8.7	4,914,000	1,942,367,220	15.1	5,962
3/25/2003	24	3,900	8.7	5,616,000	1,947,983,220	17.2	5,979
3/26/2003	24	3,900	8.7	5,616,000	1,953,599,220	17.2	5,996
3/27/2003	24	3,900	8.7	5,616,000	1,959,215,220	17.2	6,013
3/28/2003	24	3,900	8.7	5,616,000	1,964,831,220	17.2	6,031
3/29/2003	24	3,900	8.7	5,616,000	1,970,447,220	17.2	6,048
3/30/2003	24	3,900	8.7	5,616,000	1,976,063,220	17.2	6,065
3/31/2003	24	3,900	8.7	5,616,000	1,981,679,220	17.2	6,082

		Scofield Reservoir Storage Capacity 73,600 ac-ft					Electric Lake Storage Capacity 31,500 ac-ft						
		ECCLES CREEK					**ELECTRIC LAKE**					**Discharge to Both Drainages**	
		Discharge to Eccles			Cumulative		Discharge to Electric Lake			Cumulative		Cumulative	
Month	Days	GPM	CFS	MGD	Gallons	Ac-Ft	GPM	CFS	MGD	Gallons	Ac-Ft	Gallons	Acre-Feet
Jan-99	31	340	0.8	0.49	15,190,000	47						15,190,000	47
Feb-99	28	229	0.5	0.33	24,430,000	75						24,430,000	75
Mar-99	31	465	1.0	0.67	45,200,000	139						45,200,000	139
Apr-99	30	215	0.5	0.31	54,500,000	167						54,500,000	167
May-99	31	278	0.6	0.40	66,900,000	205						66,900,000	205
Jun-99	30	188	0.4	0.27	75,000,000	230						75,000,000	230
Jul-99	31	181	0.4	0.26	83,060,000	255						83,060,000	255
Aug-99	31	229	0.5	0.33	93,290,000	286						93,290,000	286
Sep-99	30	139	0.3	0.20	99,290,000	305						99,290,000	305
Oct-99	31	243	0.5	0.35	110,140,000	338						110,140,000	338
Nov-99	30	514	1.1	0.74	132,340,000	406						132,340,000	406
Dec-99	31	90	0.2	0.13	136,370,000	419						136,370,000	419
Jan-00	31	722	1.6	1.04	168,610,000	517						168,610,000	517
Feb-00	29	681	1.5	0.98	197,030,000	605						197,030,000	605
Mar-00	31	993	2.2	1.43	241,360,000	741						241,360,000	741
Apr-00	30	1,354	3.0	1.95	299,860,000	920						299,860,000	920
May-00	31	1,181	2.6	1.70	352,560,000	1,082						352,560,000	1,082
Jun-00	30	1,000	2.2	1.44	395,760,000	1,215						395,760,000	1,215
Jul-00	31	1,236	2.8	1.78	450,940,000	1,384						450,940,000	1,384
Aug-00	31	993	2.2	1.43	495,270,000	1,520						495,270,000	1,520
Sep-00	30	1,361	3.0	1.96	554,070,000	1,700						554,070,000	1,700
Oct-00	31	2,354	5.2	3.39	659,160,000	2,023						659,160,000	2,023
Nov-00	30	1,688	3.8	2.43	732,060,000	2,247						732,060,000	2,247
Dec-00	31	2,201	4.9	3.17	830,330,000	2,548						830,330,000	2,548
Jan-01	31	2,569	5.7	3.70	945,030,000	2,900						945,030,000	2,900
Feb-01	28	2,500	5.6	3.60	1,045,830,000	3,210						1,045,830,000	3,210
Mar-01	31	3,542	7.9	5.10	1,203,930,000	3,695						1,203,930,000	3,695
Apr-01	30	4,028	9.0	5.80	1,377,930,000	4,229						1,377,930,000	4,229
May-01	31	3,542	7.9	5.10	1,536,030,000	4,714						1,536,030,000	4,714
Jun-01	30	2,986	6.7	4.30	1,665,030,000	5,110						1,665,030,000	5,110
Jul-01	31	4,514	10.1	6.50	1,866,530,000	5,728						1,866,530,000	5,728
Aug-01	31	4,514	10.1	6.50	2,068,030,000	6,347						2,068,030,000	6,347
Sep-01	30	7,795	17.4	11.23	2,404,786,960	7,380	969	2.2	1.40	41,860,500	128	2,446,647,460	7,508
Oct-01	31	9,000	20.1	12.96	2,806,546,960	8,613	2,136	4.8	3.08	137,198,100	421	2,943,745,060	9,034
Nov-01	30	8,907	19.8	12.83	3,191,314,960	9,794	1,509	3.4	2.17	202,406,100	621	3,393,721,060	10,415
Dec-01	31	7,911	17.6	11.39	3,544,460,560	10,878	1,270	2.8	1.83	259,106,100	795	3,803,566,660	11,673

		Scofield Reservoir Storage Capacity 73,600 ac-ft					Electric Lake Storage Capacity 31,500 ac-ft						
		ECCLES CREEK					**ELECTRIC LAKE**					**Discharge to Both Drainages**	
		Discharge to Eccles			Cumulative		Discharge to Electric Lake			Cumulative		Cumulative	
Month	Days	GPM	CFS	MGD	Gallons	Ac-Ft	GPM	CFS	MGD	Gallons	Ac-Ft	Gallons	Acre-Feet
Jan-02	31	7,297	16.3	10.51	3,870,198,640	11,877	2,250	5.0	3.24	359,546,100	1,103	4,229,744,740	12,981
Feb-02	28	7,012	15.6	10.10	4,152,926,800	12,745	2,250	5.0	3.24	450,266,100	1,382	4,603,192,900	14,127
Mar-02	31	7,196	16.0	10.36	4,474,142,800	13,731	2,044	4.6	2.94	541,526,100	1,662	5,015,668,900	15,393
Apr-02	30	8,200	18.3	11.81	4,828,382,800	14,818	2,250	5.0	3.24	638,726,100	1,960	5,467,108,900	16,778
May-02	31	7,740	17.2	11.15	5,173,896,400	15,878	2,145	4.8	3.09	734,468,100	2,254	5,908,364,500	18,132
Jun-02	30	8,188	18.2	11.79	5,527,605,040	16,964	2,080	4.6	3.00	824,324,100	2,530	6,351,929,140	19,493
Jul-02	31	8,927	19.9	12.85	5,926,103,440	18,187	2,080	4.6	3.00	917,175,300	2,815	6,843,278,740	21,001
Aug-02	31	8,773	19.5	12.63	6,317,748,880	19,388	1,183	2.6	1.70	970,001,220	2,977	7,287,750,100	22,365
Sep-02	30	9,282	20.7	13.37	6,718,735,600	20,619	2,100	4.7	3.02	1,060,721,220	3,255	7,779,456,820	23,874
Oct-02	31	7,023	15.6	10.11	7,032,262,480	21,581	2,382	5.3	3.43	1,167,065,220	3,582	8,199,327,700	25,163
Nov-02	30	9,846	21.9	14.18	7,457,606,800	22,887	2,540	5.7	3.66	1,276,781,220	3,918	8,734,388,020	26,805
Dec-02	31	9,652	21.5	13.90	7,888,459,120	24,209	4,100	9.1	5.90	1,459,805,220	4,480	9,348,264,340	28,689
Jan-03	31	9,231	20.6	13.29	8,300,520,880	25,473	4,100	9.1	5.90	1,642,829,220	5,042	9,943,350,100	30,515
Feb-03	28	10,216	22.8	14.71	8,712,434,320	26,737	4,539	10.1	6.54	1,825,853,220	5,603	10,538,287,540	32,341
Mar-03	31	9,224	20.6	13.28	9,124,199,440	28,001	4,100	9.1	5.90	2,008,877,220	6,165	11,133,076,660	34,166

PHC ADDENDUM

APPENDIX B
NORWEST TECHNICAL REPORT
"MANTI-LA SAL NATIONAL FOREST FLAT CANYON EIS"

TECHNICAL REPORT SURFACE-WATER AND GROUNDWATER RESOURCES IN THE FLAT CANYON AREA

NorWest

Mine Services

TECHNICAL REPORT SURFACE-WATER AND GROUNDWATER RESOURCES IN THE FLAT CANYON AREA

Submitted to:
MANTI-LA SAL NATIONAL FOREST

AND

BUREAU OF LAND MANAGEMENT, UTAH STATE OFFICE

October 21, 2000

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DIV OF OIL GAS & MINING

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1.0 INTRODUCTION

Canyon Fuel Company, LLC (CFC), submitted a Federal Lease Application to the Bureau of Land Management (BLM) for the Flat Canyon Tract (Tract) in March of 1998. A joint Manti-LaSal Forest Service (FS)/BLM Tract Delineation Team (TDT) ratified the Tract boundaries as submitted by CFC in August 1999.

The Tract is just west of the Wasatch Plateau Known Recoverable Coal Resource Area. The surface of the area is managed by the FS and the mineral estate by the BLM. The FS and BLM (Utah State Office) jointly determined that an Environment Impact Statement would be required as a basis for leasing decisions. The Office of Surface Mining (OSM) and Bureau of Reclamation (BOR) will participate as co-operating agencies.

The Tract encompasses some 2,692 acres immediately west of the existing CFC Skyline Mine as shown generally on Figure 1.1 and more particularly on Figure 1.2. Effects of mining the Tract may spill over into neighboring areas. The greater area of influence is termed the Reasonably Foreseeable Development Scenario Area (RFDS Area). While the terms Tract and RFDS Area define slightly different footprints, they are often used interchangeably in this Report.

This technical report describes groundwater and surface water resources in the Flat Canyon Coal Lease Tract and the adjacent fee lands (Figure 1.2). Together the tract and the private lands are described as the 'RFDS area' in this report. The study area for this investigation extends beyond the RFDS as shown in Figure 1.2. This investigation relies on data, information, and experience from the existing Skyline Mine permit area (Figure 1.2), which is east of and contiguous with the RFDS area. This area is referred to throughout this report as the Skyline Mine area.

The EIS Summary is attached as Appendix A. The Table of Resource Element Evaluation is attached as Appendix B.

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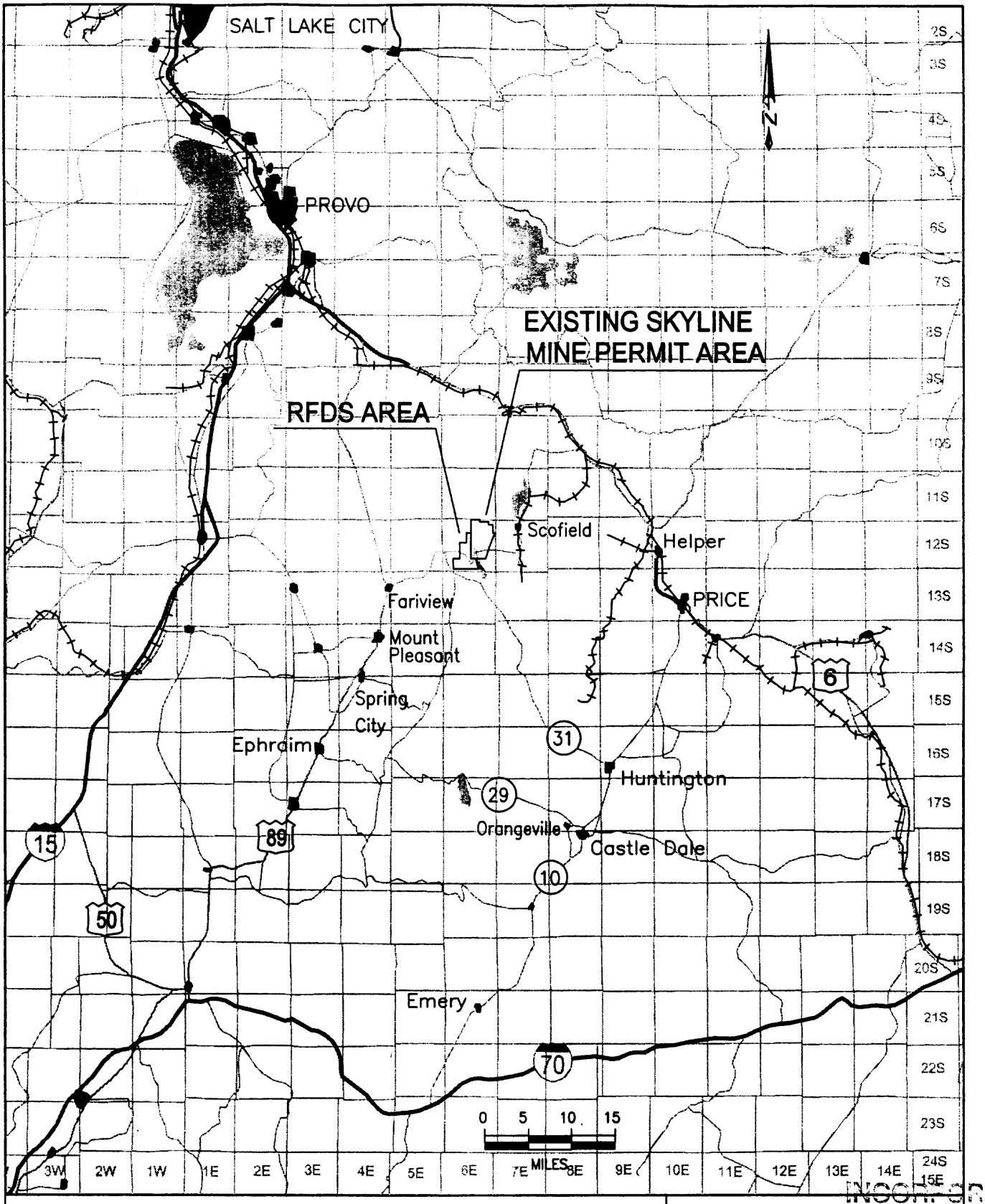

LEGEND

- RAILROAD
- HIGHWAY
- ROAD
- LAKE/RIVER
- CITY

DETAIL AREA

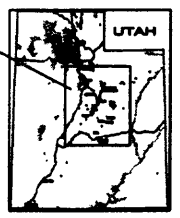

FIGURE 1.1
PROJECT LOCATION MAP

DATE: 10/18/2000
FILE: 2439LOCATION

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1.1 AUTHORS

This technical report was prepared by NorWest Mine Services, Inc. (NorWest) and Mayo and Associates, LC (Mayo). Primary authors are:

- Kelly Payne (Groundwater), Hydrogeologist, NorWest
- Erik Petersen (Surface Water), Hydrologist, Mayo

Contributing authors and reviewers are:

- James (Jim) Alto, Co-Project Manager, NorWest
- Conrad (Con) Houser, Co-Project Manager, NorWest
- Patrick Mullen, Senior Biologist, Maxim Technologies, Inc.

1.2 PROPOSED ACTION

The FS and BLM propose to offer the Tract for competitive leasing based on CFC's application for lease as modified by the Interagency Tract Delineation Team. Only when or if it is determined that lease of this Tract, with special stipulations established by FS and BLM, can meet the primary objectives of all supervising agencies, will the Tract be offered.

1.3 PURPOSE AND NEED

The FS and BLM propose to offer the Tract for competitive leasing based on CFC's application for lease as modified by the Interagency Tract Delineation Team. The Tract would be accessed from the existing Skyline Mine. The TDT concluded, "no other independent access to the coal appears to be feasible." If a company other than CFC were to acquire the Tract, the most likely access to coal reserves would be through a 1200-foot shaft in the Boulger Canyon area between Boulger Reservoir and Electric Lake, as the coal does not outcrop. This is unlikely to be economically feasible (see the TDT's Reasonable Foreseeable Development Scenario discussed below).

Successful acquisition of the Tract by CFC would extend the life of the Skyline Mine by nine to twelve years, based on the reserves defined by the BLM Tract Delineation Report and an annual production rate from 3 to 4 million tons. However, if the BLM special stipulations are applied for resource protection then the reserves and mine life could be significantly reduced.

The Skyline Mine is a longwall operation. This technique for coal extraction would be extended into the Tract. Mine water discharge would be either from the existing permitted discharge point in Eccles Canyon or a proposed discharge into Electric Lake in the Huntington Creek drainage.

Surface disturbance associated with the development of facilities and exploration drilling on the Tract would be small: being limited to a number of exploratory drill holes and one or two passive ventilation shafts being the only newly constructed facilities. The locations of the exploratory holes are preliminary and subject to change depending on geologic and environmental considerations.

Each drill hole would require a pad with an area of about one-half acre, approximately 100 ft by 200 ft and a temporary access road about 1,000 ft in length. If 10 additional holes are drilled, the area disturbed would be about 7.4 acres including drill pads and roads.

Ventilation shafts would not be constructed until underground mining progressed to each location and additional ventilation was required for safe operations. The construction footprint for each ventilation shaft would be approximately one acre. Total disturbance for access roads to each ventilation shaft would be about 1,000 ft by 16 ft, or 0.36 acres for both shafts. The two shafts would be used for the life of the mine and would be abandoned and reclaimed thereafter. Disturbance and reclamation would be completed in accordance with permits issued by the FS and the State of Utah.

Total new surface disturbance for the Tract would be approximately 9.8 acres. This disturbance is related to predicted surface facilities only and does not include subsidence.

1.4 REASONABLE FORESEEABLE DEVELOPMENT SCENARIO (RFDS) - SUMMARY

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The Tract covers an area of 2,692 acres and would be mined using longwall methods with multiple seam mining of two seams over the majority of the area and a total of 36 million tons of coal estimated to be recoverable. Continuous miners would be used for mine development. The reasonable range of longwall operational mining height would be from 7 to 12.5 ft and vary for each seam. Combined longwall extraction of two seams, based on reasonable operational constraints, could be as much as 22.5 ft of coal in some areas. These mining limits should not be

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regarded as rigid, as it may be possible to extract coal with a thickness down to 6 feet, or greater than 12.5 feet in some cases. Additional coal resources, not amenable to longwall mining, may be recovered by room and pillar methods with partial or full extraction.

The Tract would be accessed from the existing Skyline Mine (Federal Leases U-044076 and U-0147570) adjacent to the Huntington Creek drainage. A development corridor, running parallel and under Huntington Creek, is the most likely mining scenario for main access to the Tract. This corridor is located mainly within the existing lease, but a small portion is within private land in the south. Development with full support

room and pillar mining under the existing lease would be used to preclude subsidence of this creek.

1.5 REVIEWING AGENCY OBJECTIVES

The primary objectives of the BLM are to ensure:

- maximum economic recovery (MER) of the coal is achieved;
- the environment is protected; and
- all potential impacts resulting from mining are addressed and resolved.

To meet these objectives, the EIS must evaluate the Tract based on the following assumptions:

- assume full extraction mining to determine all potential surface impacts;
- surface areas determined to be not conducive to full extraction mining must be re-evaluated for impacts from partial extraction, first mining, or development mining;
- protective non-subsidence buffer zones must be considered (with appropriate angle-of-draw) for protection of sensitive resources, where these resources are protected by applicable laws, regulations, and management direction if the need is indicated or effects are relatively uncertain;
- geologic conditions that could limit coal extraction (other than coal thickness, interburden and depth) have only been considered where the data is thought to be sufficiently reliable;
- drilling of about 10 additional exploration holes would be necessary to delineate the reserves; and
- development of two passive vent holes.

The Forest Service has a wide range of Forest Management goals including the following:

- manage geologic resources to meet resource needs and minimize adverse effects;
- maintain satisfactory watershed conditions while providing favorable conditions for water flow;
- provide for production of mineral resources consistent with applicable laws, regulations, and Forest Plan management direction; and
- provide for public safety.

Where there is conflict between MER and the other objectives, the EIS must consider the effects of a reasonable range of alternatives, including no action, to allow for informed scientifically based decisions to be made.

1.6 ALTERNATIVES

Four alternatives were developed to address the significant issues associated with this proposed lease action and to meet the requirements of NEPA. This Technical Report will address Alternatives 2 and 3 and make recommendations to help FS and BLM compile special lease stipulations needed for inclusion in Alternative 4.

1.6.1 No Action (Alternative 1)

This alternative provides a baseline for estimating the effects of the action alternatives. Under this alternative, the lease Tract would not be offered for leasing and there would be no mining.

1.6.2 Offer The Tract For Leasing As Delineated With Special Lease Stipulations (Alternative 2)

Under this alternative the Tract would be offered for competitive leasing, as delineated, with standard terms and conditions and special stipulations to protect non-mineral resources and uses. Subsidence of perennial drainages, Boulger Dam and Reservoir, Flat Canyon Campground, State Highway SR 264 and Mainline #41 gas transmission pipeline would not be allowed.

1.6.3 Offer The Tract For Leasing As Delineated Without Special Lease Stipulations (Alternative 3)

Under this alternative the Tract would be offered for competitive leasing, as delineated by the TDT with standard lease terms and conditions. No special stipulations would be included. Longwall (full-extraction) mining

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would be allowed throughout the Tract resulting in subsidence of perennial drainages, Boulger Dam and Reservoir, and Flat Canyon Campground. It would be analyzed as the basis for comparison with other action alternatives that would include special stipulations needed to protect non-mineral resources and uses.

1.6.4 Offer The Tract With A Specific List Of Special Stipulations Needed To Protect Non-Mineral Resources (Alternative 4)

This alternative will be developed to address significant social, economic, or environmental issues or opportunities.

1.7 STATEMENT OF ISSUES AND EVALUATION CRITERIA

Hydrologic issues have been identified by the agencies and are analyzed in this technical report. Issues are listed below together with evaluation criteria.

- Subsidence could change the flow of springs and seeps, affecting spring discharge rates and groundwater contribution to streams. This could, in turn, affect agricultural, domestic, and industrial water supplies as well as ecosystems.

  Evaluation Criteria: Description of effects and duration, % probability.

- Subsidence of perennial streams and the Boulger Dam and Reservoir could intercept flowing/impounded water and divert it underground, changing the hydrologic balance. Changes in stream gradient could cause changes in stream morphology.

  Evaluation Criteria: Description of potential flow changes by quantity and duration of baseflow and % probability; description of bedload/sediment transport associated with change in stream gradient.

- Interception of ground water in underground mine workings and subsequent discharge to Eccles Creek (the existing mine water discharge point) or discharge Electric Lake could cause transbasin diversions of surface and ground water. This could affect agricultural, domestic, and industrial water supplies as well as ecosystems.

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Evaluation Criteria: Description of potential diversions, estimates of amount of water that may be encountered, amount and location of discharge to surface waters, % probability. Change in mine water discharge to each watershed, expected change in flow duration and base flows in Eccles and Upper Huntington Creeks (gpm, acre-feet, %), expected change to inflow and discharge (%, acre-feet) to/from Scofield Reservoir and Electric Lake.

- Discharge of mine water into Eccles Creek or Electric Lake could change quality of receiving waters. This could affect agricultural, domestic, and industrial water supplies as well as ecosystems.

  Evaluation Criteria: Water quality of the discharge water vs. water quality standards associated with the most restrictive of the designated beneficial uses of the receiving waters (meets/does not meet), change in receiving stream water quality (parameters with and without limits specific to beneficial use standards including TDS, RCRA metals, oil and grease, TMDL, and drinking water standards) addressed in part by estimating volume of discharge water as percentage of resulting total flows and determining whether discharge water is being diluted or receiving waters are being "contaminated", change in lake chemistry, including water column and lake bed sediments.

- Equipment and materials spilled, used, and/or abandoned in underground mine workings could change ground water quality and any connected surface water sources. This could affect agricultural, domestic, and industrial water supplies as well as ecosystems.

  Evaluation Criteria: Description of potential changes in quality by affected parameter and duration.

1.8 CONTACTS MADE

The CFC Environmental Manager, Chris Hansen, and the Skyline Mine Geologist, Mark Bunnell, provided information regarding environmental activities, data, and other relevant affairs at the Skyline Mine and the Tract.

Mr. Keith Zobell, former environmental was contacted regarding hydrologic monitoring questions.

FS and BLM personnel provided data and insights.

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1.9 DESCRIPTION OF DATA

1.9.1 Previous Investigations

As part of the Mining and Reclamation Permit (MRP), CFC (1996) described groundwater and surface water hydrology in the current permit area. Included as part of the Skyline Mine MRP, is a report prepared by EarthFax Engineering (1992) describing the probable hydrologic consequences of mining in the Skyline Mine area.

CFC, the Manti-La Sal National Forest, and the USDA Forestry Sciences Laboratory (Logan, Utah) have jointly investigated the hydrologic impacts of undermining Burnout Creek (Figure 1.2), a perennial watercourse. This study included measurements of stream morphology characteristics, stream sediment grain size compositions, longitudinal and cross sectional profiles, and stream discharge. Results of this investigation have been reported by Forestry Sciences Laboratory (1998), Mattson et al. (1995), and Sidle et al. (2000).

Mayo and Associates (1994) investigated the factors contributing to the solute composition and concentration of Skyline Mine's discharge water. Mayo and Associates (1996) characterized groundwater and surface water systems and mining-related impacts in the Skyline Mine area. Recent groundwater inflows have also been investigated by Mayo and Associates (1999a).

Two regional hydrogeologic investigations have been conducted by BYU graduate students. Peltier (1999) characterized the hydrogeology of the coal producing sequences in the Wasatch Plateau. Bills (2000) described groundwater flow systems in the Star Point Sandstone in the Wasatch Plateau.

1.9.2 Existing Data

CFC has collected baseline hydrologic information in the RFDS area since 1997. These data include:

- spring and seep location, discharge rate, and field parameter data from inventories conducted during Fall 1997 and Springtime 1998;
- high-flow and low-flow baseline water quality and discharge rate data for 24 springs and 8 creek sites beginning in Fall 1997; and
- unstable isotopic data collected from selected springs in the RFDS area in Fall 1997 and Springtime 1998.

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Baseline data are presented in Table 1.1. Table 1.2 reports average water quality for the period of record. Table 1.3 reports the unstable isotopic data for the RFDS area. Hydrologic monitoring sites in the RFDS area and in the Skyline Mine area are shown on Figure 1.2.

Hydrologic data has been collected at springs and creeks in the Skyline Mine area since 1981. These data were obtained in electronic format from the DOGM (2000) hydrologic database. Data from the Upper Huntington Creek drainage have been included in tabulations of average baseline hydrologic data for this report (Table 1.1).

The USGS (2000) collected daily streamflow discharge data for Boulger Creek from 1938 to 1949. No other continuous or quasi-continuous stream discharge data are known.

Information regarding water rights has been obtained from the Utah Division of Water Rights.

1.9.3 Field Visits

During early July 2000, perennial reaches of Boulger, Flat, Swens, and Little Swens Creeks were surveyed. The purpose of the survey was to evaluate and map stream morphology, bank stability, and stream ecology. As part of the survey, individual stream reaches were classified according to Rosgen's (1996) stream classification system. Also noted during the stream survey were the nature of the channel substrate (i.e., bedrock, gravel, or fines dominated), riparian vegetation types, and the general stability and vegetative cover of the canyon walls adjacent to the streams.

As part of this analysis, perennial stream reaches have been delineated based upon baseline stream discharge data, field observations of vegetation types, and through analysis of aerial photographs. As additional data are collected in the future, the delineation of perennial stream reaches may be refined.

1.10 METHODOLOGY

The description of hydrologic resources presented in this report is based on graphical and statistical analysis of hydrologic data collected within the study area, field observations, and hydrologic characterizations of the Skyline Mine area. Hydrologic characterizations of the Skyline Mine area are valuable for understanding surface water and groundwater conditions in the study area because the two areas have similar stratigraphy, geomorphology, climate, and vegetative cover.

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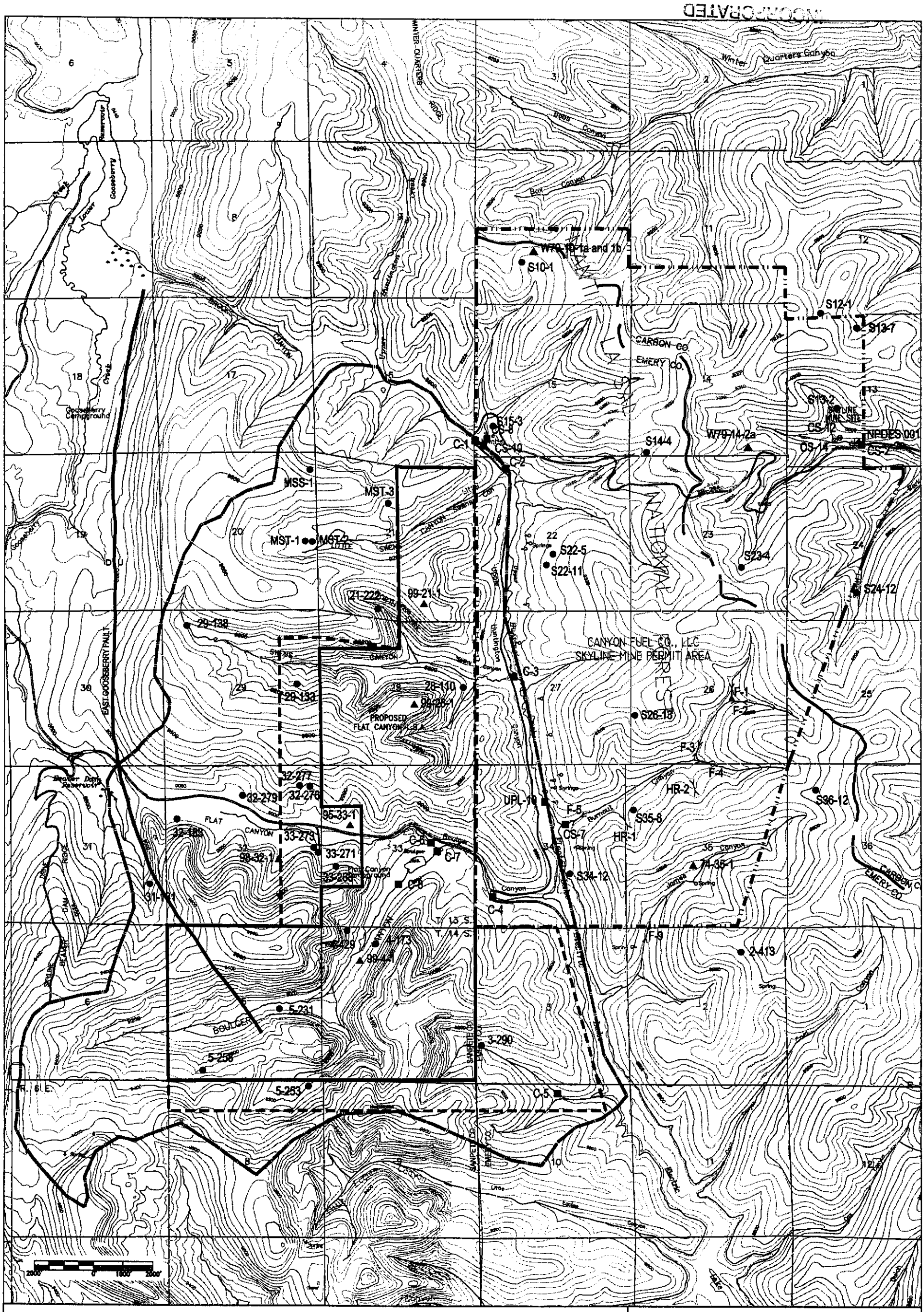

LEGEND

- FLAT CANYON COAL LEASE TRACT
- RFDS AREA
- SKYLINE MINE PERMIT AREA
- HYDROLOGY STUDY AREA
- STREAM
- SPRING
- WELL – MONITORING
- MINE DISCHARGE
- NPDES DISCHARGE POINTS
- STREAM FLOW MONITORING SITE (FLUME OR HALF-ROUND)

FIGURE 1.2
LOCATION MAP AND HYDROLOGIC MONITORING POINTS

FILE: HYDRO1-2.DWG	SCALE 1" = 3200'	NorWest
DATE: 10/13/2000		

Table 1.1 Flat Canyon Tract Baseline Hydrologic Data

Site	Date	pH	Flow gpm	Cond. µS/cm	Temp. °C	HCO3 mg/L	CO3 mg/L	T Alk. mg/L	As (D) mg/L	B (D) mg/L	Cd (D) mg/L	Ca (D) mg/L	Cl mg/L	Hard. mg/L	Fe (D) mg/L	Fe (T) mg/L	Pb (D) mg/L	Mg (D) mg/L	Mn (D) mg/L	Mn (T) mg/L	Hg (D) mg/L	NO3 mg/L	NO2 mg/L	O&G mg/L	D.O. mg/L	PO4 mg/L	K mg/L	Se mg/L	Na (D) mg/L	TDS mg/L	TSS mg/L	SO4 mg/L	Turb NTU
Springs																																
2-413	10/8/97	6.9	5	304	6.8	241	0	198	0	0.2	0	60	5	187	0	0.4	0	9	0	0	0	0.3	0			0.03	0	0	2	240		6	
2-413	7/22/98	7.8	4	270	10.7	253	<5	207	<0.01	0.1	<0.01	62	4	192	<0.1	2.1	<0.1	9	<0.1	<0.1	0.2	1.6	<0.03			<0.05	<1	<0.01	2	245		4	
2-413	10/13/98	8.4	2.1	360	4.5	247	<5	203	<0.01	0.1	<0.01	62	4	188	<0.1	2.7	<0.1	8	<0.1	<0.1	<0.2	2.4	<0.03			<0.05	<1	<0.01	2	226		4	
2-413	7/7/99	7.54	6	382	5.8	244	<5	200	<0.01	0.2	<0.01	63	4	194	<0.1	<0.1	<0.1	9	<0.1	<0.1	<0.2	2.18	<0.03			<0.05	<1	<0.01	2	224		4	
2-413	10/19/99	7.8	2.3	377	4.9	240	<5	197	<0.01	0.2	<0.01	64	4	201	<0.1	2.5	<0.1	10	<0.1	<0.1	<0.2	2.75	<0.03			<0.05	<1	<0.01	3	220		4	
3-290	10/13/97	7.1	3	336	5.2	215	0	176	0	0.1	0	53	3	173	0	1.6	0	8	0	0	0	0.4	0			0.05	0	0	4	200		5	
3-290	7/23/98	7.2	4.6	230	5.1	205	<5	168	<0.01	0.1	<0.01	52	1	163	<0.1	0.3	<0.1	8	<0.1	<0.1	<0.2	0.4	<0.03			<0.05	<1	<0.01	2	210		4	
3-290	10/13/98	7.9	2.7	250	5.5	220	<5	180	<0.01	0.2	<0.01	57	2	175	<0.1	0.3	<0.1	8	<0.1	<0.1	<0.2	0.5	<0.03			<0.05	<1	<0.01	2	209		4	
3-290	7/8/99	7.13	6	265	4.1	180	<5	147	<0.01	0.1	<0.01	44	1	139	<0.1	0.3	<0.1	7	<0.1	<0.1	<0.2	0.63	<0.03			0.06	<1	<0.01	2	171		3	
3-290	10/19/99	7.83	7.6	267	3.1	176	<5	144	<0.01	0.1	<0.01	44	1	143	<0.1	0.2	<0.1	8	<0.1	<0.1	<0.2	0.27	<0.03			<0.05	<1	<0.01	2	151		4	
4-173	10/9/97	7.2	5	322	4.6	195	0	160	0	0.2	0	49	2	159	0	0.2	0	9	0	0	0	0.9	0			0.04	0	0	2	200		5	
4-173	7/21/98	6.2	2.5	160	4.3	191	<5	156	<0.01	0.1	<0.01	48	2	157	<0.1	0.2	<0.1	9	<0.1	<0.1	<02	0.9	<0.03			0.04	<1	<0.01	1	204		6	
4-173	10/13/98	7.6	2.1	230	4.5	200	<5	164	<0.01	0.1	<0.01	49	2	159	<0.1	<0.1	<0.1	9	<0.1	<0.1	<0.2	0.9	<0.03			<0.05	<1	<0.01	2	188		5	
4-173	7/7/99	7.33	1.5	199	2.9	192	<5	158	<0.01	0.1	<0.01	45	1	149	<0.1	<0.1	<0.1	9	<0.1	<0.1	<0.2	1.17	<0.03			<0.05	<1	<0.01	3	171		5	
4-173	10/19/99	7.8	1.2	303	3.3	196	<5	161	<0.01	0.2	<0.01	49	1	164	<0.1	0.3	<0.1	10	<0.1	<0.1	<0.2	1.18	<0.03			<0.05	<1	<0.01	2	163		5	
5-231	10/13/97	7.1	3	244	3.4	143	0	117	0	0.2	0	38	2	115	0	2.4	0	5	0	0	0	1.2	0			0.09	0	0	1	140		17	
5-231	7/21/98	6.2	3	120	2.8	137	<5	112	<0.01	0.1	<0.01	38	1	107	<0.1	1.2	<0.1	3	<0.1	<0.1	<0.2	<0.1	<0.03			<0.01	<1	<0.01	1	161		5	
5-231	10/13/98	7.8	2.4	170	3.5	152	<5	124	<0.01	0.2	<0.01	40	2	116	<0.1	<0.1	<0.1	4	<0.1	<0.1	<0.2	<0.1	<0.03			<0.05	<1	<0.01	2	148		6	
5-231	7/7/99	7.16	8	205	1.9	132	<5	113	<0.01	0.1	<0.01	35	<1	100	<0.1	<0.1	<0.1	3	<0.1	<0.1	<0.2	0.34	<0.03			0.07	<1	<0.01	3	133		5	
5-231	10/19/99	7.3	1.4	231	2.7	146	<5	120	<0.01	0.2	<0.01	40	<1	125	<0.1	<0.1	<0.1	6	<0.1	<0.1	<0.2	0.44	<0.03			0.07	<1	<0.01	2	130		6	
5-238	10/9/97	7.2	6	459	4.3	267	0	219	0	0.2	0	71	10	210	0	0	0	8	0	0	0	0.6	0			0.02	0	0	4	230		0	
5-253	10/9/97	6.6	20+	151	3.8	100	0	82	0	0.1	0	24	1	68	0	0	0	2	0	0	0	0.6	0			0.02	0	0	1	70		19	
5-253	7/21/98	5.97	1.4	80	3.3	86	<5	71	<0.01	<0.1	<0.01	24	<1	68	<0.1	<0.1	<0.1	2	<0.1	<0.1	<0.2	0.5	<0.03			<0.01	<1	<0.01	<1	118		2	
5-253	10/13/98	7.8	12	100	4.1	95	<5	78	<0.01	0.2	<0.01	24	1	72	<0.1	0.1	<0.1	3	<0.1	<0.1	<0.2	0.5	<0.03			<0.05	<1	<0.01	1	91		2	
5-253	7/7/99	6.76	12	140	2.3	87	<5	71	<0.01	0.1	<0.01	23	<1	66	<0.1	<0.1	<0.1	2	<0.1	<0.1	<0.2	2.43	<0.03			<0.05	<1	<0.01	2	80		2	
5-253	10/19/99	7	18	141	3.2	90	<5	74	<0.01	0.1	<0.01	24	<1	72	<0.1	<0.1	<0.1	3	<0.1	<0.1	<0.2	0.89	<0.03			<0.05	<1	<0.01	1	79		3	
21-222	10/9/97	7.2	10	350	4.4	208	0	171	0	0.1	0	51	2	177	0	0.8	0	12	0	0	0	1	0			0.02	0	0	2	190		9	
21-222	7/21/98	7.3	18	200	6.4	190	<5	155	<0.01	<0.1	<0.01	45	1	154	<0.1	0.2	<0.1	10	<0.1	<0.1	<0.2	1	<0.03			0.01	<1	<0.01	1	200		5	
21-222	10/13/98	7.7	6	280	4.1	218	<5	178	<0.01	0.1	<0.01	52	1	179	<0.1	0.5	<0.1	12	<0.1	<0.1	<0.2	1	<0.03			<0.05	<1	<0.01	2	196		7	
21-222	7/7/99	7.41	12	260	2.4	178	<5	146	<0.01	0.2	<0.01	40	<1	137	<0.1	<0.1	<0.1	9	<0.1	<0.1	<0.2	1.21	<0.03			<0.05	<1	<0.01	1	160		5	
21-222	10/19/99	7.5	5.5	339	3.5	221	<5	181	<0.01	0.1	<0.01	55	<1	191	<0.1	0.1	<0.1	13	<0.1	<0.1	<0.2	1.51	<0.03			<0.05	<1	<0.01	2	204		7	
28-110	10/8/97	7.2	2.1	310	6.5	219	0	179	0	0.2	0	56	2	181	0	0	0	10	0	0	0	0	0			0.03	0	0	2	200		7	
28-110	7/21/98	7.4	2	250	5.9	224	<5	184	<0.01	0.1	<0.01	56	2	177	<0.1	0.2	<0.1	9	<0.1	<0.1	<0.2	0.3	<0.03			<0.01	<1	<0.01	2	226		7	
28-110	10/13/98	7.8	1.8	330	5.8	238	<5	195	<0.01	0.1	<0.01	55	2	179	<0.1	<0.1	<0.1	10	<0.1	<0.1	<0.2	0.3	<0.03			<0.05	<1	<0.01	2	209		7	
28-110	7/7/99	7.48	1.3	327	4.8	219	<5	179	<0.01	0.2	<0.01	53	1	169	<0.1	1.8	<0.1	9	<0.1	0.2	<0.2	0.52	<0.03			<0.05	<1	<0.01	2	194		7	
28-110	10/19/99	7.42	1.9	343	5.5	225	<5	185	<0.01	0.2	<0.01	58	1	190	<0.1	0.2	<0.1	11	<0.1	<0.1	<0.2	1.21	<0.03			<0.05	<1	<0.01	3	204		7	

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Table 1.1 Flat Canyon Tract Baseline Hydrologic Data (continued)

Site	Date	pH	Flow gpm	Cond. µS/cm	Temp. °C	HCO3 mg/L	CO3 mg/L	T Alk. mg/L	As (D) mg/L	B (D) mg/L	Cd (D) mg/L	Ca (D) mg/L	Cl mg/L	Hard. mg/L	Fe (D) mg/L	Fe (T) mg/L	Pb (D) mg/L	Mg (D) mg/L	Mn (D) mg/L	Mn (T) mg/L	Hg (D) mg/L	NO3 mg/L	NO2 mg/L	O&G mg/L	D.O. mg/L	PO4 mg/L	K mg/L	Se mg/L	Na (D) mg/L	TDS mg/L	TSS mg/L	SO4 mg/L	Turb NTU
29-133	10/8/97	7.2	20	278	8.5	205	0	168	0	0.3	0	60	2	170	0	0	0	5	0	0	0	0	0			0.03	0	0	2	180		6	
29-133	7/21/98	6.9	60	230	3.4	205	<5	168	<0.01	0.1	<0.01	60	1	166	<0.1	<0.1	<0.1	4	<0.1	<0.1	<0.2	0.3	<0.03			0.02	<1	<0.01	1	212		6	
29-133	10/13/98	7.8	15	270	3.4	224	<5	184	<0.01	0.1	<0.01	61	2	169	<0.1	<0.1	<0.1	4	<0.1	<0.1	<0.2	0.4	<0.03			<0.05	<1	<0.01	2	203		5	
29-133	7/8/99	7.47	60	290	2.5	205	<5	168	<0.01	0.1	<0.01	56	<1	156	<0.1	<0.1	<0.1	4	<0.1	<0.1	<0.2	1.23	<0.03			<0.05	<1	<0.01	3	181		4	
29-133	10/19/99	7.5	25	322	2.9	215	<5	176	<0.01	0.2	<0.01	60	1	179	<0.1	<0.1	<0.1	7	<0.1	<0.1	<0.2	0.91	<0.03			<0.05	<1	<0.01	2	195		6	
29-138	10/8/97	7.0	15	478	6.4	300	0	246	0	0.2	0	79	2	226	0	0.5	0	7	0	0	0	0	0			0.03	0	0	2	280		5	
29-138	7/21/98	7	30	350	4.8	299	<5	245	<0.01	0.1	<0.01	85	13	241	<0.1	<0.1	<0.1	7	<0.1	<0.1	<0.2	0.2	<0.03			<0.01	<1	<0.01	2	293		3	
29-138	10/13/98	7.6	1.7	390	5.9	307	<5	252	<0.01	0.1	<0.01	85	2	145	<0.1	<0.1	<0.1	8	<0.1	<0.1	<0.2	0.3	<0.03			<0.05	<1	<0.01	2	270		4	
29-138	7/8/99	7.34	28	420	3.9	295	<5	242	<0.01	0.2	<0.01	78	<1	224	<0.1	<0.1	<0.1	7	<0.1	<0.1	<0.2	0.65	<0.03			<0.05	<1	<0.01	3	251		3	
29-138	10/19/99	7.28	3.1	448	5.1	300	<5	246	<0.01	0.1	<0.01	84	1	259	<0.1	<0.1	<0.1	12	<0.1	<0.1	<0.2	0.71	<0.03			<0.05	<1	<0.01	3	262		5	
31-181	10/8/97	7.4		484	4.4	309	0	254	0	0.2	0	86	2	248	0	0	0	8	0	0	0	0	0			0.02	0	0	1	280		5	
32-183	10/9/97	6.9	4	230	4.2	136	0	111	0	0.2	0	32	2	100	0	0	0	5	0	0	0	0.4	0			0.02	0	0	2	140		6	
32-183	7/21/98	5.9	17	80	3.6	95	<5	78	<0.01	<0.1	<0.01	23	1	74	<0.1	<0.1	<0.1	4	<0.1	<0.1	<0.2	0.3	<0.03			<0.01	<1	<0.01	1	131		4	
32-183	10/13/98	7.5	4	160	3.8	133	<5	109	<0.01	0.2	<0.01	32	1	105	<0.1	<0.1	<0.1	6	<0.1	<0.1	<0.2	0.4	<0.03			<0.05	<1	<0.01	2	134		6	
32-183	7/7/99	7.03	20	134	2.5	95	<5	78	<0.01	0.2	<0.01	22	<1	71	<0.1	0.1	<0.1	4	<0.1	<0.1	<0.2	0.4	<0.03			<0.05	<1	<0.01	1	91		4	
32-183	10/19/99	7.88	3.2	193	1.9	140	<5	114	<0.01	0.1	<0.01	33	<1	111	<0.1	<0.1	<0.1	7	<0.1	<0.1	<0.2	0.64	<0.03			<0.05	<1	<0.01	2	117		6	
32-277	10/13/97	7.5	1.5	208	6.1	163	0	134	0	0.2	0	41	2	131	0	2	0	7	0	0.2	0	0.9	0			0.04	0	0	1	180		10	
32-277	7/21/98	6.1	2.1	150	5.2	154	<5	126	<0.01	0.1	<0.01	40	1	125	<0.1	<0.1	<0.1	6	<0.1	<0.1	<0.2	0.9	<0.03			<0.01	<1	<0.01	2	176		7	
32-277	10/13/98	7.9	0.75	240	5.9	189	<5	155	<0.01	0.2	<0.01	44	1	143	<0.1	0.9	<0.1	8	<0.1	<0.1	<0.2	0.4	<0.03			<0.05	1	<0.01	2	181		8	
32-277	7/7/99	7.33	3	228	4.2	147	<5	121	<0.01	0.2	<0.01	36	<1	115	<0.1	1.8	<0.1	6	<0.1	<0.1	<0.2	1.2	<0.03			<0.05	<1	<0.01	1	137		6	
32-277	10/19/99		Damp																														
32-279	10/9/97	7.3	2.8	360	7.2	247	0	202	0	0.1	0	57	2	204	0	0	0	15	0	0	0	1	0			0.01	0	0	2	230		11	
32-279	7/21/98	7.2	2.8	210	5.6	224	<5	184	<0.01	0.1	<0.01	52	1	187	<0.1	<0.1	<0.1	14	<0.1	<0.1	<0.2	0.7	<0.03			<0.01	<1	<0.01	1	234		5	
32-279	10/13/98	7.4	0.9	310	5.9	259	<5	212	<0.01	0.1	<0.01	57	2	212	<0.1	<0.1	<0.1	17	<0.1	<0.1	<0.2	0.9	<0.03			<0.05	<1	<0.01	2	240		10	
32-279	7/7/99	7.44	6	283	4.3	215	<5	176	<0.01	0.2	<0.01	47	<1	167	<0.1	<0.1	<0.1	12	<0.1	<0.1	<0.2	1.49	<0.03			<0.05	<1	<0.01	1	190		6	
32-279	10/19/99	7.4	1.6	387	5.4	250	<5	205	<0.01	0.2	<0.01	58	<1	215	<0.1	<0.1	<0.1	17	<0.1	<0.1	<0.2	1.08	<0.03			<0.05	<1	<0.01	3	224		10	
33-268	10/13/97	6.6	1	114	3.4	46	0	37	0	0.1	0	14	2	47	0	0	0	3	0	0	0	0.9	0			0.12	0	0	1	70		9	
33-268	10/13/98	8.1	0	60	3.9	46	<5	47	<0.01	0.1	<0.01	13	2	37	<0.1	6.9	<0.1	1	<0.1	<0.1	<0.2	0.9	<0.03			<0.05	<1	<0.01	2	73		5	
33-271	10/13/97	6.5	0.25	98	3.8	47	0	39	0	0.1	0	13	2	45	0	0	0	3	0	0	0	0.6	0			0.08	0	0	0	60		0	
33-273	10/13/97	7.3	3	295	4.1	160	0	131	0	0.2	0	48	3	145	0	0	0	6	0	0	0	0.3	0			0.13	0	0	1	140		17	
MSS-1	9/11/97	7.7		370	6	236	0	193	0	0	0	59	2	180	0	0.9	0	8	0	0	0	0.4	0			0.03	0	0	2	240		10	
Spring-Supplied Water Tanks																																	
4-429	10/20/97	7.2	2	149	6	84	0	69	0	0.1	0	22	2	71	0	0	0	4	0	0	0	0	0			0.05	0	0	2	80		0	
4-429	10/19/99	7.3	1.4	133	5.8	83	<5	68	<0.01	0.1	<0.01	21	<1	69	<0.1	<0.1	<0.1	4	<0.1	<0.1	<0.2	1.38	<0.03			0.08	<1	<0.01	1	76		3	
32-276	10/13/97	7.2	1	4.6	6.9	260	0	213	0	0.2	0	58	2	202	0	0	0	14	0	0	0	1	0			0.02	0	0	3	220		7	

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Table 1.1 Flat Canyon Tract Baseline Hydrologic Data (continued)

Site	Date	pH	Flow gpm	Cond. µS/cm	Temp. °C	HCO3 mg/L	CO3 mg/L	T Alk. mg/L	As (D) mg/L	B (D) mg/L	Cd (D) mg/L	Ca (D) mg/L	Cl mg/L	Hard. mg/L	Fe (D) mg/L	Fe (T) mg/L	Pb (D) mg/L	Mg (D) mg/L	Mn (D) mg/L	Mn (T) mg/L	Hg (D) mg/L	NO3 mg/L	NO2 mg/L	O&G mg/L	D.O. mg/L	PO4 mg/L	K mg/L	Se mg/L	Na (D) mg/L	TDS mg/L	TSS mg/L	SO4 mg/L	Turb NTU
MST-1	9/11/97	7.8		369	9.6	237	0	194	0	0	0	62	1	188	0	0	0	8	0	0	0	0.3	0			0.03	0	0	1	200		0	
MST-2	9/11/97	8.2		195.2	8	112	0	92	0	0	0	30	2	83	0	0	0	2	0	0	0	0.3	0			0.03	0	0	2	140		0	
MST-3	9/11/97	7.8		423	7.9	270	0	221	0	0	0	57	2	208	0	0	0	16	0	0	0	0.2	0			0.02	0	0	2	250		6	
MST-3	7/21/98	8.2	15	230	20																											
Creeks																																
C-1	10/20/97	7.7	0.88	239	3.2	119	0	98	0	0.1	0	34	4	101	0.2	0.7	0	4	0	0	0	0.1	0	0	4.2	0.02	0	0	4	140	0	17	
C-1	7/21/98	7.9	325	200	13.5	132	<5	108	<0.01	0.1	<0.01	38	2	107	<0.1	0.6	<0.1	3	<0.1	<0.1	<0.2	0.2	<0.01	<2		0.01	<1	<0.01	2	170	<5	10	
C-1	10/12/98	8.5	292	180	6.7	134	<5	109	<0.01	0.2	<0.01	39	4	122	0.1	0.7	<0.1	6	<0.1	<0.1	<0.2	0.2	<0.03	<2		<0.05	1	<0.01	3	151	7	18	
C-1	7/8/99	8.14	628	195	12.7	126	<5	104	<0.01	0.2	<0.01	37	2	109	0.1	0.6	<0.1	4	<0.1	<0.1	<0.2	0.34	<0.03	<2		<0.05	<1	<0.01	<1	137	<5	9	
C-1	10/19/99	7.95	140	252	-0.3	140	<5	114	<0.01	0.2	<0.01	44	3	130	<0.1	0.6	<0.1	5	<0.1	<0.1	<0.2	0.71	<0.03	<2	5.2	<0.05	<1	<0.01	3	154	8	22	
C-2	7/21/98	8.2	211	220	13.2	145	11	138	<0.01	<0.1	<0.01	46	2	135	<0.1	0.3	<0.1	5	<0.1	<0.1	<0.2	0.4	<0.03	<2		0.02	<1	<0.01	2	183	15	6	
C-2	10/12/98	8.5	16	180	3.4	181	<5	163	<0.01	0.2	<0.01	47	3	141	<0.1	0.1	<0.1	7	<0.1	<0.1	<0.2	0.4	<0.03	<2		<0.05	1	<0.01	2	176	<5	9	
C-2	7/7/99	8.4	115	244	13.4	158	<5	136	<0.01	0.1	<0.01	44	<1	130	<0.1	0.1	<0.1	5	<0.1	<0.1	<0.2	1.09	<0.03	<2		<0.05	<1	<0.01	<1	151	<5	4	
C-2	10/19/99	7.97	21	324	-0.6	216	<5	177	<0.01	0.2	<0.01	60	2	183	<0.1	<0.1	<0.1	8	<0.1	<0.1	<0.2	1	<0.03	<2	4.6	<0.05	<1	<0.01	3	214	6	11	
C-3	10/20/97	8.3	1.54	322	2.8	210	0	172	0	0.1	0	53	3	161	0	0.3	0	7	0	0	0	0.2	0	0	5.4	0.01	0	0	3	180	0	8	
C-3	7/21/98	8.5	300	230	13.1	172	12	162	<0.01	<0.1	<0.01	52	<1	150	<0.1	0.5	<0.1	5	<0.1	<0.1	<0.2	0.1	0.14	3		0.02	<1	<0.01	1	200	7	4	
C-3	10/12/98	8.3	32	220	6.7	180	<5	209	<0.01	0.4	<0.01	45	2	145	<0.1	0.2	<0.1	8	<0.1	<0.1	<0.2	0.2	<0.03	<2		<0.05	1	<0.01	2	178	<5	7	
C-3	7/7/99	8.5	300	218	13.4	182	7	161	<0.01	0.1	<0.01	52	<1	150	<0.1	0.3	<0.1	5	<0.1	<0.1	<0.2	0.4	<0.03	<2		<0.05	<1	<0.01	<1	177	9	4	
C-3	10/19/99	8.2	200	306	-0.5	215	<5	176	<0.01	0.2	<0.01	59	<1	176	<0.1	0.2	<0.1	7	<0.1	<0.1	<0.2	0.54	<0.03	<2	4.4	<0.05	<1	<0.01	2	213	5	8	
C-4	10/20/97	8.3	4.5	279	5.7	161	0	136	0	0.1	0	39	6	122	0	0.2	0	6	0	0	0	0.9	0	0	5.1	0.02	0	0	4	140	0	7	
C-4	7/21/98	8.1	1828	250	14.8	148	14	144	<0.01	<0.1	<0.01	46	3	145	<0.1	0.2	<0.1	7	<0.1	<0.1	<0.2	0.1	<0.03	<2		<0.01	<1	<0.01	2	190	<5	5	
C-4	10/12/98	8.3	964	200	10.1	158	<5	129	<0.01	0.2	<0.01	38	4	124	<0.1	0.2	<0.1	7	<0.1	<0.1	<0.2	0.1	<0.03	<2		<0.05	<1	<0.01	2	144	5	5	
C-4	7/8/99	8.51	3120	270	14.4	171	<5	146	<0.01	0.1	<0.01	46	2	140	<0.1	0.2	<0.1	6	<0.1	<0.1	<0.2	1.28	<0.03	<2		<0.05	<1	<0.01	1	168	6	5	
C-4	10/19/99	8.25	450	255	5.2	160	<5	131	<0.01	0.1	<0.01	42	3	134	<0.1	0.1	<0.1	7	<0.1	<0.1	<0.2	0.41	<0.03	<2	4.2	<0.05	<1	<0.01	3	161	<5	5	
C-5	10/20/97	7.5	0.36	244	4.6	148	0	121	0	0.1	0	36	2	110	0	0.3	0	5	0	0	0	0.9	0	0	4.8	0.03	0	0	3	140	16	6	
C-5	7/23/98	8	44.6	170	8.8	138	<5	113	<0.01	<0.1	<0.01	33	1	103	<0.1	0.1	<0.1	5	<0.1	0.1	<0.2	0.3	<0.03	<2		<0.05	<1	<0.01	2	153	<5	4	
C-5	10/13/98	7.6	20	190	5.6	170	<5	140	<0.01	<0.1	<0.01	42	2	134	<0.1	0.3	<0.1	7	<0.1	<0.1	<0.2	0.2	<0.03	<2		<0.05	<1	<0.01	3	165	<5	5	
C-5	7/8/99	8.07	70	192	9	123	<5	100	<0.01	0.1	<0.01	31	1	98	<0.1	0.1	<0.1	5	<0.1	<0.1	<0.2	0.45	<0.03	<2		<0.05	<1	<0.01	2	118	5	4	
C-5	10/19/99	7.76	23	266	1.6	161	<5	132	<0.01	0.1	<0.01	42	1	134	<0.1	0.2	<0.1	7	<0.1	<0.1	<0.2	0.61	<0.03	<2	4.2	<0.05	<1	<0.01	2	155	7	4	
C-6	10/19/99	8.23	91	268	1.2	169	<5	139	<0.01	0.2	<0.01	46	5	144	<0.1	0.2	<0.1	7	<0.1	<0.1	<0.2	0.66	<0.03	<2	5.1	<0.05	<1	<0.01	4	169	6	7	
C-7	10/19/99	8.35	530	236	4.9	172	<5	141	<0.01	0.1	<0.01	41	<1	131	<0.1	0.2	<0.1	7	<0.1	<0.1	<0.2	0.34	<0.03	<2	5.3	<0.05	<1	<0.01	2	151	9	3	
C-8	10/19/99	8.4	390	252	4.2	164	<5	134	<0.01	0.1	<0.01	44	1	135	<0.1	0.1	<0.1	6	<0.1	<0.1	<0.2	0.76	<0.03	<2	5.5	<0.05	<1	<0.01	2	156	<5	4	

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Table 1.2 Flat Canyon Area Average Water Quality Data

Site	n	pH	Cond. µS/cm	HCO3 mg/L	CO3 mg/L	T Alk. mg/L	As (D) mg/L	B (D) mg/L	Cd (D) mg/L	Ca (D) mg/L	Cl mg/L	Hard. mg/L	Fe (D) mg/L	Fe (T) mg/L	Pb (D) mg/L	Mg (D) mg/L	Mn (D) mg/L	Mn (T) mg/L	Hg (D) mg/L	NO3 mg/L	NO2 mg/L	O&G mg/L	D.O. mg/L	PO4 mg/L	K mg/L	Se mg/L	Na (D) mg/L	TDS mg/L	TSS mg/L	SO4 mg/L	Turb NTU
Springs																														
2-413	5	7.7	339	245	0	201	0	0.16	0	62.2	4.2	192	0	1.54	0	9	0	0	0.04	1.8	0			0.006	0	0	2.2	231		4.4
3-290	5	7.4	270	199	0	163	0	0.12	0	50.0	1.6	159	0	0.54	0	7.8	0	0	0	0.4	0			0.022	0	0	2.4	188		4
4-173	5	7.2	243	195	0	160	0	0.14	0	48.0	1.6	158	0	0.14	0	9.2	0	0	0	1.0	0			0.016	0	0	2	185		5.2
5-231	5	7.1	194	142	0	117	0	0.16	0	38.2	1	113	0	0.72	0	4.2	0	0	0	0.4	0			0.046	0	0	1.8	142		7.8
5-238	1	7.2	459	267	0	219	0	0.2	0	71.0	10	210	0	0	0	8	0	0	0	0.6	0			0.02	0	0	4	230		0
5-253	5	6.8	122	92	0	75	0	0.1	0	23.8	0.4	69	0	0.02	0	2.4	0	0	0	1.0	0			0.004	0	0	1	88		5.6
21-222	5	7.4	286	203	0	166	0	0.1	0	48.6	0.8	168	0	0.32	0	11.2	0	0	0	1.1	0			0.006	0	0	1.6	190		6.6
28-110	5	7.5	312	225	0	184	0	0.16	0	55.6	1.6	179	0	0.44	0	9.8	0	0.04	0	0.5	0			0.006	0	0	2.2	207		7
29-133	5	7.4	278	211	0	173	0	0.16	0	59.4	1.2	168	0	0	0	4.8	0	0	0	0.6	0			0.01	0	0	2	194		5.4
29-138	5	7.2	417	300	0	246	0	0.14	0	82.2	3.6	219	0	0.1	0	8.2	0	0	0	0.4	0			0.006	0	0	2.4	271		4
31-181	1	7.4	484	309	0	254	0	0.2	0	86.0	2	248	0	0	0	8	0	0	0	0.0	0			0.02	0	0	1	280		5
32-183	5	7.0	159	120	0	98	0	0.14	0	28.4	0.8	92	0	0.02	0	5.2	0	0	0	0.4	0			0.004	0	0	1.6	123		5.2
32-277	5	7.2	207	163	0	134	0	0.175	0	40.3	1	129	0	1.175	0	6.75	0	0.05	0	0.9	0			0.01	0.25	0	1.5	169		7.75
32-279	5	7.3	310	239	0	196	0	0.14	0	54.2	1	197	0	0	0	15	0	0	0	1.0	0			0.002	0	0	1.8	224		8.4
33-268	2	7.4	87	46	0	42	0	0.1	0	13.5	2	42	0	3.45	0	2	0	0	0	0.9	0			0.06	0	0	1.5	72		7
33-271	1	6.5	98	47	0	39	0	0.1	0	13.0	2	45	0	0	0	3	0	0	0	0.6	0			0.08	0	0	0	60		0
33-273	1	7.3	295	160	0	131	0	0.2	0	48.0	3	145	0	0	0	6	0	0	0	0.3	0			0.13	0	0	1	140		17
MSS-1	1	7.7	370	236	0	193	0	0	0	59.0	2	180	0	0.9	0	8	0	0	0	0.4	0			0.03	0	0	2	240		10
Spring-Supplied Water Tanks																														
4-429	2	7.3	141	84	0	69	0	0.1	0	21.5	1	70	0	0	0	4	0	0	0	0.7	0			0.065	0	0	1.5	78		1.5
33-276	1	7.2	5	260	0	213	0	0.2	0	58.0	2	202	0	0	0	14	0	0	0	1.0	0			0.02	0	0	3	220		7
MST-1	1	7.8	369	237	0	194	0	0	0	62.0	1	188	0	0	0	8	0	0	0	0.3	0			0.03	0	0	1	200		0
MST-2	1	8.2	195	112	0	92	0	0	0	30.0	2	83	0	0	0	2	0	0	0	0.3	0			0.03	0	0	2	140		0
MST-3	2	8.0	327	270	0	221	0	0	0	57.0	2	208	0	0	0	16	0	0	0	0.2	0			0.02	0	0	2	250		6
Creeks																														
C-1	5	8.0	213	130	0	107	0	0.16	0	38.4	3	114	0.08	0.64	0	4.4	0	0	0	0.3	0	0	4.7	0.006	0.2	0	2.4	150	3	15.2
C-2	5	8.3	242	175	3	154	0	0.125	0	49.3	1.75	147	0	0.125	0	6.25	0	0	0	0.7	0	0	4.6	0.005	0.25	0	1.75	181	5.25	7.5
C-3	5	8.4	259	192	4	176	0	0.16	0	52.2	1	156	0	0.3	0	6.4	0	0	0	0.3	0.028	0.6	4.9	0.006	0.2	0	1.6	190	4.2	6.2
C-4	5	8.3	251	160	3	137	0	0.1	0	42.2	3.6	133	0	0.18	0	6.6	0	0	0	0.6	0	0	4.65	0.004	0	0	2.4	161	2.2	5.4
C-5	5	7.8	212	148	0	121	0	0.06	0	36.8	1.4	116	0	0.2	0	5.8	0	0.02	0	0.4	0	0	4.5	0.006	0	0	2.4	146	5.6	4.6
C-6	1	8.2	268	169	0	139	0	0.2	0	46.0	5	144	0	0.2	0	7	0	0	0	0.7	0	0	5.1	0	0	0	4	169	6	7
C-7	1	8.4	236	172	0	141	0	0.1	0	41.0	0	131	0	0.2	0	7	0	0	0	0.3	0	0	5.3	0	0	0	2	151	9	3
C-8	1	8.4	252	164	0	134	0	0.1	0	44.0	1	135	0	0.1	0	6	0	0	0	0.8	0	0	5.5	0	0	0	2	156	0	4
CS-10	70	7.5	237	133	1	112	0	0.0282	0	38.6	3.13	120	0.17	0.74	0.0006	4.58	0.016	0.032		0.1	0	0.2111	8.5	0.01	0.51	0	4.25	139	4.88	17.27	10.92
CS-7	62	7.9	375	226	2	193	0	0.0373	0	61.1	3.42	198	0.01	0.16	0.0007	11.49	0	0.0077		0.5	0	0.3	7.9	0.01	0.44	0	4.95	208	7.07	13.31	3.78
CS-8	71	7.6	300	188	3	162	0	0.0405	0	50.0	8.02	181	0.02	0.37	0	8.51	0	0.0128		0.3		0.15	8.5	0.02	0.45	0	6.21	191	6.84	16.80	6.59
UPL-10	69	7.9	295	183	2	154	0	0.0282	0	53.0	6.30	158	0.05	0.36	0.0003	9.91	0.002	0.0183		0.1	0	3.225	8.4	0.02	0.54	0	3.67	182	4.78	14.28	8.71

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Table 1.3 Unstable Isotopic Compositions

Site	Date	^{14}C (pmC)	^{3}H (TU)
2-413	10/8/97	95.71	14.9
2-413	7/22/98	91.68	15
7-242	10/9/97	73.52	10.5
8-253	10/9/97	84.39	29.7
8-253	7/21/98	79.06	30
29-138	10/8/97	88.58	12.9
29-138	7/21/98	90.96	14
32-279	10/9/97	68.62	14.0
32-279	7/21/98	71.67	15
MST-3	9/11/97		13.1
MST-3	7/21/98	71.35	10.3

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2.0 SURFACE WATER

All surface waters in the study area, with a single exception, drain into Upper Huntington Creek, which is a tributary of the San Rafael River. The San Rafael River flows into the Green River approximately 80 miles southeast of the study area. A small portion (< 6%) of the study area is in the Upper Gooseberry Creek drainage. Upper Gooseberry Creek flows into Fish Creek above the Scofield Reservoir on the Price River. The Price River flows into the Green River approximately 60 miles southeast of the study area. The region of investigation for this analysis is an area of approximately 12.7 square miles.

Perennial stream reaches have been identified in Boulger, Flat, Swens, Little Swens, and Cunningham Canyons. Upper Huntington Creek, which defines the northern and eastern boundaries of the study area, is also a perennial stream. In order to simplify the characterization and analysis of surface water systems in the study area, the surface water drainages have been divided into sub-basins. These sub-basins are shown on Figure 2.1. Also shown on Figure 2.1 are the reaches of the individual streams that have been classified as perennial for this analysis.

Several drainages that have not previously been classified as perennial were determined to possibly be perennial as a part of this study. These reaches are indicated on Figure 1.2. Determinations of possibly perennial were based on field observations of streamflow and vegetation types and through inspection of aerial photographs.

The specific characteristics of each sub-basin in the study area are described below.

2.1 FLAT CANYON SUB-BASIN

The Flat Canyon sub-basin includes an area of 1.76 square miles, which is approximately 13.8% of the study area. The gradient in Flat Canyon, approximately 0.93%, is the lowest of any of the sub-basins in the RFDS area. Flat Canyon is so called because of the broad, flat-bottomed valley floor through which Flat Canyon Creek flows. The broad riparian corridor in Flat Canyon is up to 1,000 feet wide. Flat Canyon Creek, in its upper reaches, where it meanders through the broad alluvial valley, is a Rosgen (1996) E5 type stream. This reach is dominated by run features. The channel substrate underlying the creek in Flat Canyon consists primarily of thick, saturated

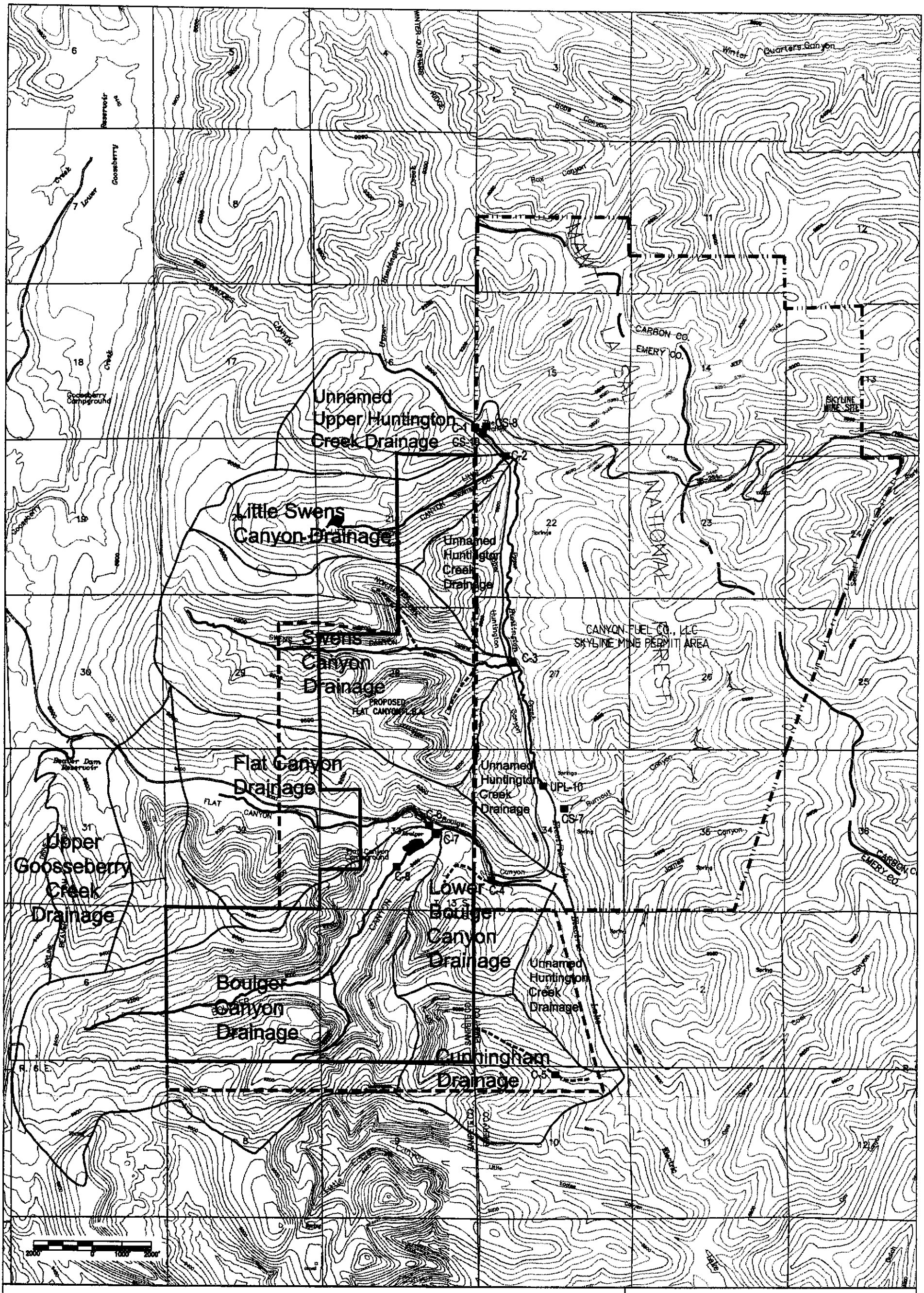

FIGURE 2.1

WATERSHED BOUNDARIES AND PERENNIAL STREAM REACHES

FILE: HYDRO1-2.DWG	SCALE 1" = 3200'	NorWest
DATE: 8/30/2000		

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glacio-lacustrine sediments. The sediments along the margin of the canyon are approximately 80 feet thick, consisting mostly of sand.

In the lower reaches of Flat Canyon Creek, the channel is more deeply incised and the gradient is much steeper (3%). This reach is a Rosgen (1996) B3 type, which consists primarily of riffles with less than 5% pools. The banks in this reach are well vegetated and stable. The substrate in lower Flat Canyon Creek consists primarily of cobbles and boulders. It appears well armored and stable.

The north-facing canyon walls in Flat Canyon are vegetated with dense conifer forests. Portions of these conifer stands have recently undergone logging. The south facing canyon walls are vegetated primarily with scattered, dense stands of quaking aspen.

Flat Canyon creek is separated from the underlying coal seams by 1,000 to 1,800 feet of overburden.

Discharge and water quality at Flat Canyon Creek have were monitored in October 1999 and July 2000 (Table 1.1). The October discharge measurement was 91 gpm while the July measurement was 215 gpm. The water in Flat Canyon Creek during October was of the calcium-bicarbonate chemical type with a TDS concentration of 169 mg/l.

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2.2 BOULGER CANYON SUB-BASIN

The Boulger Canyon sub-basin, which occupies approximately 3.92 square miles, or 30.8% of the study area, is the largest of the sub-basins. Included in this area are the upper drainage (above Boulger Reservoir), which is approximately 3.22 square miles in area, and the lower drainage, which occupies an area of approximately 0.70 square miles (Figure 2.1). Boulger Creek is a third order stream that flows to the northeast where it joins Flat Canyon Creek and then flows into Electric Lake. The gradients on Boulger Creek are steeper than are those of the adjacent Flat Canyon creek. The gradient on the main reach below the confluence of the two forks and above the reservoir averages 1.7%.

The reach of Boulger Creek extending from below the upper forks to Electric Lake contains reaches that are Rosgen (1996) types C3 and B3. The stream in this area, which meanders tightly, is 8-10 feet wide and is dominated by riffles and runs with a channel depth ranging from 6 inches to 2 feet. The substrate in areas of low gradient appears stable and well armored. It is composed of

approximately 50% cobbles, 15% gravel, and 35% sand/silt. The stream banks in this portion of the drainage are well vegetated and appear stable. The drainage in this area supports a moderately wide strip of riparian vegetation up to approximately 350 feet wide along the valley bottom. Much of the riparian vegetation along the margins of the valley bottom appears to be supported by inflows of alluvial and colluvial groundwater (Section 3.3) from the lower canyon walls. This groundwater also provides recharge to the creek.

Approximately 1,800 feet above the confluence with Electric Lake, a small unnamed tributary to Boulger Creek enters from the south side of the canyon (Figure 2.1). This stream appears to be perennial based on the narrow corridor of riparian vegetation that exists along and adjacent to the stream channel. Discharge and field parameters were measured in this drainage by Mayo and Associates during October 1999 and July 2000. On both occasions water was flowing in the stream. The stream was flowing at 32.8 gpm during July 2000. Inspection of aerial photographs suggests that the stream has the appearance of being perennial for a distance of approximately one-half mile above the confluence with Boulger Creek.

The right (north) fork of Boulger Creek has an average gradient of approximately 4.3%. There is a narrow strip of riparian vegetation associated with this reach of the creak. For the first approximately 1,800 feet of this drainage, the stream is a Rosgen (1996) type B3 stream. The channel substrate in this reach is made up of material ranging from 2-inch gravels to 12-inch and greater cobble/boulder material. Runs and riffles make up approximately 60% of the stream, with approximately 40% pools. Raleigh Consultants (1992) noted sedimentation in the right fork of Boulger Creek that was attributed potentially to inactive beaver dams. The next approximately 2,000 feet of the right fork consists of a meandering Rosgen (1996) C3 type stream. The channel in this reach is approximately 10 feet wide and 6 inches deep. The stream contains approximately 80% riffles and runs and 20% pools and the substrate in this reach is made up of approximately 50% cobbles, 20% sand and silt, and 35% gravel. The stream banks appear stable. The final approximately 5,000 feet in the uppermost portion of the drainage is a steep, Rosgen (1996) type A2 or B2 stream with riffles comprising about 90% and pools 10%. The width of the stream in this reach is approximately 5 feet, with depths ranging from 4 inches in the riffles to 1 foot in the pools. The substrate in this reach is dominated by large cobbles, boulders, and bedrock.

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The left (south) fork of Boulger Creek is a steep drainage with an average gradient of approximately 7.5%. The channel in the lower reach of the left fork is a Rosgen (1996) type A3 channel, while the upper, headwaters area is a Rosgen (1996) C5 or E5 type. The channel substrate in the lower part of the south fork is comprised of large cobbles and boulders. In the headwaters region of the left fork a large meadow is present in a glacial cirque. The stream channel substrate in this region consists primarily of fine-grained alluvial material. Much of the baseflow of the left fork of Boulger Creek originates from springs along the margins of this meadow.

The depth of cover separating Boulger Creek from the coal seams that may be mined ranges from 700 feet in the lower reaches near Electric Lake to more than 2,200 feet in the headwaters areas.

Discharge and water quality in Boulger Creek have been monitored at C-4, C-7, and C-8 (Table 1.1; Figure 2.2). Discharge has been measured at C-4 (below the confluence with Flat Canyon creek) since 1997 (Table 1.1). The maximum recorded discharge, 3,120 gpm, occurred during July 1999. A minimum flow of 450 gpm was measured during October 1999. Streamwater in Boulger Creek is of the calcium-bicarbonate chemical type. TDS concentrations at C-4 have remained relatively constant during the baseline monitoring period, ranging from 140 to 190 mg/l.

Boulger Reservoir is a man-made water body with a surface area of approximately 4.52 acres with a storage capacity of 45 acre-feet. The reservoir is a popular recreation site for fishing, swimming, and rafting. Boulger Reservoir is separated from the underlying coal seams by approximately 1,200 feet of cover. Comparison of discharge and water quality measurements from C-8 (immediately above the reservoir) and C-7 (immediately below the reservoir) suggests that the water quality of Boulger Creek is not degraded as a result of being in the reservoir (Table 1.1).

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2.3 SWENS CANYON SUB-BASIN

The Swens Canyon sub-basin occupies 2.33 square miles or 18.4% of the study area. The stream drains westward into Upper Huntington Creek, with a gradient averaging 3.1%. Swens Canyon Creek is a third order stream that meanders tightly, particularly in the lower reaches of the drainage. The stream banks and adjacent areas are heavily vegetated with riparian vegetation and appear to be relatively stable. Swens Canyon Creek appears to be a gaining stream over its entire reach. It is apparent that much of the

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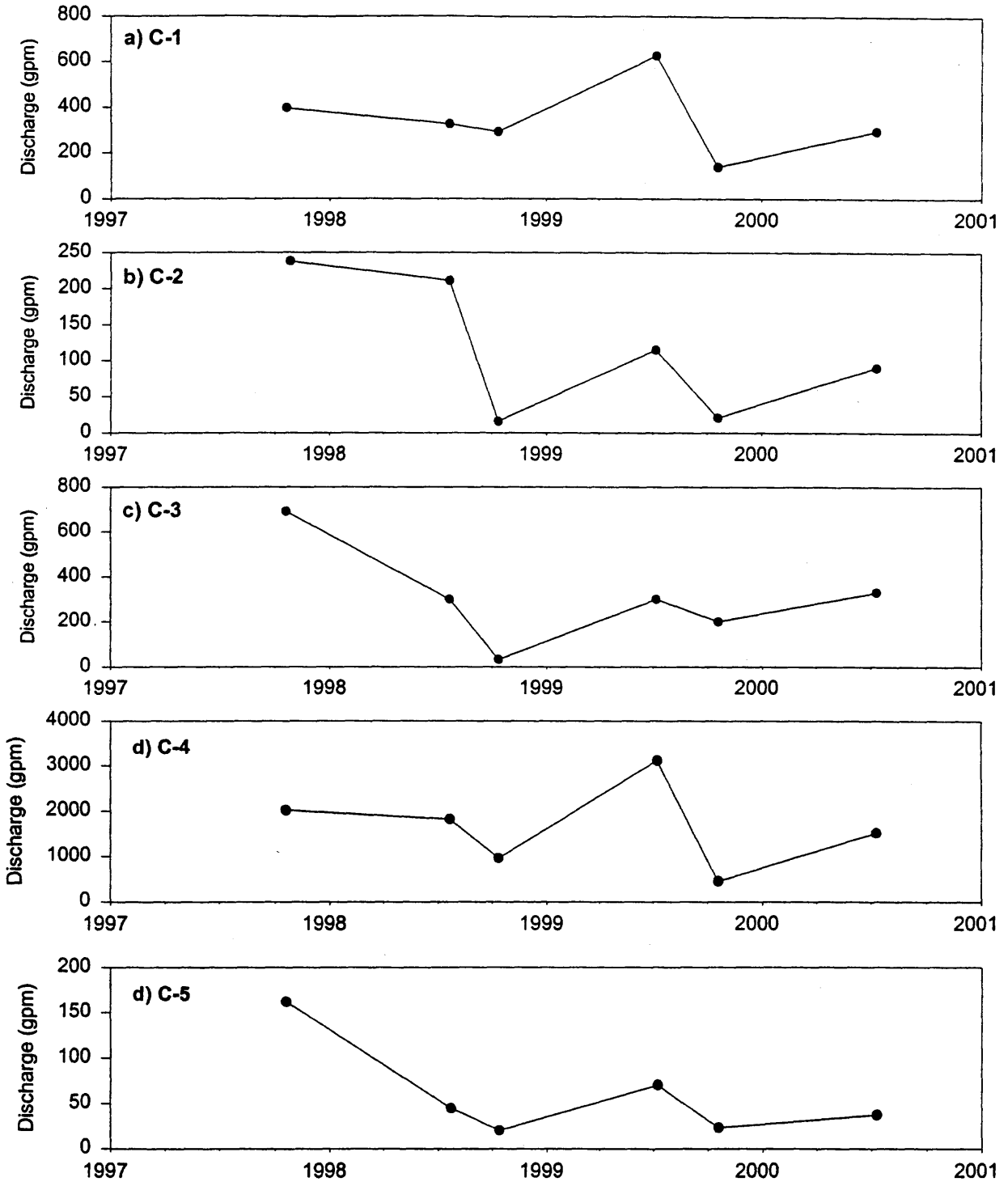
Figure 2.2
Plots of Discharge Versus Time for Creeks in the Study Area



riparian vegetation along the margins of the valley bottom in Swens Canyon Creek is not sustained by direct recharge from the stream. Rather, these vegetated areas appear to be sustained by discharge from shallow, colluvial groundwater systems discharging low on the canyon walls.

Along the length of Swens Canyon Creek, there is evidence that the hillsides have periodically encroached into the stream channel resulting in impounding of the stream. These encroachments appear to be the result of mass movement (i.e. hillside slumping) of the Blackhawk Formation sediments that compose the hillsides. The fact that the lowermost canyon slopes are commonly wet from groundwater seepage may be a contributing factor to the frequency of mass movements. It is evident that the drainage has also been periodically dammed in many locations by beavers. As a result of these occurrences, thick sections of sediment have been emplaced by stream deposition in the backwater areas that existed when the stream was dammed, while adjacent areas have not experienced that degree of sedimentation. These conditions, in conjunction with changes in geologic formation or geologic structure underlying the stream bottom, have resulted in a somewhat stair-stepped topography in the canyon bottom.

The lower 5,000 feet of the stream channel in Swens Canyon is comprised of fine-grained material interspersed with gravel, cobbles, and occasional boulders. This reach is a Rosgen (1996) C3 type. This reach of the stream consists of approximately 80-90% runs and riffles, and 10-20% pools. In this reach the stream meanders tightly and the stream channel is well incised in its channel. Groundwater inflows are apparent along much of the extent of this reach of the drainage. These commonly consist of small springs or seepage fronts that emerge near the transition between the valley bottom and the canyon walls.

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A small tributary to Swens Canyon Creek enters from the south approximately 1,000 feet above the confluence with Upper Huntington Creek. This tributary, which extends for approximately one-half mile, appears to possibly be perennial based upon the well-established riparian vegetation along the stream banks. No baseline discharge data are available for this tributary. However, it was noted by Mayo and Associates that there was appreciable flow in the drainage during October 1999 and again in July 2000.

The North Fork enters Swens Canyon Creek approximately 3,000 feet above the confluence with Upper Huntington Creek (Figure 2.1). This

tributary is approximately 2,500 feet in length and is very steep. The average channel gradient is approximately 13.8%. This stream reach appears to possibly be perennial based upon the well-established riparian vegetation along the stream banks. No baseline discharge data are available for this tributary. However, it was noted by Mayo and Associates that there was appreciable flow in the drainage during October 1999 and again in July 2000. Much of the baseflow discharge to the stream originates from a series of springs discharging from colluvial groundwater systems in its headwaters region.

In the reach of Swens Canyon Creek extending from the confluence with the North Fork and upstream for approximately 3,500 feet the stream channel narrows considerably. In this reach, the channel substrate is dominated by cobbles and boulders. In some locations, bedrock outcrops are visible in the channel bottom. The channel, which meanders slightly in this reach, contains many active and inactive beaver dams.

In the headwaters reaches of Swens Canyon Creek, the valley broadens into a region of wide meadows and grasslands. The stream channel in this reach is a narrow Rosgen (1996) A2 type. Much of the baseflow to Swens Canyon Creek appears to originate in this region. Many springs and groundwater seepages enter the stream channel from the lower hillsides adjacent to the stream.

Swens Canyon Creek is separated from the underlying coal seams by 800 feet of cover at the confluence with Upper Huntington Creek to approximately 2,400 feet of cover in its headwaters area.

Swens Canyon Creek has been monitored by CFC at C-3 since 1997 (Table 1.1; Figure 2.2). Discharge has ranged from 30 gpm during October 1998 to 300 gpm during both July 1998 and July 1999. The water in Swens Canyon Creek is of the calcium-bicarbonate chemical type. Baseline TDS concentrations in Swens Canyon Creek have ranged from 177 to 213 mg/l.

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2.4 LITTLE SWENS SUB-BASIN

Little Swens Creek flows northeast from highland areas toward its confluence with Upper Huntington Creek. The basin encompasses an area of 0.98 square miles, which is 7.7% of the study area. The drainage is steep, with a stream gradient of approximately 5.9%. Little Swens

Canyon Creek is a tightly meandering stream with relatively stable, well-vegetated stream banks. Like the adjacent Swens Canyon drainage, there is evidence of a long history of encroachment of hillsides by mass movement onto valley floor. There is also evidence of a long history of beaver dam construction in the drainage. These conditions have resulted in accumulation of sediment in some areas with considerably less sediment in other areas resulting in a somewhat stair-stepped topography on along the canyon bottom.

The stream channel in the lower approximately one-half mile of the drainage is a Rosgen (1996) B3 type. The valley bottom in this reach is approximately 30 feet wide. The channel substrate in this reach consists of gravel, cobbles and boulders. Generally, the stream channel in Little Swens Canyon is more dominated by rocky material and appears to have less fine-grained material in the substrate than does the adjacent Swens Canyon. The stream banks in this reach are heavily vegetated and appear stable.

In the next 1,000 feet of the drainage, the channel narrows slightly and the channel substrate is dominated by boulders and bedrock. This reach appears to have been impacted considerably by beaver dams and encroachment of the lower canyon walls into the drainage by mass movement. This reach of the drainage is a Rosgen (1996) A2 type.

A small reservoir has been constructed in the upper reaches of this drainage. This pond has a surface area of approximately 3.15 acres and is used for recreation purposes by a privately owned girl's camp that surrounds the pond.

The Little Swens Canyon drainage is separated from the underlying coal seams by 1,100 feet of overburden near the confluence of the stream with Upper Huntington Creek. In the headwaters regions, the overburden is approximately 2,100 feet. The overburden between the reservoir at the girls camp and the coal seams ranges from about 1,900 to 2,000 feet

Baseline water quality and discharge measurements have been performed on Little Swens Canyon Creek at C-2 from 1998 to 2000 (Table 1.1; Figure 2.2). Discharge at C-2 has varied from 16 gpm during October 1998 to 211 gpm during July 1998. Discharge in the creek is of the calcium-bicarbonate chemical type. TDS concentrations have ranged from 151 to 214 mg/l.

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2.5 CUNNINGHAM CANYON SUB-BASIN

The Cunningham Canyon sub-basin, with an area of 0.92 square miles, is a relatively small drainage located near the southern margin of the RFDS area. Cunningham Canyon Creek is an easterly flowing drainage that flows into Electric Lake in the Upper Huntington Creek drainage. The drainage has a steep gradient, averaging 8.0%. The channel substrate in the upper reaches is dominated by cobbles and boulders. In the lower reaches, near the confluence with Electric Lake, the channel substrate is dominated by fine-grained materials including silt and soil. The stream is entrenched below the land surface by approximately 1 to 2 feet in the lower reaches of the drainage. Riparian vegetation along the stream banks and adjacent flood plain in the lower reaches of the canyon is dense and the stream channel appears stable.

Water quality and discharge have been monitored by CFC at C-5 (Table 1.1; Figure 2.2) from 1997 to 2000. Discharge at C-5 has varied from 20 gpm in October 1998 to 162 gpm during October 1997. TDS concentrations at C-5 have varied from 118 to 165 mg/l.

The Cunningham Canyon drainage is separated from the coal seams by 700 feet in its lower reaches near Electric Lake to approximately 1,900 feet in the headwaters area.

2.6 UPPER HUNTINGTON CREEK SUB-BASIN

Within the RFDS area there are a series of unnamed small, east and northeast facing ephemeral drainages to Upper Huntington Creek (Figure 2.1). These drainages, which all exist on the steep, western slope of Upper Huntington Creek, range in size from 0.4 to 0.78 square miles. Gradients of the unnamed Upper Huntington Creek sub-basins are all very steep, ranging from approximately 17% to 32%.

None of these drainages are known to support perennial streams. One intermittent stream located immediately south of Little Swens Canyon (Figure 2.1) was monitored for discharge and field parameters by CFC in July 2000. Discharge from this stream was meager at 7 gpm.

The overburden separating the unnamed Upper Huntington Creek drainages from the coal seams ranges in thickness from approximately 700 feet near Electric Lake to more than 2,000 feet in the highland areas above Huntington Canyon

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2.7 UPPER GOOSEBERRY CREEK SUB-BASIN

A small portion (0.73 square miles, less than 6%) of the RFDS area drains to the Upper Gooseberry Creek drainage. Gooseberry Creek drains to the north-northwest and flows into Fish Creek which discharges to Scofield Reservoir. While Upper Gooseberry Creek near the RFDS area may possibly be perennial, the stream itself is beyond the RFDS area and would not be undermined. For this reason, this stream has not been investigated.

All of the Upper Gooseberry Creek sub-basin within the RFDS area is separated from the coal seams by more than 1,500 feet of cover.

2.8 SUMMARY OF GENERAL CHARACTERISTICS OF SURFACE-WATER SYSTEM IN THE RFDS AREA

Both ephemeral and perennial drainages in the RFDS area are supported in the late winter and spring months by the annual snowmelt event. Because of the large quantities of snowmelt water relative to the amount of groundwater that can be stored and discharged from shallow groundwater systems in the area, perennial streams commonly have high-flow discharge rates that exceed their low-flow baseflow discharge rates by many times.

Perennial streams in the RFDS area exist where 1) there is adequate groundwater recharge and subsurface storage capacity in the drainage basins to sustain discharge from shallow groundwater systems throughout the year and 2) there is a low-permeability confining layer beneath the stream that prevents downward percolation of water in the stream channel (i.e. the stream is perched).

Field observations by the principal authors during 1997-2000 suggest that the perennial streams in the RFDS area are generally gaining streams. Observations of stream conditions in the springtime and late fall suggest that this condition persists throughout the year. The streams gain flow from discharge from shallow groundwater systems in the form of springs, seeps, and discharge directly to the stream channel. These are common along the lengths of the perennial drainages (Sections 3.3.1 and 3.3.2).

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3.0 GROUNDWATER

3.1 CLIMATIC SETTING

The study area is located in an area of subalpine climate. Precipitation is measured at the Skyline Mine surface facility in Eccles Canyon west of the study area. Between 1985 and 1995 the average annual (calendar year) precipitation ranged from 17.2 to 29.4 and averaged 23.9 inches (Mayo and Associates, 1996). Monthly average temperatures at the mine range from 8.0 to 74.4 °F (CFC, 1999).

The National Resource Conservation Service (NRCS) maintains two high elevation precipitation stations east of the study area. During the period 1961-1990 (NRCS, 1995) the average annual precipitation was 29 inches at the Mammoth-Cottonwood Station (elevation 8,800 feet), and 33 inches at the Red Pine Ridge Station (elevation 9,200).

A tool that has been useful in understanding the relationship between surface water and groundwater discharge in the Wasatch Plateau is the Palmer Hydrologic Drought Index (PHDI; NCDC, 2000; Karl, 1986; Guttman, 1991). The PHDI is a monthly value generated by the National Climatic Data Center (NCDC) that indicates the severity of a wet or dry spell and is useful for identifying longer-term climatic trends. The PHDI is computed from climatic and hydrologic parameters such as temperature, precipitation, evapotranspiration, soil water recharge, soil water loss, and runoff. Because the PHDI takes into account parameters that affect the balance between moisture supply and moisture demand, the index is a useful tool for evaluating the long-term relationship between climate and groundwater recharge and discharge.

Figure 3.1 is a plot of the PHDI for Utah Division 5. On this graph, positive numbers indicate wet conditions and negative numbers indicate dry conditions. The magnitude of the value indicates the severity of the wet or dry spell.

This graph indicates several extremely wet years during the early and mid 1980s, followed by an extended drought from 1987 to 1993. Since 1993 the region has enjoyed mostly wet conditions. However, beginning in January 2000 the region entered a drought period. It is important to note

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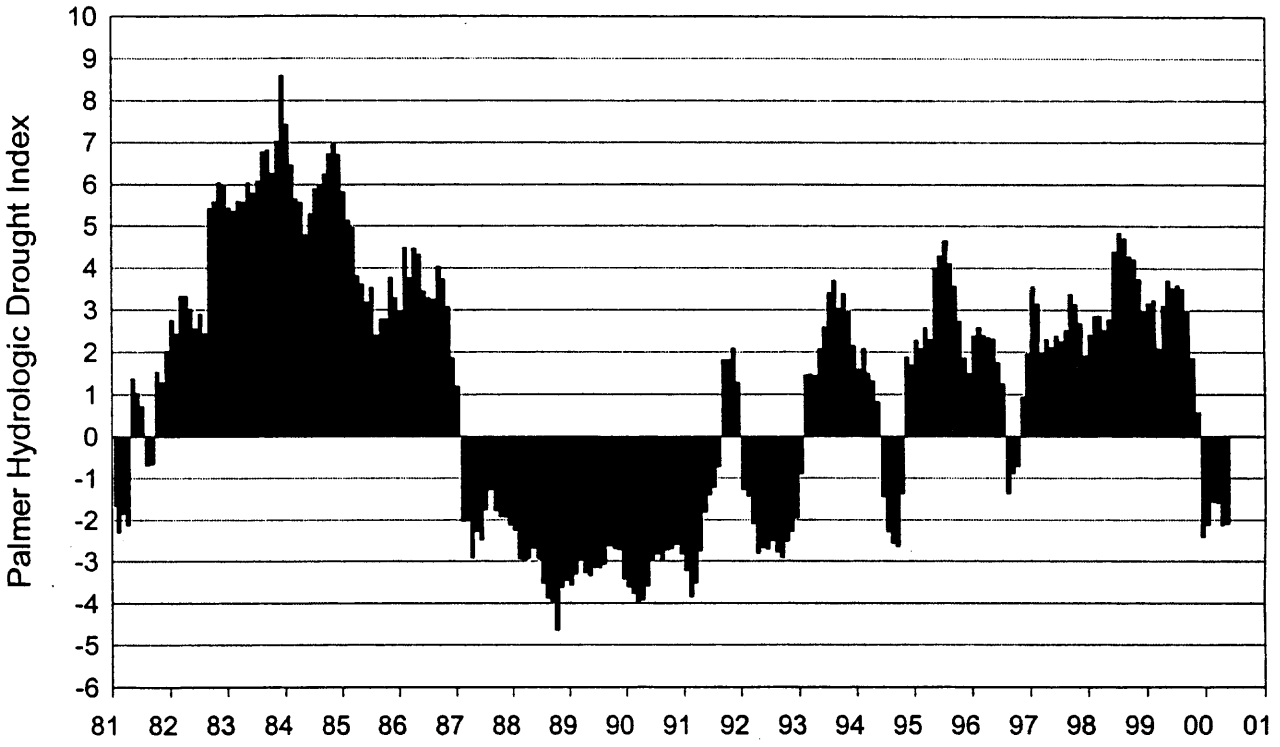
that most baseline hydrologic collection by CFC occurred during the moderately wet period in the late 1990s.

Figure 3.1
Palmer Hydrologic Drought Index (PHDI) for Utah Division 5



3.2 GEOLOGIC SETTING

The geology of the study area has been described in the Geology, Mining, Subsidence, and Seismicity Technical Report (NorWest, 2000) prepared concurrently with this report. Five bedrock formations of concern to coal mining activities in the study area are, in descending stratigraphic order, the North Horn Formation, Price River Formation, Castlegate Sandstone, Blackhawk Formation, and Star Point Sandstone. These rocks are composed of interbedded shale, mudstone, siltstone, and sandstone layers that are laterally discontinuous. The heterogeneity and lateral discontinuity of these rocks have a profound effect on water-bearing and water-transmitting properties. Water is not generally transmitted great

distances either vertically or horizontally, and the many low-permeability units create perched conditions. Unconsolidated alluvial, colluvial, and glacial deposits as well as soil are important hydrogeologic units in the study area.

3.3 GROUNDWATER SYSTEMS

The concept of a groundwater system refers to 1) where and how recharge occurs, 2) how flow is accommodated, and 3) where and how groundwater discharges. Five types of groundwater systems are defined in the study area. These systems are:

- colluvial/shallow bedrock groundwater systems;
- Boulger Canyon alluvial groundwater system;
- Flat Canyon groundwater system;
- deep Blackhawk Formation groundwater systems; and
- Star Point Sandstone groundwater systems

These five systems have been defined because stratigraphic, lithologic, and structural constraints cause each type of system to operate differently. The concept of a groundwater system is limited to how a system operates and does not indicate or preclude hydraulic communication among the systems of a given type. This concept is useful in places such as the study area where groundwater commonly occurs in localized areas, and where aquifers, in which there is hydraulic communication over a greater expanse, do not exist.

Each type of groundwater system is described below.

3.3.1 Colluvial/Shallow Bedrock Groundwater Systems

Colluvial/shallow bedrock groundwater systems occur throughout the study area. This type of system occurs in the thick soil mantle, slope wash colluvial deposits, and shallow bedrock in which the porosity has been enhanced by weathering or fracturing. Groundwater in shallow alluvial deposits is also included in this type of system. The abundance of relatively low-permeability horizons in bedrock formations of the study area hinders appreciable migration of groundwater to deeper stratigraphic horizons and creates perched groundwater conditions in colluvium and shallow bedrock.

The depth of colluvial/shallow bedrock groundwater systems has not been investigated but is estimated to range from several tens of feet to perhaps over 100 feet in some areas. Data from the Skyline Mine area indicate that a water monitoring well (W79-14-2a; Section 4.1.2) completed in the Blackhawk Formation at a depth of 102 to 122 feet exhibits seasonal water level responses (Mayo and Associates, 1996), which, as discussed below, is a characteristic of colluvial/shallow bedrock groundwater systems. However, two wells completed at depths ranging from 150 to 200 feet do not show seasonal water level responses.

Colluvial/shallow bedrock groundwater systems are directly recharged by snowmelt, especially snow that melts relatively slowly in dense wooded stands common in the study area. Groundwater flow follows topographic gradient and flow path lengths are relatively short: no more than from the top of a ridge to a canyon bottom.

Groundwater in colluvial/shallow bedrock systems supports discharge from nearly all of the springs in the study area. Discharge from this type of system directly to creeks is indicated by gaining stream flows (Section 2.8). Groundwater discharge from this type of system occurs primarily along the bottoms of canyons. Some groundwater discharge occurs higher on a number of hillsides because of 1) local breaks in slope such as in the head of Swens Canyon where glacial moraine materials create a less steep slope, or 2) groundwater in permeable shallow bedrock, such as a sandstone paleochannel or the Castlegate Sandstone, encounters a less permeable bedrock horizon.

Storage in colluvial/shallow bedrock groundwater systems is small because of the generally limited depth of colluvial and shallow bedrock materials, short flow path lengths, relatively large hydraulic conductivities, and relatively steep hydraulic gradients. Consequently, this type of groundwater system is acutely sensitive to seasonal and climatic variations in precipitation.

Seasonal and climatic dependence is demonstrated by variations in spring discharge rates. Discharge plots for springs in the study area are shown on Figure 3.2. These plots indicate that discharge from springs is typically greatest in the springtime and declines appreciably during the summer and fall months. Discharge from several springs monitored in the RFDS area (4-173 and 28-110) does not appear to vary greatly. This is attributed to the fact that the peak discharge likely occurred earlier in the season than when springtime discharge measurements were made at the spring

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Figure 3.2
Plots of Discharge Versus Time for Springs in the Study Area

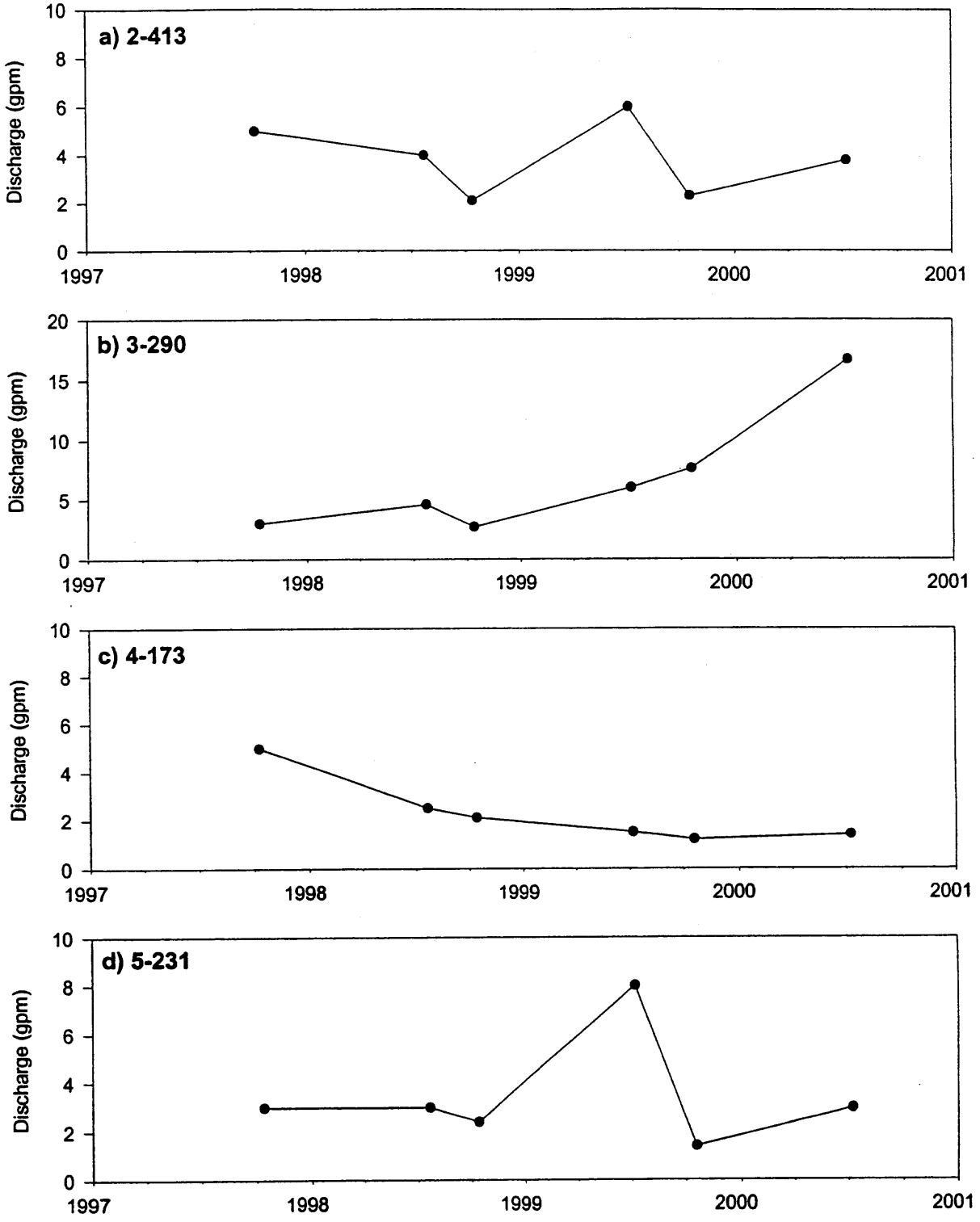

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Figure 3.2 (continued)
Plots of Discharge Versus Time for Springs in the Study Area

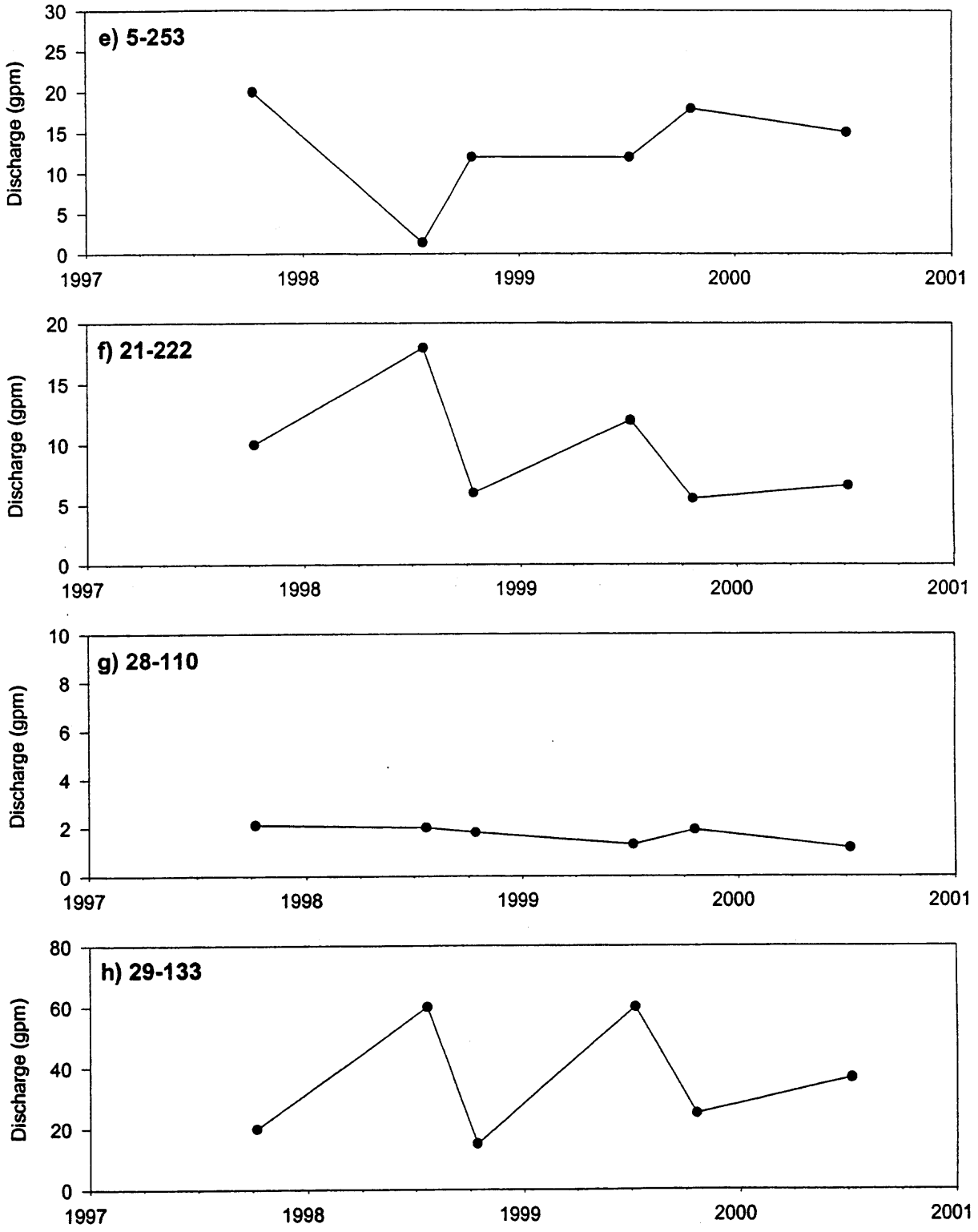

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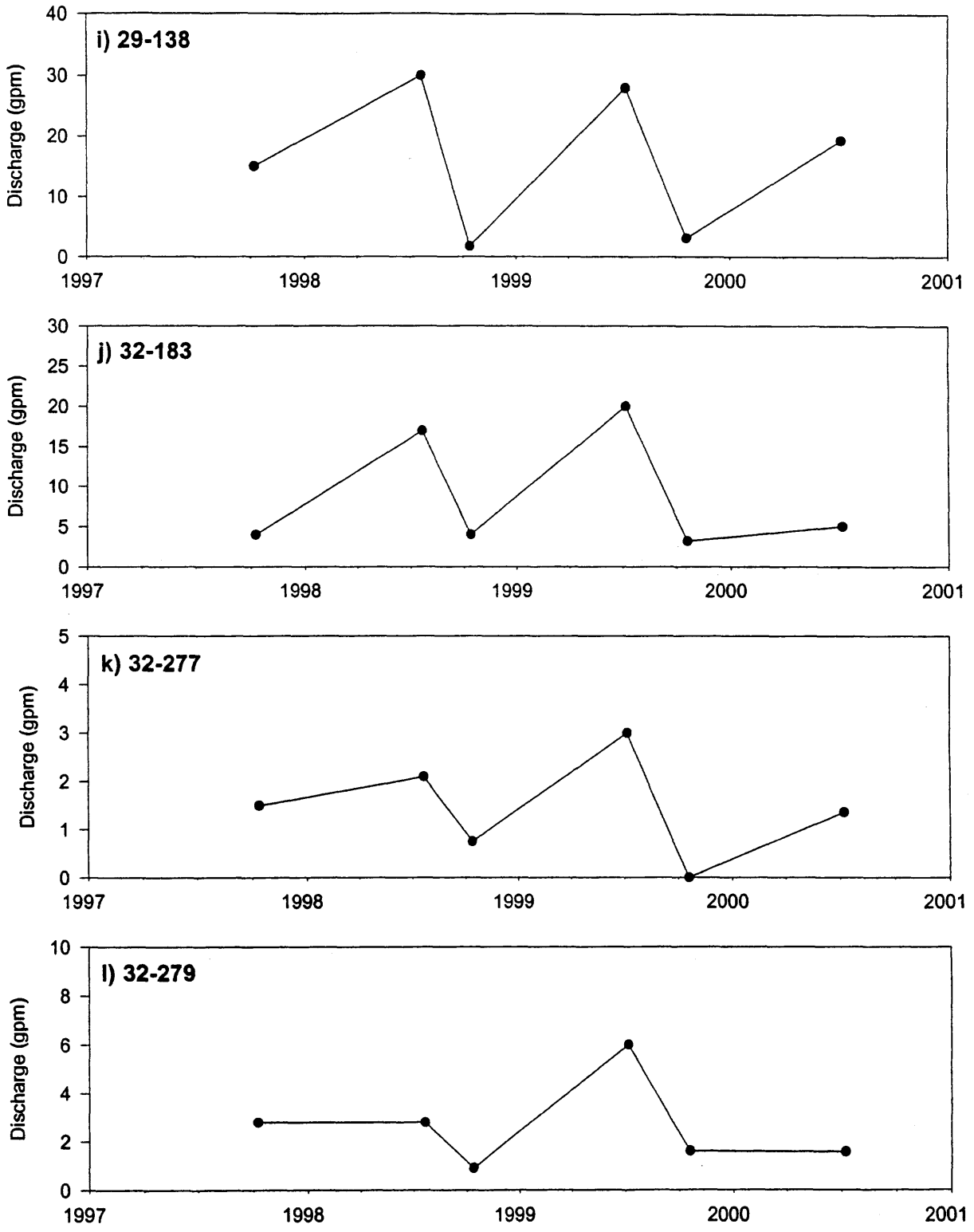
Figure 3.2 (continued)
Plots of Discharge Versus Time for Springs in the Study Area



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location. Discharge from two other springs (3-290 and 5-253) does not follow the pattern of high springtime flows and low fall discharge. The discharge history of these springs is problematic and is perhaps attributable to how discharge measurements were made. A number of springs had lower discharges in springtime 2000 than during previous springtimes. This reflects sensitivity to climatic changes such as the drought conditions that the region has seen since the beginning of 2000 (Figure 3.1).

Spring and seep survey data also indicate the dependence on seasonal recharge. The total discharge from all of the springs located in the Fall 1997 survey was 1,073 gpm. During the following spring the total discharge was 2,895 gpm, a nearly three-fold increase. Although these data were not collected during the same snowmelt recharge cycle, both surveys were conducted during similar moderately wet climatic conditions (Figure 3.1).

That springs respond quickly to season and climate suggests that time between recharge and discharge in colluvial/shallow bedrock groundwater systems is less than one year. As noted, much of the baseline discharge data for these springs have been collected during a lengthy wet-spell (Table 1.1; Figure 3.1). Because of the heavy climatic dependence of these springs, it is expected that many of the springs in the study area would have much lower discharge rates or dry up in drought years.

CFC has collected unstable isotopic data from five springs in the study area. These data are shown in Table 1.3. All spring waters sampled in the study area contain anthropogenic carbon and abundant tritium. These compositions indicate that recharge to the groundwater systems supporting discharge from these springs occurred within the last approximately 50 years.

3.3.2 Boulger Canyon Alluvial Groundwater System

Alluvial sediments deposited in the relatively broad-bottomed portions of Boulger Canyon support groundwater. A distinct groundwater system has been designated for these sediments because of the comparatively larger depth and extent of these deposits relative to other, much steeper canyons in the RFDS area. The depth of this alluvium is known in one location where exploration drilling (drill hole 99-4-1; Figure 1.2) encountered 40 feet of alluvial sediments.

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Groundwater in these sediments is recharged largely by interflow from colluvial/shallow bedrock groundwater systems. During dry times Boulger Creek could also provide recharge. However, visual observations of the creek by the principal authors suggest that Boulger Creek is a gaining creek year round, suggesting that discharge from the alluvial groundwater system is predominately to the creek.

3.3.3 Flat Canyon Groundwater System

Exploration drilling by CFC in the Flat Canyon area has revealed that there is a thick deposit of unconsolidated sediments in the canyon. Drill logs for wells 98-32-1 and 95-33-1 were provided for review by CFC. The locations of these two wells are indicated on Figure 1.2. The drill logs indicate that these sediments are 70 to 90 feet thick on the margins of Flat Canyon. These sediments consist primarily of sand and gravel with only minor fine-grained materials, and thus are expected to be fairly permeable. Inspection of geomorphology in air photos and in the field suggests that these alluvial sediments were likely deposited in an impoundment created by the glacier(s) in Boulger Canyon and the lateral and terminal moraine deposits of the Boulger Canyon glacier(s). Glacial moraine deposits typically have low hydraulic permeabilities (Freeze and Cherry, 1979). Consequently, water is largely impounded in glacio-lacustrine sediments behind the lateral and end moraines at the confluence of Flat and Boulger Canyons. Because of the thickness, lateral extent, and saturation of these deposits, the Flat Canyon glacio-lacustrine sediments have been designated as a distinct groundwater system.

Discharge from colluvial/shallow bedrock groundwater systems provides the bulk of recharge to the Flat Canyon glacio-lacustrine sediments.

A large portion of the discharge from the Flat Canyon groundwater system occurs directly to Flat Canyon Creek. Flat Canyon Creek does not appear to be fed by perennial creeks in any of the side drainages. Rather, Flat Canyon Creek appears to gradually gain flow throughout the year along its course due to discharge from springs and groundwater discharge directly to the creek.

A limited amount of water is also transmitted from the Flat Canyon alluvium through the glacial moraine deposits. This water supports several small wet areas on the hillslope west of Boulger Reservoir. Groundwater discharge from the Flat Canyon alluvium at this location has not been quantified or monitored. It is believed that this groundwater discharge is largely consumed by transpiration due to the presence of

phreatophytes on the hillside. It is expected that because of the large storage volume in the Flat Canyon glacio-lacustrine sediments, that discharge in this location will be essentially constant even during drier climatic cycles.

Discharge from the Flat Canyon groundwater system may also occur via underflow through the basal moraine deposits or bedrock underlying the moraine deposits. Any underflow would recharge the glacial/alluvial sediments below the moraine and would ultimately discharge to either Boulger Creek below the reservoir or via groundwater inflow to Electric Lake. A small amount of water may also migrate downward and recharge underlying bedrock. However, there is no evidence suggesting that discharge occurs via these two mechanisms.

3.3.4 Deep Blackhawk Formation Groundwater Systems

Deep Blackhawk Formation groundwater systems occur at depths greater than about 150 feet where the Blackhawk Formation is the exposed at the surface. Deep Blackhawk Formation groundwater systems have been encountered in underground workings at the Skyline Mine and have been encountered by exploration drilling in the RFDS area (CFC, 1999). These systems occur in paleochannel sandstones that are encased in three dimensions by relatively impermeable mudstones and shales. Consequently there is poor hydraulic communication between sandstones both laterally and vertically. Groundwater in these sandstone channels may occur under unconfined or confined conditions. Confined conditions in the underlying Star Point Sandstone attest to the ability of fine-grained units in the Blackhawk Formation to act as substantial barriers to vertical groundwater flow.

Experience at Skyline Mine and other mines in the Wasatch Plateau indicates that coal seams themselves do not bear water; in fact, water must be used to control dust as coal is cut by mining equipment.

The mechanics of deep Blackhawk Formation groundwater systems are not as well understood as the mechanics of near surface groundwater systems described above. Mining encounters groundwater in these systems at a point along the flow path but recharge and discharge locations are not obvious. Groundwater flow direction is estimated to be in the direction of bedrock dip (westward).

Mayo and Associates (1996) have determined that groundwaters in the deep Blackhawk Formation groundwater system have radiocarbon ages of

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2,500 to 18,500 years and contain essentially no tritium. This suggests that these systems are hydraulically isolated from the surface and that groundwater flow is likely slow. The stable isotopic ratios (δ^2H and $\delta^{18}O$) of mine inflow waters are considerably more negative than shallow subsurface groundwaters, suggesting that these waters likely recharged anciently under cooler paleoclimatic conditions such as glacial periods.

Mayo and Associates (1996) cite several other lines of evidence to demonstrate that deep Blackhawk Formation groundwater systems are discontinuous and hydraulically isolated from the surface (and recharge sources). First, a 192-foot long upward well was constructed in the roof of the lower O'Connor A seam (Hydrometrics, 1987). The well only encountered groundwater at the 40-, 100-, and 120-foot intervals while all other horizons were dry. Similarly, a 128-foot deep well in the floor of the mine intercepted water at 98 feet. From the bottom of the mine to 98 feet the rock was not saturated. Second, discharge rates decline rapidly in newly exposed roof drips. Lastly, the total mine water discharge rate does not increase appreciably with time despite the fact that the total mined area continues to increase. The rate of discharge from mine workings is dependent on the rate of coal production and the timing of the encounter of large water-bearing features.

Faults do not appear to be important in the conveyance of water in the deep Blackhawk Formation groundwater system. CFC (1999) reports that of the 44 individual fault planes that were encountered prior to 1999, groundwater inflows occurred from only five. Four of the five appeared to intersect water-saturated sandstone paleochannels in the mine roof. Indeed, experience has indicated that most water-bearing faults encountered in Wasatch Plateau coal mines are associated with sandstone paleochannels. Thus, it is not anticipated that in the RFDS area, large volumes of water would be encountered in faults in the Blackhawk Formation. Recently large groundwater inflows have occurred in the Skyline Mine from two faults; however, these appear to be connected with the Star Point Sandstone and are discussed in the subsequent section.

Potential discharge locations of deep Blackhawk Formation groundwater systems have not been identified. Due to the estimated low flow rates in this type of groundwater system, groundwater discharge at the natural discharge location is not expected to be large in magnitude and thus would be difficult to identify. Nevertheless, because of the westward dip of rocks in the Skyline Mine area and the RFDS area, groundwater in deep perched bedrock groundwater systems likely discharges, under natural

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conditions, west of the RFDS area. However, there are no outcrops of the lower Blackhawk Formation west of the RFDS area. Instead, the lower Blackhawk Formation is dissected by the East Gooseberry Fault west of the study area (Figure 1.2), which likely hinders further westward groundwater flow.

Experience in the Wasatch Plateau suggests that large-offset faults are generally barriers to lateral flow across a fault due to the presence of low-permeability fault gouge. If the East Gooseberry Fault is indeed a barrier to horizontal flow across the fault, then groundwater flow is diverted at the fault in some direction along the fault. The damage zone (rock on either side of the fault that is fractured due to faulting) likely facilitates and supports groundwater flow along the fault. It is doubtful that groundwater from deep Blackhawk Formation groundwater systems discharges to the surface along the surface trace of the East Gooseberry Fault because deep perched systems would not have sufficient hydraulic head.

3.3.5 Star Point Sandstone Groundwater Systems

As described in the Geology, Mining, Subsidence, and Seismicity Technical Report (NorWest, 2000), the Star Point Sandstone is comprised of two sandstone members, the upper Storrs Tongue and the lower Panther Tongue. Mining at the Skyline Mine has encountered water associated with both the Storrs Tongue and the Panther Tongue. Because of the westward dip of the bedrock, there is a high probability that mining in the RFDS area would encounter additional inflows of water from the Star Point Sandstone.

As indicated on Figure 3.3, the Storrs Tongue interfingers with the Blackhawk Formation and divides the Lower O'Connnor A Seam from the Flat Canyon Seam. However, in the western portion of the RFDS area, the Storrs Tongue pinches out and the Lower O'Connor A Seam and the Flat Canyon Seam merge. The Panther Tongue underlies the Flat Canyon Seam, the lower-most seam where mining would occur in the RFDS area. The Flat Canyon Seam is separated from the Panther Sandstone by 15-30 feet of shale, mudstone, and thin coals.

The tongues of the Star Point Sandstone are laterally more extensive than individual sandstones in the overlying Blackhawk Formation. It is anticipated that over larger areas, such as the Skyline Mine and RFDS areas, each tongue operates as a single groundwater system. However, it is not believed that the Star Point Sandstone is a regional aquifer in the sense that there is hydraulic continuity throughout the Wasatch Plateau.

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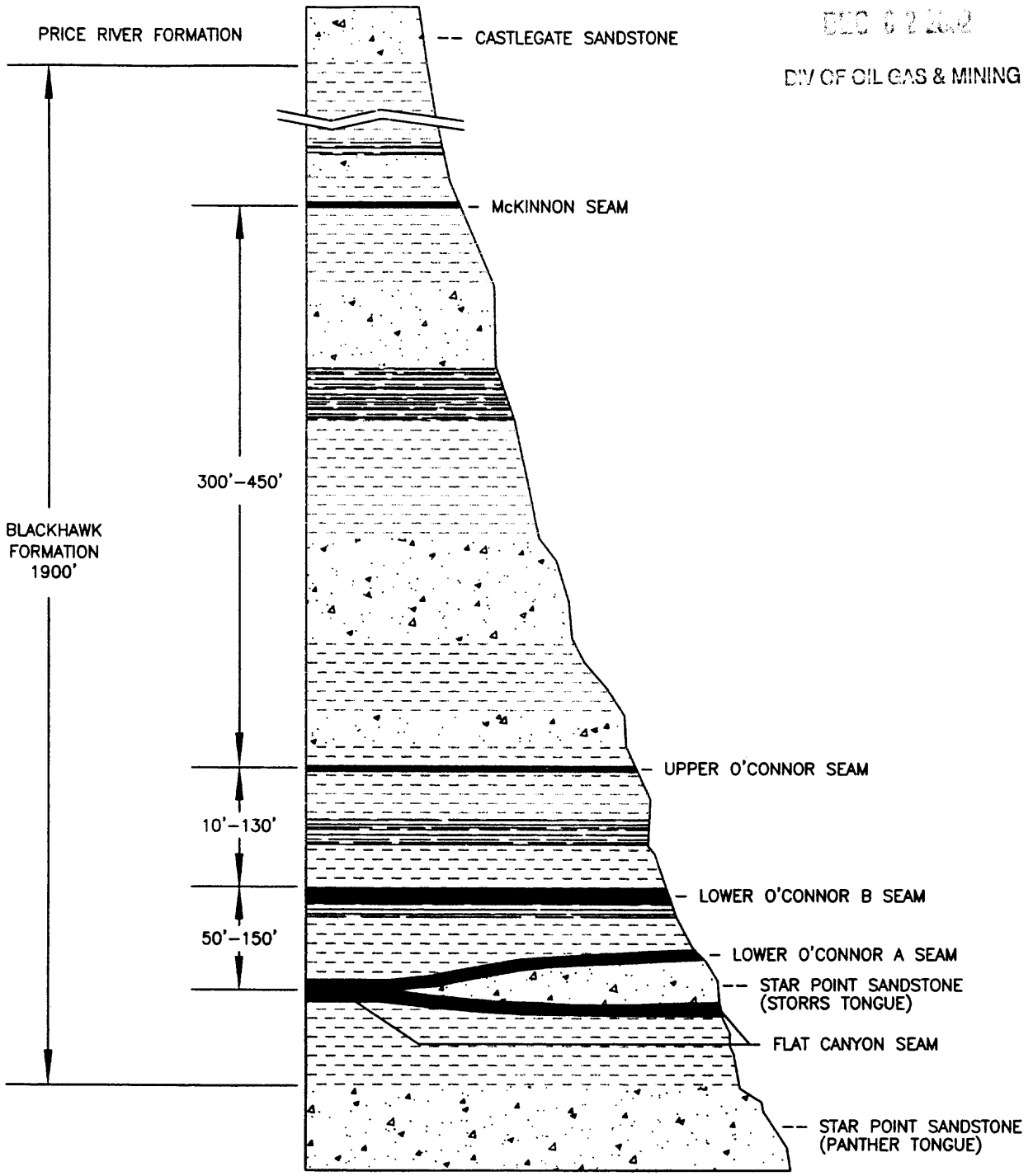

FIGURE 3.3
GENERALIZED COLUMNAR SECTION
FLAT CANYON TRACT AREA

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The mechanics of Star Point Sandstone groundwater systems are not well understood. The Star Point Sandstone is exposed in Pleasant Valley east of the Skyline Mine area and the RFDS area and dips westward. This suggests that recharge occurs in the east and groundwater flow is to the west. Because of the inclination of the formation and the low hydraulic conductivity of Blackhawk Formation shales and mudstones overlying the Star Point Sandstone members, confined groundwater conditions are created. Similar confined conditions in the Star Point Sandstone have been observed at other coal mines in the Wasatch Plateau such as the Trail Mountain Mine.

Large groundwater inflows from faults have recently been encountered in the workings of the Flat Canyon Seam in the Skyline Mine. CFC (1999) reports that a fault with approximately 8 feet of offset was encountered during development of the 14L Headgate. The fault initially produced water from the roof and the floor at a rate of 1,200 to 1,400 gpm. Discharge from the roof ceased after a short period but water still continues to be produced from the floor. A second fault along the same trend was encountered in the 16L Headgate. This fault produces 300 gpm of water from the floor. It is believed that this water discharges from the Panther Tongue of the Star Point Sandstone.

Mayo and Associates (1999a) report that groundwater inflows to the Skyline Mine from the Star Point Sandstone have radiocarbon ages greater than 13,000 years and contain no tritium. This suggests that groundwater flow through the Star Point Sandstone is slow and that there is limited hydraulic communication with the surface. Slow flow rates in the Star Point Sandstone are substantiated by the measurement of hydraulic conductivity in other areas of the Wasatch Plateau. At the Crandall Canyon Mine in the Huntington Canyon area, slug testing revealed a hydraulic conductivity of 4.8×10^{-8} to 7.4×10^{-8} ft/s (Mayo and Associates, 1997a). Bills (2000) determined a hydraulic conductivity of 4.06×10^{-6} ft/s for the Star Point Sandstone in the Straight Canyon area. This latter result is higher than the first because of fracturing associated with the Straight Canyon syncline.

The Star Point Sandstone does not crop out west of Pleasant Valley. Consequently discharge locations for Star Point Sandstone groundwater systems have not been observed in the study area. The Storrs Tongue pinches out in the RFDS area indicating that groundwater is not transmitted westward beyond the study area by the Storrs Tongue. As noted in the previous section, the East Gooseberry Fault truncates the

bedrock formations west of the RFDS area. This fault is presumed to be a barrier to lateral flow across the fault. This being the case, groundwater flow is diverted at the fault in some direction along the fault and flow is accommodated in the damage zone of the fault. Potentiometric levels in two monitoring wells, 99-21-1, and 99-28-1 (Figure 1.2), in the RFDS area that are completed in the first sandstone below the Flat Canyon Seam (which may be the Panther Tongue) suggest that the hydraulic head in the Panther Sandstone (elevation 8,419 and 8,515 feet, respectively) may not be sufficient to cause water to discharge at the surface trace of the East Gooseberry Fault (elevation greater than about 8,800 feet, directly west of the RFDS area).

Although it is not known where groundwater in the Star Point Sandstone in the study area ultimately discharges, it can be surmised with some certainty that groundwater in the Star Point Sandstone in the study area is not in hydraulic communication with the Star Point Sandstone groundwater systems that supply water to the large-discharge culinary water supply springs in Huntington Canyon (Big Bear, Little Bear, or Birch springs). First, as noted above, the radiocarbon ages of Panther tongue water encountered at the Skyline Mine is 13,000 years. The radiocarbon ages of groundwater that discharges from the Huntington Canyon Springs (Mayo and Associates, 1997b; Mayo and Associates, 1999b) are summarized below.

Spring	Radiocarbon Age
Birch Spring	1,700-3,600 years
Big Bear Spring	Mixed; 3,500-4,500 years
Little Bear Spring	Modern

Because water in the Star Point Sandstone in the study area has appreciably greater radiocarbon ages, it is unlikely that this water is hydraulically connected to the Star Point Sandstone in the Huntington Canyon. Second, the East Gooseberry Fault, the surmised location for groundwater discharge from the Panther Tongue, is not structurally connected to fault systems in the vicinity of the Huntington Canyon springs. The Huntington Canyon springs discharge in and near the Pleasant Valley Graben and associated faults whereas the Gooseberry Graben is on the same trend as the Joes Valley Graben.

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3.4 WATER QUALITY

Groundwater discharge from springs in the study area is low-TDS, calcium-bicarbonate water. For springs that have been monitored for baseline water quality, the average TDS ranges from 60 to 280 mg/l and the average TDS is 180 mg/l (Table 1.2). Concentrations of sodium ion and sulfate are very low (Table 1.2). Groundwater quality meets State of Utah drinking water standards for the parameters that have been analyzed. Untreated spring water is used throughout the study area at cabins and campgrounds for culinary uses. Additionally, groundwater discharge supports baseflow to creeks that have been classified as "High Quality Waters – Category 1" by the State of Utah (UAC R317-2).

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4.0 HYDROLOGIC IMPACTS FROM COAL MINING AT THE SKYLINE MINE

Analysis of the hydrologic consequences of mining in the Skyline Mine area is useful for predicting the probable hydrologic consequences of mining in the RFDS area. In the Skyline Mine area several springs, stretches of perennial creeks, and several water monitoring wells have been undermined and subsided. Appreciable groundwater has been intercepted in mine workings. This section describes the impacts of mining in the Skyline Mine area to water quantity, water quality, and stream morphology.

4.1 WATER QUANTITY

4.1.1 Spring Discharge Rates

Two springs, S10-1 and S23-4, which are part of the CFC hydrologic monitoring program have been undermined and subsided at the Skyline Mine. The locations of these springs are shown on Figure 1.2. Three additional springs, S13-2, S13-7, S14-4, have been undermined by full support mining and have not been subsided. Nine other springs are monitored by CFC that are located above unmined portions of the Skyline permit area or just outside the permit area. Discharge data for all of these springs are plotted on Figure 4.1 and discussed below. Data are included in tabular format in Appendix D.

Spring S10-1 is located near the top of a ridge and does not have a large potential recharge area. Consequently the spring is extremely sensitive to climatic variations (Figure 4.1a). Large flows in the springtime are attributed to snowmelt in the immediate vicinity of the spring. The magnitude of the peak is dictated by the depth of snowpack and springtime temperatures.

Spring S10-1 was undermined in September 1993 as indicated on Figure 4.1a. The spring is located above the end of a longwall panel where the strata have been placed in permanent tension. The overburden in this area is over 1,800 feet. Since the spring was undermined, the annual high-flow peaks have been muted relative to annual peaks prior to undermining. However, the baseflow (late season) discharge has not been appreciably impacted. The period since 1993 when the spring was undermined has been moderately wet as indicted by the PHDI (Figure 3.1). Baseflow discharge should be more sensitive to mining-related effects because baseflow is derived from storage in the groundwater system. Thus, because baseflow discharge has not been appreciably impacted, it

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Figure 4.1
Plots of Discharge Versus Time for Springs in the Skyline Mine area

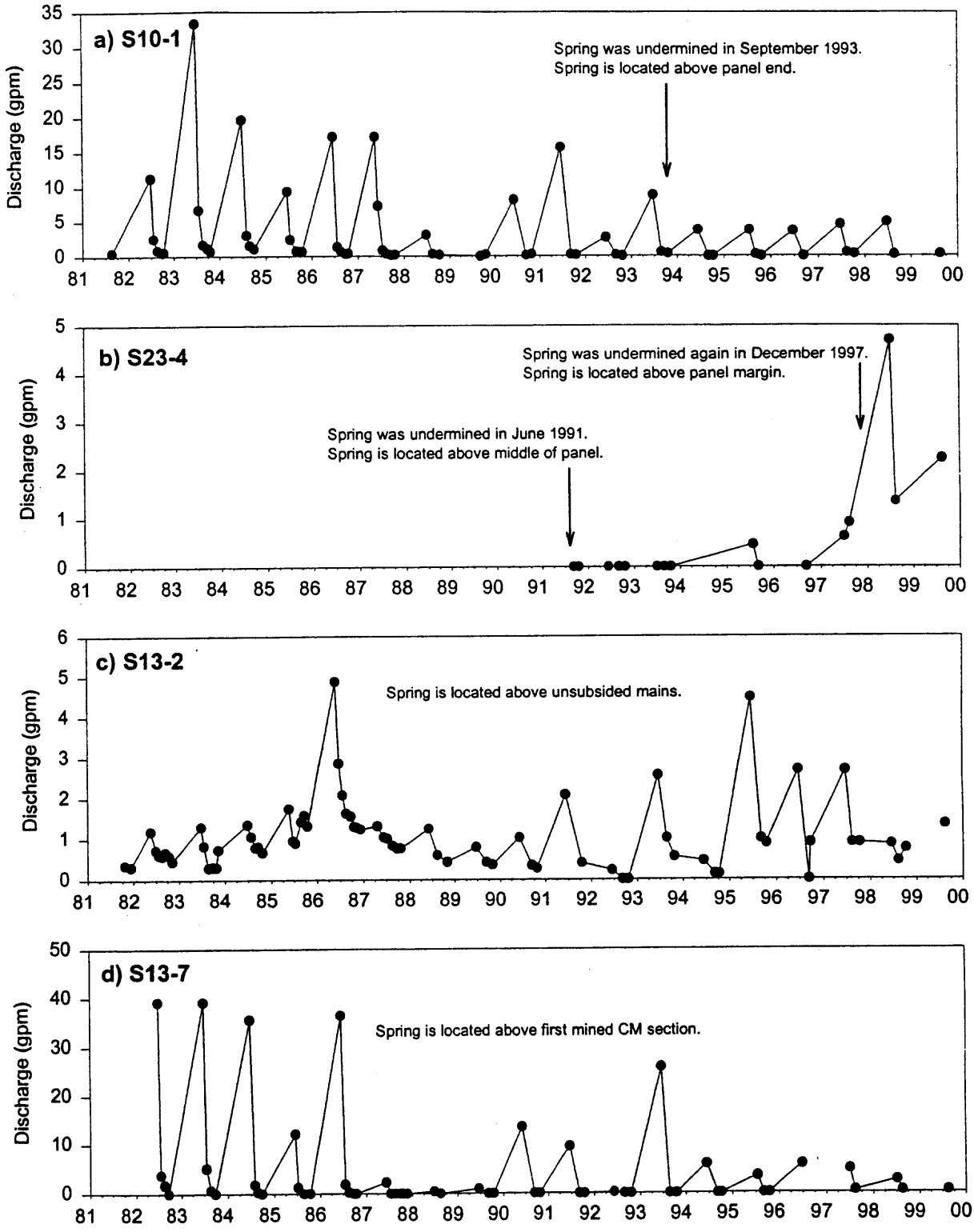

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Figure 4.1 (continued)
Plots of Discharge Versus Time for Springs in the Skyline Mine area

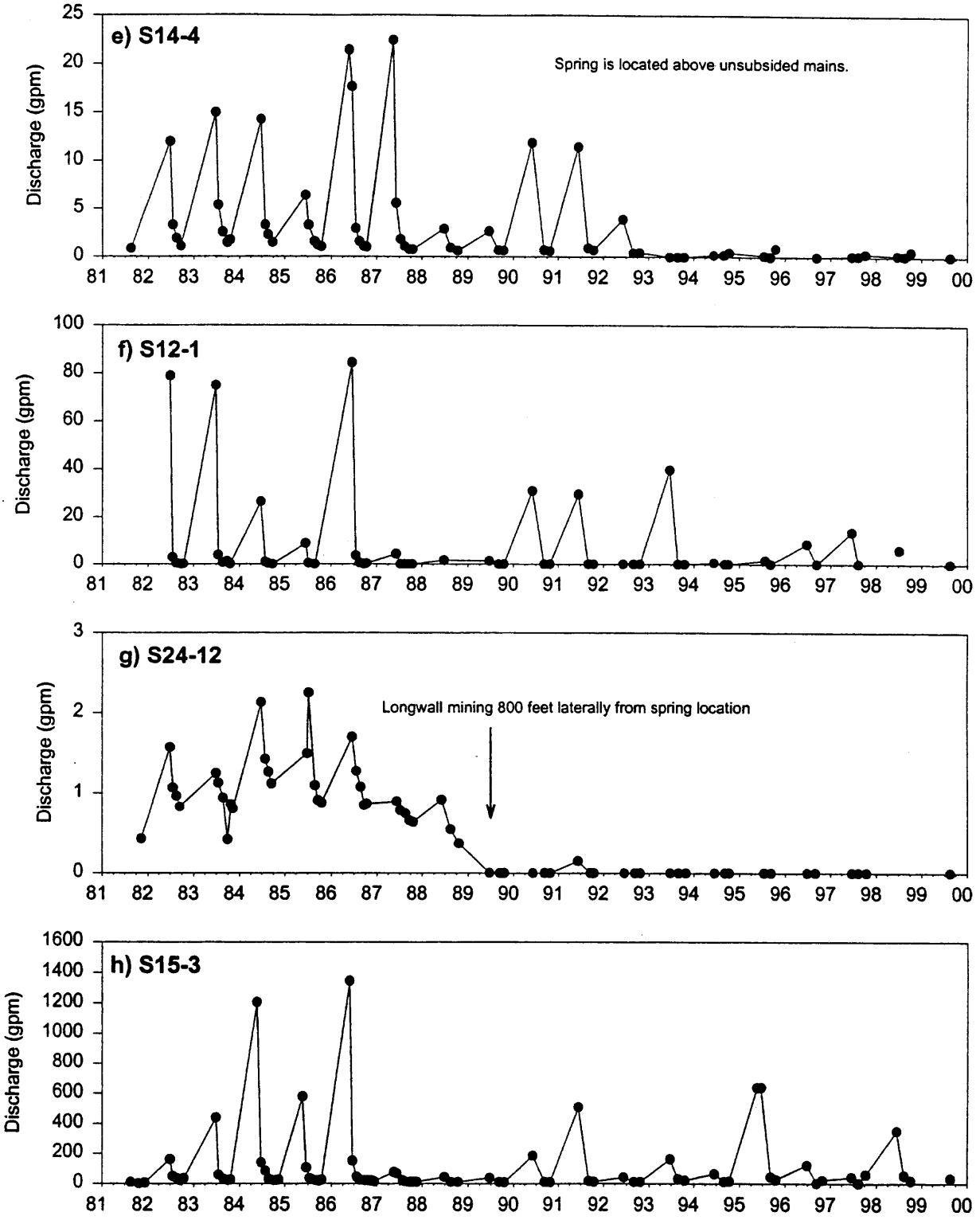

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Figure 4.1 (continued)
Plots of Discharge Versus Time for Springs in the Skyline Mine area

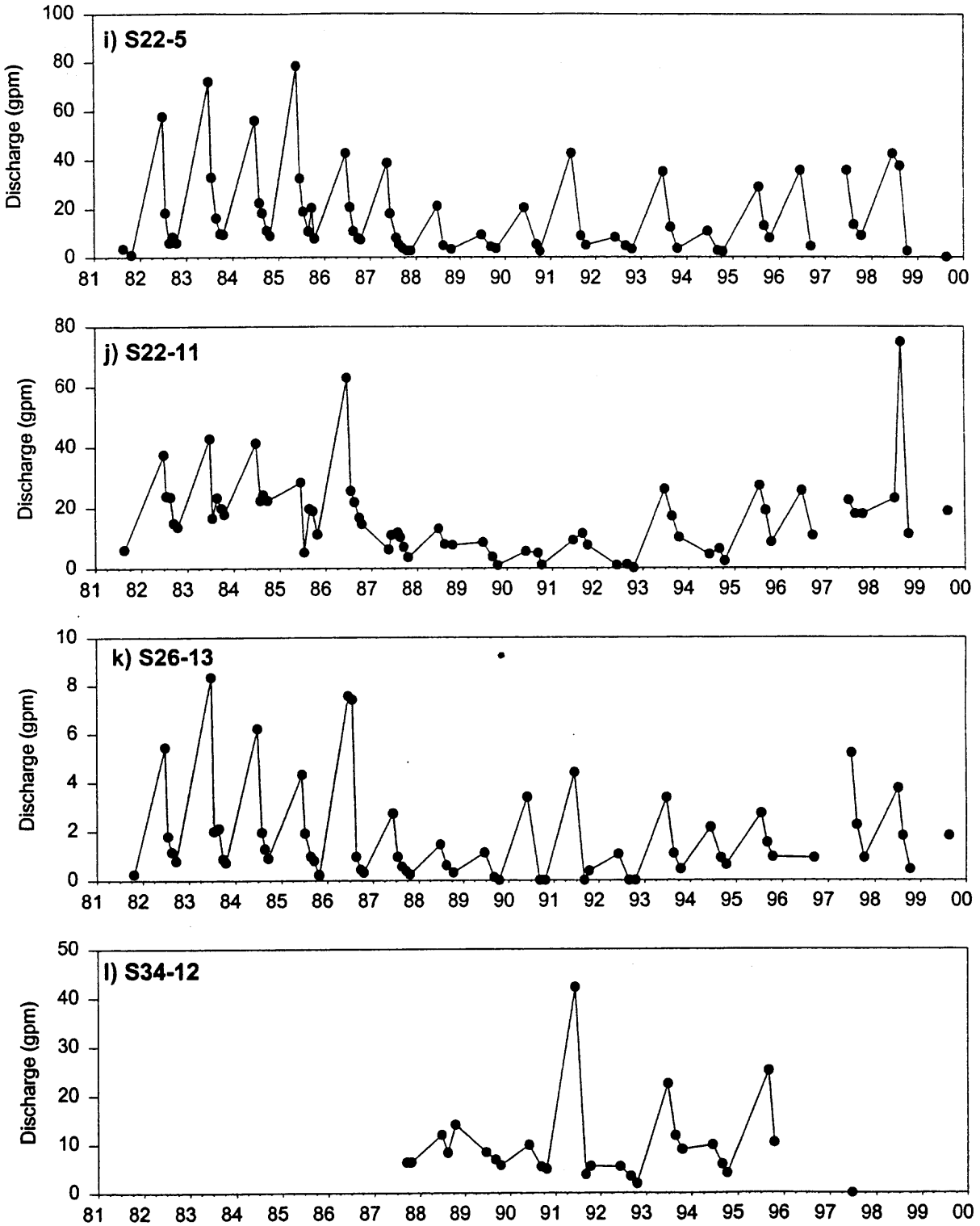
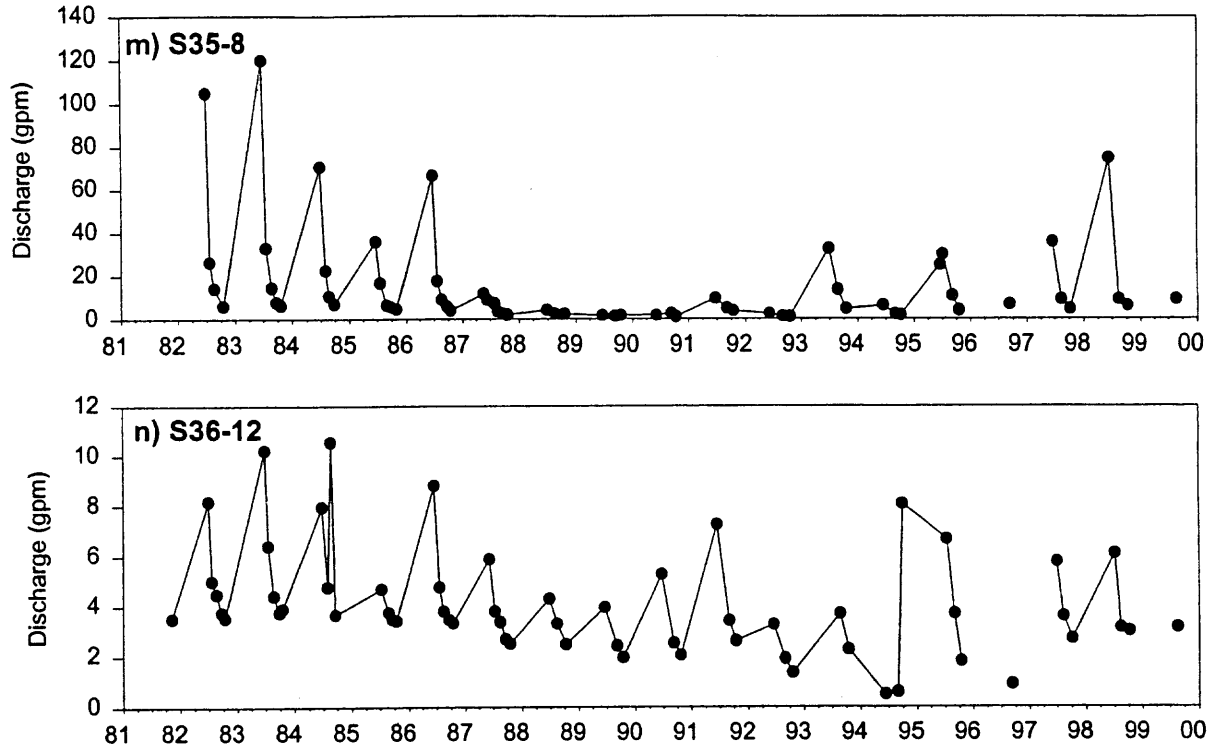


Figure 4.1 (continued)
Plots of Discharge Versus Time for Springs in the Skyline Mine area



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is unlikely that the muted peak flows are attributable to mining. Instead it is postulated that the muted peak flows are attributable to local climatic factors, such as timing of the snowmelt. Two springs, S12-1 and S13-7 (discussed below), are located on nearby ridgetops and had similar muted peak flows since 1994, substantiating the idea of a local climatic factor affecting discharge of these springs.

Additionally, as discussed in Section 4.1.2, water levels in a nearby monitoring well, W79-10-1b, registered a response to undermining but indicated that the saturated horizon that the well is completed in (790-810 feet bgs) was not dewatered. If the horizon monitored by 79-10-1b was not dewatered, it is unlikely that overlying horizons were dewatered. Also, experience in the Wasatch Plateau suggests that single seam extraction under 1,800 feet of cover should not have a deleterious impact to near-surface groundwater systems.

Spring S23-4 is a seep that has supported a small puddle about 16 inches in diameter. This puddle has not had measurable outflow since monitoring was initiated and only water quality samples have been collected from this spring. Spring S23-4 was undermined in June 1991 and is located above the middle of a panel in the upper coal seam. After S23-4 was undermined in June 1991, the puddle dried up. (Keith Zobell, Personal Communication, 2000). Beginning in 1997, an adjacent spring located 50-100 feet away from S23-4 has been monitored and in 1998 was designated as S23-4. This new monitoring location was undermined in December 1997 and is located above a panel margin in the lower coal seam. Although the discharge history at this new location is short (Figure 4.1b), it appears that discharge from the new location has not been diminished by mining.

Spring S13-2 is located above fully supported main entries. Discharge from S13-2 (Figure 4.1c) does not show any unusual variations in peak-flow or baseflow discharge over the period of record.

Spring S13-7 is located above fully-supported gateroads of a pillar panel that was first mined only in the early 1980s and has not been subsided. Discharge from S13-7 (Figure 4.1d) is very responsive to climate such as the extremely wet years of the early 1980s. However, this spring has had muted peak flows since 1994 despite the region experiencing a wet period. The muted peak flows are not believed to be a consequence of mining as no subsidence has occurred within one-half mile of the spring. The muted peak discharge rates from S13-7 are attributed to either a natural phenomenon or, perhaps, a change in monitoring methods. There is copious evidence throughout the Wasatch Plateau of historic spring discharge (e.g. tufa deposits) where there is no longer a spring. This spring is

located near S12-1 and S10-1, which, as discussed above and below, have also shown muted peak flows since about 1994.

Spring S14-4 is a developed livestock watering spring. This spring is located above fully supported main entries above which there has been no subsidence. Like spring S13-7, this spring is acutely responsive to climate but has had appreciably lower discharge rates since 1993 (Figure 4.1e). Mining of the longwall panels adjacent to the mains above which S14-4 is located did not occur until late 1995 and late 1996, after the spring first demonstrated decreased discharge. According to personnel working for Skyline Mine at the time (Keith Zobell, Personal Communication, 2000), the decrease in discharge was reported to the Forest Service and repairs were made to the spring collection system. The repairs have not been successful in restoring spring flow to previous levels. Diminution of discharge from S14-4 is attributed to problems with the spring collection system. It is doubtful that mining has had any impact on the discharge from this spring.

Discharge from S12-1 has had muted annual peak discharges since 1994 (Figure 4.1f). This spring has not been undermined, but is located within 500 lateral feet of an area that has been first mined only and has not been subsided. This spring is located in the same area at S13-7 and S10-1, which, as discussed above, also have had muted peak flows since about 1994.

Discharge data from spring S24-12 (Figure 4.1g) indicate that the spring has been dry since late 1989. According to personnel working for Skyline Mine at the time (Keith Zobell, Personal Communication, 2000), S24-12 discharges from a landslide along the surface trace of a major fault. Movement occurred along this landslide in 1989 and discharge from the spring became diffuse whereas before the landslide the discharge was concentrated. Consequently water no longer discharged at the spot originally designated at S24-12, but discharged lower down the slope. In mid 1989, mining was initiated in a longwall panel located laterally about 800 feet from the spring. Although the spring area was not subsided, mining could have precipitated continued movement of the landslide. However, it does not appear that mining has dewatered the groundwater system supporting this spring.

Discharge hydrographs (Figure 4.1h through 4.1n) for other springs that have not been undermined show recent peak flows consistent with previous years.

4.1.2 Monitoring Well Water Levels

Monitoring wells in two locations (Figure 1.2) have been undermined and subsided. Water level hydrographs for these wells are shown on Figure 4.2.

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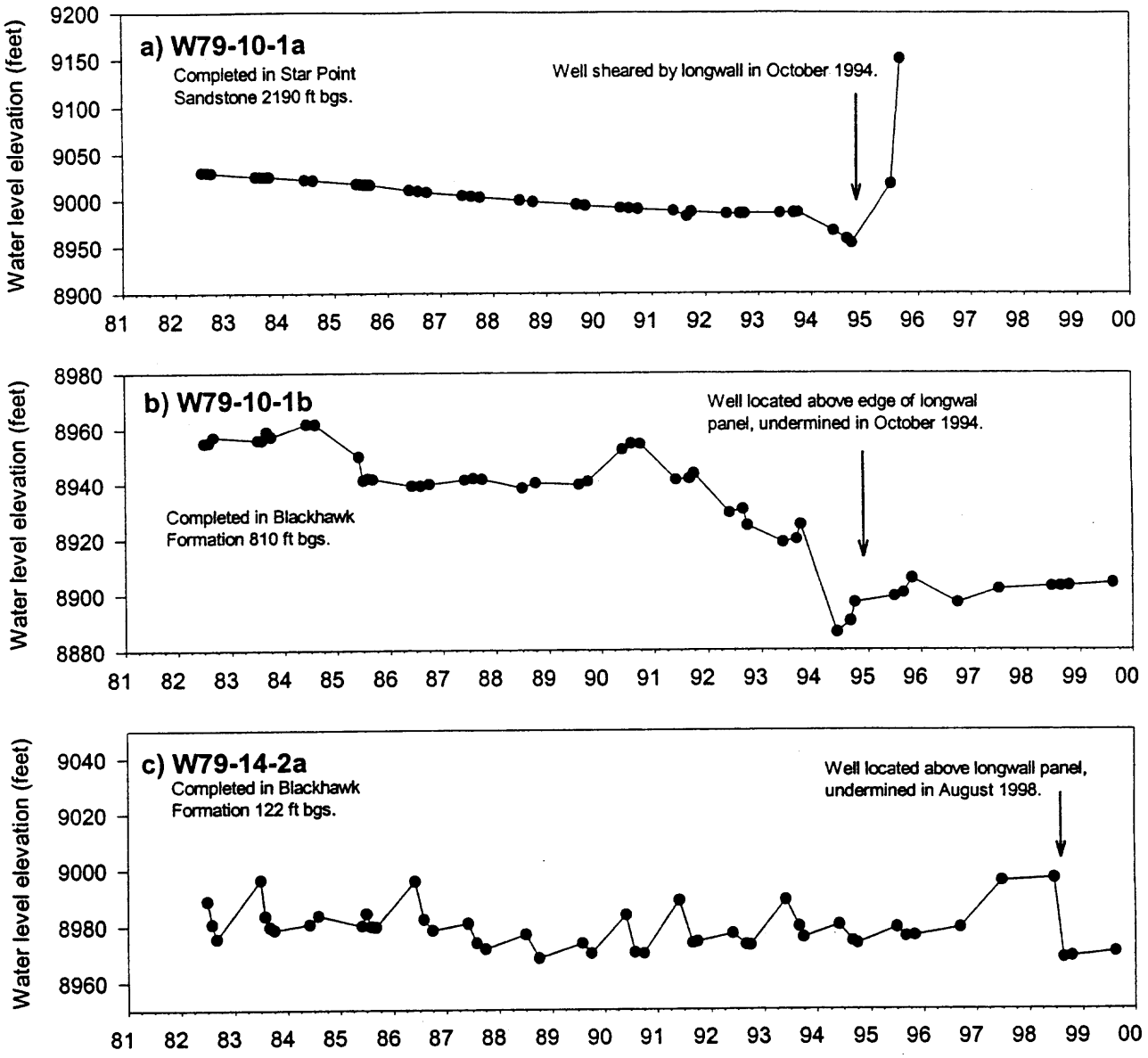
Figure 4.2
Monitoring Well Water Level Hydrographs



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The nested well pair W79-10-1a and W79-10-1b was undermined in October 1994. Well W79-10-1a is completed in the Star Point Sandstone, 2170 to 2190 feet below ground surface (bgs). When undermined, W79-10-1a was sheared at the elevation of the coal seams. Water remained in the well bore after the well was mined through (Figure 4.2a), the reason for which is not understood.

A response to undermining was seen in the shallower of these two wells, W79-10-1b, which is screened in the Blackhawk Formation 790 to 810 feet bgs and over 1,200 feet above the mined coal seams. This well is monitored quarterly by CFC (Figure 4.2b). Additionally, as part of a study by the U.S. Bureau of Mines (Mattson et al., 1995), this well was outfitted with a pressure transducer and data logger that monitored water levels daily for three months prior to undermining and for one year after undermining the well location.

CFC data (Figure 4.2b) indicate that the water level in 79-10-1b began a steady decline in 1990. However, longwall mining in the vicinity of the well did not begin until July 1992. At least several months prior to the well being undermined there was a precipitous water level drop, likely as a result of extracting the adjacent panel in the latter part of 1993. After the well was undermined, the water level rose slightly and restabilized at a level about 60 feet lower than the pre-mining level.

Mattson et al. (1995) report that the water level in the well began to rise in 79-10-1b as the longwall face approached the well. After the face passed the well, the water level initially dropped then increased dramatically. With time the water level gradually decreased but remained above the level measured when the data logger was installed prior to undermining. They state that the dramatic variations in water level indicate that the water-bearing zone was not damaged by subsidence (i.e. dewatered) but rather pressurized as a result of stresses building in the overburden after mining. This conclusion is consistent with the longer-term CFC data described above.

Well W79-14-2a is a shallow well completed in the Blackhawk Formation 102-122 feet bgs. The groundwater system that this well monitors appears to be in good hydraulic communication with the surface as indicated by seasonal water level responses. This well was undermined in August 1998. Approximately a year prior to undermining the water rose 16 feet. Immediately after the well was undermined there was a precipitous 28-foot water level decline. In the short time since undermining, data indicate that the water level has not continued to decrease but has stabilized at a level equivalent to the levels observed during the dry years 1987-1992. This type of response, a rise followed by a decline in water level, is attributed to pressure changes in the groundwater system as a response to

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differential subsidence. It does not appear that the groundwater system that this well monitored was dewatered.

4.1.3 Stream Discharge Rates And Stream Morphology

As part of this investigation, discharge data from Burnout Creek, which is a perennial drainage in Skyline Mine area, were compiled and analyzed. Burnout Creek is located on the eastern slope of Huntington Canyon less than 1 mile from the RFDS area. The purpose of this analysis is to determine whether stream water has been or is being lost as a result of undermining and subsidence of the stream. The overburden thickness in the area, which consists of the sandstones, mudstones, and shales of the Blackhawk Formation, ranges from 600 to 850 feet above the uppermost seam to be mined. These conditions are essentially identical to those beneath the perennial streams that could be undermined in the RFDS area. For this reason, it is believed that the impacts that have occurred as a result of undermining Burnout Canyon are a good predictor of the impacts that would likely occur if perennial streams in the RFDS area were undermined.

Since 1991, as the Burnout Creek drainage has been experiencing on-going single-seam or multiple-seam longwall undermining, discharge data have been regularly collected at seven monitoring stations. These include six stations on the upper forks of the stream and one station at the mouth of Burnout Creek near its confluence with Upper Huntington Creek. Discharge data are collected at these sites at frequent intervals, commonly every week to 10 days between June and November when the region is accessible. Because discharge data were generally not collected before June, it is possible that the annual maximum springtime discharge peaks were not measured in Burnout Creek. Monitoring locations are indicated on Figure 1.2 and discharge hydrographs for each station are presented in Figure 4.3.

Five of the Burnout Creek monitoring sites (F-1 through F-5) are flumes located on the main perennial tributaries of the drainage system. Sites HR-1 and HR-2 are monitoring stations located in ephemeral or intermittent drainages that are tributary to the lower trunk of the drainage. A discussion of the discharge characteristics and discharge history of each of these portions of the Burnout Creek drainage is presented below.

F-1 (Upper North Flume)

F-1 is located at the base of the northernmost perennial tributary to Burnout Creek (Figure 1.2). This drainage was first longwall undermined during late 1991 and in late 1992. A second coal seam was longwall mined beneath the drainage in 1998 and 1999. In both seams, a fire barrier pillar was left under this drainage. These two fire barrier pillars are stacked. According to the Geology, Mining, Subsidence, and

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Figure 4.3
Stream Hydrographs for Burnout and James Creeks

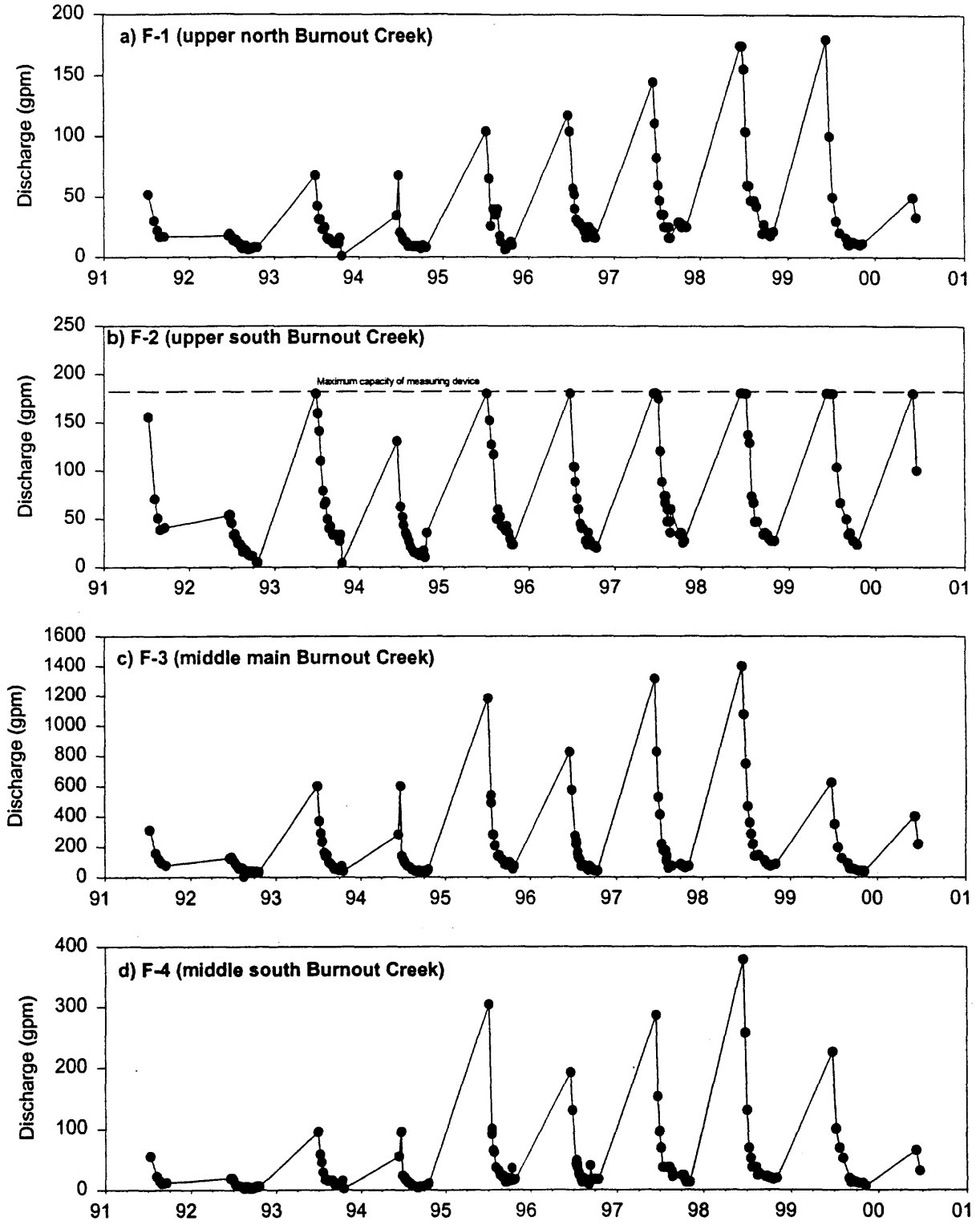

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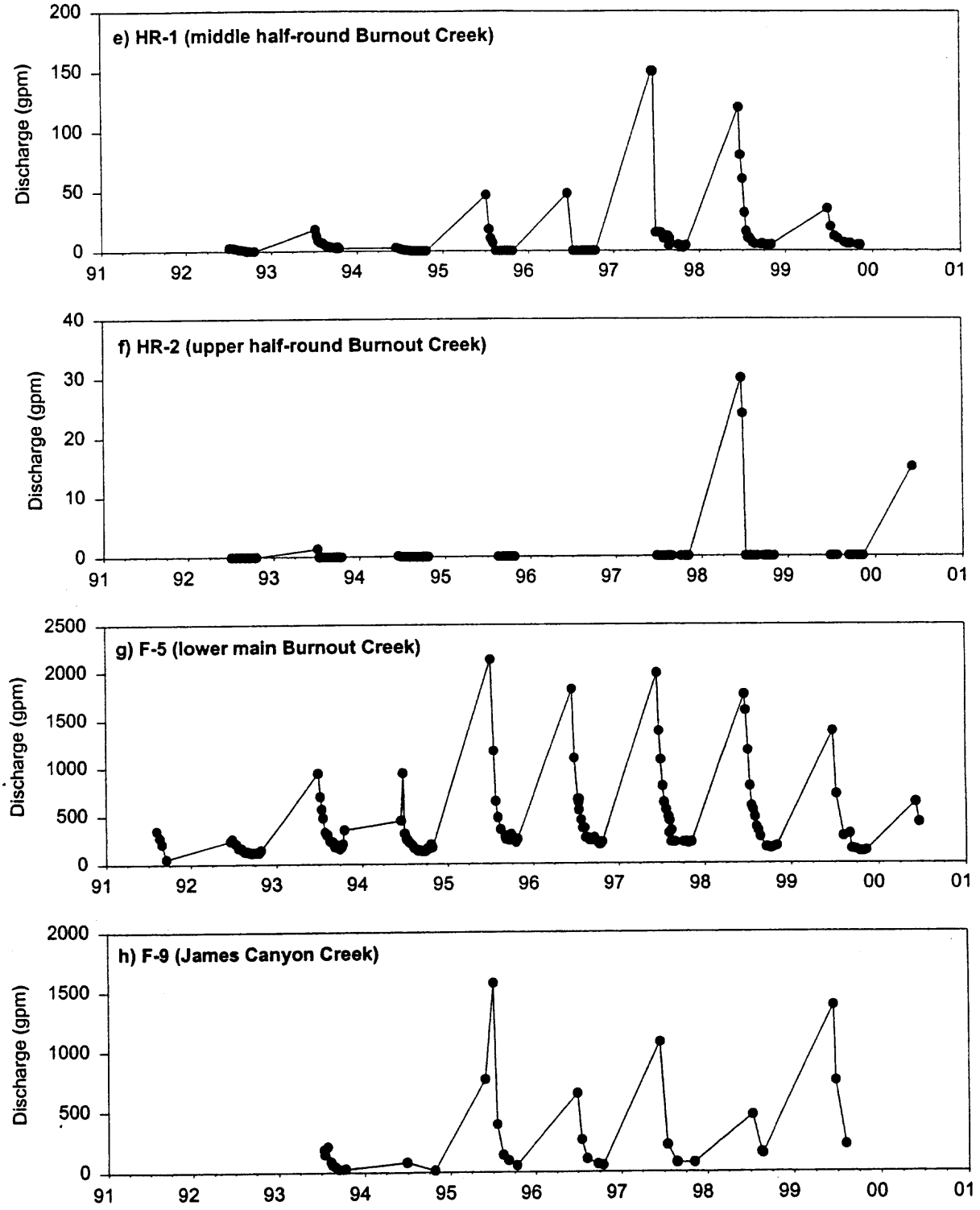
Figure 4.3 (continued)
Stream Hydrographs for Burnout and James Creeks



Seismicity technical report (NorWest, 2000) the strata overlying double stacked fire barrier pillars experience appreciable horizontal strain and have the greatest potential for cracking. However, the discharge hydrograph for F-1 indicates that during the period of undermining (1993-1999), the annual peak discharge rates correspond well with climatologic conditions as expressed by the PHDI (Figure 3.1). The relatively lower peak discharge measured at F-1 during the spring of 2000 is likely attributable the drought conditions the area experienced during this time (Figure 3.1). During the springtime of 2000, there was also an earlier than normal melting of the winter snowpack. As a result, the peak discharges in the Burnout Creek flumes may have occurred prior to the first monitoring event in early June 2000. Baseflow discharge rates during the period of record have remained relatively stable. This suggests that mining has not had a detrimental impact on discharge rates in the drainage.

F-2 (Upper South Flume)

F-2 is located at the base of the east-west trending perennial drainage immediately adjacent to site F-1. Small portions of this drainage were longwall undermined in August 1991 and October 1992. Very small portions of the drainage were again longwall undermined in April and December of 1998. Although only small portions of this drainage were longwall undermined, the undermined portions were located near the ends and lateral margins of the longwall panels, where the potential for the formation of subsidence fractures is usually greatest. The peak high-flow discharge at F-2 exceeded the measuring capacity of the flow measuring device (180 gpm) in 1993 and in each year from 1995 to 2000. Thus it is not possible to analyze the recent peak flow characteristics of this drainage. The discharge hydrograph of F-2 shows that the baseflow discharge from the drainage has increased steadily since 1993 and 1994. It is possible that the low baseflow discharge rates measured during 1992 and 1993 were mining-related impacts. However, it seems more likely that the low discharge rates were the result of the protracted, nearly continuous drought that the area experienced from 1987 to mid-1993. This hypothesis is supported by data from James Canyon, which was not undermined prior to early 1995. Since 1995, the only minimal portions of the drainage have been undermined. Although discharge data from James Canyon are not available for 1992, low baseflow discharge rates were measured during 1993 and 1994. After that time, the baseflow discharge rates in James Canyon increased in response to wetter climatic conditions (Section 3.1). In either case, the data indicate that there were no long-lasting detrimental effects to the drainage resulting from the multiple-seam longwall mining that occurred beneath the drainage.

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F-3 (Middle Main Flume)

F-3 is located on the main trunk of Burnout Creek about ½ mile below sites F-1 and F-2. This portion of the drainage was first longwall undermined during 1992, 1994, and 1995. A second coal seam was longwall mined beneath the drainage in 1999. The annual peak discharge rates at F-3 have generally followed climatic trends and baseflow discharge rates at F-3 have remained relatively constant since 1991. The high-flow peak discharge rates measured at F-3 during 1999 and 2000 (after the area underwent second seam mining) are lower than those measured during the previous 4 years. However, as is apparent in the plot of the PHDI (Figure 3.1), the climate gradually become drier during 1999 and 2000, moving from a protracted period of moderate to extreme wetness to a period of moderate drought. It is important to note that, because the PHDI takes into account several hydrologic factors other than precipitation (among other things reservoir storage and soil moisture; Guttman, 1991) there may be a delay between a lack of precipitation and its reflection in the PHDI value. For this reason, a lack of precipitation that contributes to the overall drought severity may result in a gradual lowering of the PHDI value but may not be immediately reflected in the monthly PHDI value. Rather, there would be a declining trend in the PHDI. Thus, a decline in high-flow peak discharge rates at F-3 during 1999 and 2000 would be predicted by the climatic conditions that occurred during this period. Additionally, as discussed above, the early melting of the winter snowpack in 2000 may have resulted in the peak discharge rates at F-3 occurring prior to the first monitoring event in early June 2000. Thus, although it is possible that mining-related impacts to the drainage could have occurred, it seems much more likely that the diminished peak flow discharge rates measured at F-3 during 1999 and 2000 are a result of climatic conditions.

This suggests that there have been no measurable mining-related impacts in this section of Burnout Creek.

F-4 (Middle South Flume)

F-4 is located on the southernmost perennial tributary to Burnout Creek immediately adjacent to F-3. This drainage was first longwall undermined in 1992, late 1993, and mid-1995. The second seam was extracted beneath a portion of the drainage in mid-1999. The discharge hydrograph for F-4 shows that the annual peak discharge rates generally correlate with climate. Baseflow discharge rates also are a general reflection of climatic conditions.

The annual peak discharge rates at F-4 have followed trends essentially identical to those at F-3. As discussed for F-3 above, it is believed that the lower high-flow peak discharges measured at F-4 are the result of the general drying out of the climate during 1999 and 2000, and possibly to the early melting of the winter

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snowpack in 2000. Thus, although it is possible that mining-related impacts to the drainage could have occurred, it seems much more likely that the diminished peak flow discharge rates measured at F-4 during 1999 and 2000 are a result of climatic conditions.

This suggests that there have been no measurable mining-related impacts in this section of Burnout Creek.

HR-1 (Upper Half Round)
HR-1 is located in an ephemeral drainage that flows into the main trunk of Burnout Creek below F-3 and F-4. This drainage flows only in direct response to snowmelt or precipitation events. Since 1992, when monitoring at HR-1 began, water was measured in the drainage on only five occasions. Thus, it is not possible to determine whether mining has had any detrimental impacts on this drainage.

HR-2 (Middle Half Round)
HR-2 is located in an intermittent drainage that flows into the main trunk of Burnout Creek. The discharge in this drainage has varied with climate. Discharge during the drought years from 1992 through 1994 was meager, while discharge in the generally wet years from 1995 through 1999 has been much greater. There is no evidence that measurable mining-related impacts to discharge in this drainage have occurred.

F-5 (Lower Main Flume)
F-5 is located near the confluence of Burnout Creek with Upper Huntington Creek. The discharge measured at F-5 represents the combined discharge from all of the other monitoring stations. The cumulative effects of any mining-related diminution of flow in the Burnout Canyon drainage would be detected at F-5. The annual peak discharge flow rates measured at F-5 generally reflect climatic conditions in the area. As anticipated, the annual peak discharge rates at F-5 have followed trends that are very similar to those at F-3 and F-4. As discussed above, it is believed that the lower high-flow peak discharges measured at these locations are the result of the general drying out of the climate during 1999 and 2000, and possibly to the early melting of the winter snowpack in 2000. Thus, although it is possible that mining-related impacts to the drainage could have occurred, it seems much more likely that the diminished peak flow discharge rates measured at F-5 during 1999 and 2000 are a result of climatic conditions.

Baseflow discharge rates have remained relatively constant from 1992 to the present. There is no indication that mining activities have had any measurable or lasting impacts to discharge rates in Burnout Canyon. Rather, the baseflow

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discharge rates measured at each of the seven monitoring station during October 1999 were greater than those measured in October 1992. It is important to note that during late 1992 the region was in a period of moderate drought. During October 1999 the region was entering period of drought of similar severity to that in 1992. Thus, the baseflows measured during these periods are somewhat lower than those measured during the years intervening between 1992 and 1999.

Summary

In summary, it is apparent from the Burnout Creek discharge hydrographs (Figure 4.3) that 1) baseflow discharge rates in the creek over the past several years (Figure 4.4) are not considerably different from those measured in the early 1990s when mining in the area first began, and 2) the magnitude of the annual discharge from the creek correlates well with the PHDI for Utah Region 5 (Figure 3.1), suggesting that the source of variability in the yearly discharge peaks is a function of climatic conditions. There is no indication that measurable quantities of water have been lost from the Burnout Creek drainage as a result of the longwall undermining of the creek.

Similar findings are reported by Sidle et al. (2000), who compared baseflow discharge rates at the mouth of Burnout Creek from 1981 to 1991 with discharge measured during 1992-94, a period of direct undermining of the perennial stream. They found that the baseflow discharge during 1981-91 (193 gpm) was essentially the same as that measured during 1992-94 (179 gpm). They also found that there was no statistically significant difference between pre-mining and post-mining baseflows based on t-test comparisons (α=0.05).

Sidle et al. (2000) also evaluated changes in channel characteristics, including sediment sources and distribution, which occurred after the Burnout Creek drainage was subsided by as much as to 5 feet during 1993 and 1994. They found that 1) there was an increase in the lengths of cascades and, to a lesser extent, glides, 2) there were increases in pool length, numbers, and volumes, 3) there were increases in median particle diameter of bed sediment in pools, and 4) there was some constriction in channel geometry. They found that most of these changes appeared to be short-lived, and that the channel had recovered to near pre-mining conditions by 1994. However, they also found similar near-channel sedimentation and loss of pool volume during this same time period in the adjacent James Creek drainage, which had not at that time experienced any longwall mining. It is possible that some of the observed temporary stream morphology changes in both Burnout and James Canyons may have been related to the intense livestock grazing that occurred in both canyons during the dry summer of 1994. Thus, it is difficult to determine the degree (if any) to which the

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mining activities contributed to the changes in stream morphology in Burnout Canyon.

4.2 WATER QUALITY

The quality of spring discharge water in the Skyline Mine area has not been measurably impacted by mining (Mayo and Associates, 1996). However, discharge of mine water to Eccles Creek has had a water quality impact.

It is anticipated that the chemical quality of groundwater intercepted by mining in the RFDS area would be of the same general character as that encountered in the Skyline Mine area because of similar lithologic, mineralogic, and hydrogeologic conditions. A brief characterization of the water quality of discharge waters from the Skyline Mine is presented below.

Mine discharge water quality data from the Skyline Mine are available for both Mine 1 and Mine 3 (DOGM, 2000). Average TDS concentrations are approximately 1,100 mg/l for Mine 1 and 800 mg/l for Mine 3. Both Mine 1 and Mine 3 discharge waters are of are of the calcium-magnesium-bicarbonate-sulfate chemical type. Concentrations of total and dissolved iron and manganese are consistently below the specified discharge limits (Mayo and Associates, 1996).

Mayo and Associates (1994) report that TDS concentrations in Skyline Mine discharge water measured at NPDES-001 (combined discharge from Mine 1 and Mine 3) rose steadily between 1984 and 1992. During this period, TDS concentrations of mine discharge water increased from approximately 300 to more than 1,500 mg/l. Most of this increase in TDS was attributable to a substantial increase in the concentrations of sulfate and, to a lesser extent, bicarbonate. Mayo and Associates (1994) attributed these increases to 1) the long-term use of gypsum rock-dust in the mine, and 2) the oxidation of fugitive longwall emulsion. Thus, the increases in TDS are believed to be the result of human induced factors and are not a result of natural spatial variations in groundwater quality in the groundwater system. This suggests that when new mining areas are accessed in the RFDS area, elevated TDS mine discharges may be avoided by not using gypsum rock dust and exercising care when using longwall emulsion fluid.

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5.0 POTENTIAL ENVIRONMENTAL CONSEQUENCES—SURFACE WATER

5.1 ALTERNATIVE 2: LEASE WITH BLM STANDARD LEASE TERMS AND CONDITIONS AND FOREST SERVICE SPECIAL COAL LEASE STIPULATIONS

5.1.1 Potential Decreases In Baseflow Discharge Of Creeks

Under this alternative, the application of SCLS #9, perennial streams would not be undermined and thus the potential for direct impacts to perennial creeks is avoided.

However, creek discharge could be indirectly impacted if there were a diminution of discharge from groundwater systems that supply baseflow to perennial streams. As discussed in Section 6.1.1, the potential for diminution of discharge from shallow groundwater systems is considered negligible. This is largely because of the existence of low-permeability rocks that create perched conditions in the groundwater systems that provide baseflow to creeks. Therefore, the probability of decreased baseflow in creeks in the RFDS area under Alternative 2 is negligible.

If, in the unlikely event, there were a perceptible or quantifiable decrease in streamflow as an indirect result of subsidence, SCLS #17 would require that the operator replace, at his expense, any surface water identified for protection that may be lost or adversely affected with water from an alternate source in sufficient quality and quantity to maintain existing riparian habitat, fishery habitat, livestock and wildlife use, or other land uses.

5.1.2 Increased Sediment Loading Resulting From Subsidence

Because perennial streams would not be subsided under Alternative 2, the potential for a direct increase sediment loading under this alternative would only occur in ephemeral or intermittent drainages. However, when there is sufficient water in these drainages, the sediment in the ephemeral or intermittent streams may be transported into perennial streams, lakes, or reservoirs.

Differential subsidence of surface water drainages has the potential to increase the sediment load of streams. Differential subsidence of the land surface can locally cause increased stream gradients, which increases stream velocity and erosion potential. This increased erosion potential may result in increased sediment

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loading of the stream. Differential subsidence of surface-water drainages can also locally result in decreases in sediment loading. If there is an overall increase in the frequency of pools in a watercourse, bed-load sediment carried by the stream may be deposited in these low-energy reaches, resulting in a decrease in sediment loading downstream of the pools.

Both of these impacts, if they were to occur, are likely to be short-lived. This is because the erosion of steep-gradient regions and the deposition of material in low-gradient regions result in a gradual bringing of the stream into equilibrium with its channel. Sediment loading may result from either 1) erosion and deepening of the streambed, or 2) a widening of the stream channel as a result of bank erosion. As the stream reaches equilibrium with the channel, the sediment loading in the stream would likely return to near pre-mining conditions. The rate at which this would occur is a function of the type and resistance to erosion of the subsided sediments. If the sediments are soft and easily eroded (i.e. soil horizons or soft, weathered sedimentary rocks common in the RFDS area) the stream would rapidly come into equilibrium and the increased sediment loading in the stream would rapidly cease. If the channel substrate consists of resistant bedrock, then the stream would take much longer to achieve equilibrium with its channel, but because the rock is not easily eroded, there would be minimal or no increases in sediment loading of the stream.

It should be noted that the north facing slopes of Flat, Cunningham, and Swens Canyons have recently experienced considerable logging activities including the associated road construction and soil and vegetation disturbances. Because of these disturbances, there is a likelihood of increased sediment yield from the logged areas in the near future whether or not mining occurs.

5.1.3 Impacts To Water Quantity And Water Quality Of Eccles Creek And Downstream Watercourses Resulting From The Discharge Of Intercepted Groundwater

Skyline Mine currently discharges about 500 gpm. CFC estimates that mine discharge could be as high as 3,000 gpm if mining were to occur in the RFDS area. This rate would not be sustained continuously but represents a maximum occasional discharge. The actual discharge rate of water from mine workings would be dependant on the amount of water encountered, the amount of water that would be impounded underground, and cycles of the water handling system. The impact of additional discharge to Eccles Creek is discussed in this section.

As discussed in Section 4.2, it is anticipated that the chemical quality of groundwater encountered during mining in the RFDS area would be similar to that encountered in the Skyline Mine area. Therefore, if mine water discharge

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rates were to remain at current levels (approximately 500 gpm), and mine water were to continue to be discharged into Eccles Creek, there would be no new impacts to water quality or quantity beyond those currently occurring. Assuming that future discharge rates from the mine increased from current levels to 3,000 gpm (an approximate six-fold increase) then greater impacts to water quantity and quality in Eccles Creek and downstream watercourses would be anticipated.

The overall quality of Skyline Mine discharge water has been appreciably lower than of Eccles Creek (Mayo and Associates, 1996). Therefore there is a direct relationship between the percentage contribution of mine water to the creek and the overall quality of creek water below the mine discharge point. The greater the relative contribution of mine water to the creek, the greater would be the degradation of water quality in the creek.

Because the average solute concentrations of major ions in mine discharge water and Eccles Creek water are known, it is possible to use a flow-weighted linear mixing model to estimate the anticipated water quality at CS-2 (Eccles Creek below the mine discharge point) if additional mine discharge water enters the creek. Results of these calculations for a projected mine water discharge rate of 3,000 gpm are shown in Table 5.1. Because the Skyline Mine is currently discharging approximately 500 gpm into the creek, a total mine discharge of 3,000 gpm would represent an increase of 2,500 gpm above current levels. The linear mixing model suggests that TDS concentrations at CS-2 on Eccles Creek would average approximately 877 mg/l. Currently, with a 500-gpm mine discharge, TDS concentrations average approximately 554 mg/l (Table 5.1). A substantial portion of the TDS increase would result from increases in sulfate concentrations, which would average approximately 400 mg/l. Currently, with a 500-gpm discharge, sulfate concentrations at CS-2 average 193 mg/l. Most other solute species would have smaller increases because the concentrations of these species in mine water are nearer those of the receiving water. It should be noted that these estimates are based on a continuous mine discharge of 3,000 gpm. It is likely that pumping of mine water would occur intermittently and the long-term average pumping rate would be considerably less than 3,000 gpm. Thus, these estimates should be considered as worst-case estimates. The magnitude of the potential water quality impacts may be considerably less than those estimated above.

The results of the flow-weighted mixing calculations are acceptable for estimating the general order of impacts to Eccles Creek because of the relatively low concentrations of solute species in both mine water and receiving water. However, it should be noted that, because this technique does not consider

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Table 5.1 Flow-weighted linear mixing model results

	Flow	TDS	Ca	Mg	Na	K	HCO_3	SO_4	Cl
Historic mean values for Skyline Mine discharge water									
CS-12 (Mine 3 discharge)	242	797	74.9	49.7	52.5	7.5	280	361	11
CS-14 (Mine 1 discharge)	153	1104	141	85.3	62.9	13.1	310	525	14.8
Weighted average mine discharge water		916	100	63	57	10	292	424	12
Historic mean values for receiving waters									
CS-4 (Eccles Creek above mine discharge)	190	269	74	14	6	1	266	15	12
CS-2 (Eccles Creek below mine discharge)	1015	554	88	35	52	6.1	321	193	14
UPL-10 (Upper Huntington Creek at Electric Lake)	3857	182	53	9.9	3.7	1	183	15.2	6.5
Estimated CS-2 assuming mine discharge of 3,000 gpm	**3190**	**877**	**99**	**61**	**54**	**9**	**290**	**400**	**12**
Estimated UPL-10 assuming mine discharge of 3,000 gpm	**6857**	**503**	**74**	**33**	**27**	**5**	**231**	**194**	**9**

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thermodynamic factors, there is the potential for error in the calculations, particularly in non-dilute solutions.

Currently, Skyline Mine is permitted to discharge 7.1 tons per day of dissolved solids. Assuming that discharge increases to 3,000 gpm total mine discharge (6.68 cfs) and the average mine discharge TDS concentration of 916 mg/l remains the same, there would be a salt loading of 16.5 tons per day, an increase of 9.4 tons per day.

Scofield Reservoir and the Price River and its tributaries have been designated as protected by the Utah Division of Drinking Water (UAC R317-2) for 1) domestic purposes with prior treatment by treatment processes, 2) secondary contact recreation such as boating, wading, or similar uses, 3) cold-water species of game fish and other cold-water aquatic life, including the necessary aquatic organisms in their food chain, and 4) agricultural uses including irrigation of crops and stock watering.

Before any mine water could be discharged into these waters, the current UPDES discharge permit may need to be modified. In order to receive a new or modify an existing UPDES permit, it must be demonstrated that beneficial use standards would not be exceeded in the receiving water. When a UPDES discharge permit is issued or modified, the water quality of the proposed discharge water is evaluated by the Utah Division of Water Quality (Personal Communication, Mike Herkimer, 2000). WET testing is performed to ensure that the water is not toxic (either chronic or acute) to aquatic organisms. If harmful constituents are identified in the proposed discharge water, then an approved water treatment plan must be implemented before any water may be discharged. If constituents are found in the water that are regulated under TMDL or which may cause the receiving water to not meet the quality standards for the designated beneficial uses, then specific discharge limits are placed on these constituents. Routine water quality monitoring of the discharge water is required for all parameters requested by the Division of Water Quality to demonstrate compliance with the UPDES permit.

As demonstrated by many years of continuous water quality monitoring, the quality of raw mine discharge water from the Skyline Mine, in terms of TDS, sulfate and pH, is acceptable for all of the protected beneficial uses and is within the drinking water standards set fourth by the Utah Division of Drinking Water (UAC 317-2). Limited chemical data are available for most other chemical parameters controlled by the designated beneficial use standards. These data are summarized in Appendix D. Also included in Appendix D is a listing of the regulated chemical parameters for which no data have been located.

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With a few exceptions discussed below, the quality of the mine discharge water has generally been acceptable for all of the designated beneficial uses of the receiving water (in terms of the chemical constituents for which water quality data are available). Concentrations of total boron, cyanide, dissolved lead, total phosphorous, and TDS have on at least one occasion exceeded the concentration limits specified by one or more of its beneficial use standards. Concentrations of cyanide from CS-12 on one occasion exceeded the beneficial use standard for aquatic wildlife. On each of the other 12 monitoring events, no cyanide was detected. During the single cyanide-monitoring event from the UPDES outfall, the concentration of cyanide also slightly exceeded the standard. The concentration of total phosphorous has occasionally been exceeded in discharge from CS-12 and CS-14, and was exceeded in the single phosphorous-monitoring event from the UPDES outfall. The average concentration of total phosphorous from CS-12 discharge is within the beneficial use standards, while those standards are somewhat exceeded in the average CS-14 discharge. The concentration of total mercury also exceeded the beneficial use standards during the single mercury-monitoring event from the UPDES outfall. Concentrations of phenol, an organic compound, have exceeded the beneficial use standards on a few occasions at both CS-12 and CS-14, while on all other occasions, there was no phenol detected in the discharge water. The causes of the occasional elevated phenol concentrations in the mine discharge water are not known.

It is important to note that for each of the chemical parameters discussed above, (with the exception of phenol and possibly total phosphorous) although certain beneficial use standards have occasionally been exceeded in the discharge water from either CS-12 or CS-14, the average concentration of mine discharge water, which is a combination of water from these two sources, is generally suitable for each of the beneficial uses. As discussed above, important chemical parameters of potential mine discharge water would be strictly controlled through the UPDES permitting process and would be monitored by several Utah State regulatory agencies. Additionally, continuous, automated monitoring equipment has been installed in the Skyline Mine discharge system that ensures that water that is excessively elevated in TDS, ph, turbidity, or oil and grease concentrations would not be discharged. If poor quality mine discharge water is detected by this system, it is automatically rerouted to underground storage areas within the Skyline Mine and is not discharged.

The addition of approximately 2,500 gpm (5.57 cfs) of mine discharge water to Eccles Creek above current levels (about 500 gpm) would constitute a considerable increase to the natural discharge in the creek. During low-flow periods, discharge in Eccles Creek measured at CS-2 is commonly between about

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0.1 and 2 cfs. Thus, an addition of 5.57 cfs would result in a discharge between 2.8 and 56 times current levels. The addition of this amount of sediment-free water during low-flow periods would cause increased sediment transport. The magnitude of this impact has not been quantified. The data necessary to perform a rigorous and meaningful analysis have not been collected. However, the erosion potential would be mitigated in part because of the well-armored nature of the stream channel. The stream channel in Eccles Creek is dominated by cobbles and boulders and appears to be relatively stable. During periods of high flow in the creek, when current discharges commonly exceed 10 to 50 cfs, the addition of 5.57 cfs of mine discharge water would constitute a relatively smaller impact.

Eccles Creek is a tributary of Mud Creek, which is a tributary of Scofield Reservoir. Therefore an increase in the mine water discharge rate to Eccles Creek would also impact downstream watercourses including Mud Creek and Scofield Reservoir. Unlike Eccles Creek, the channel substrate in Mud Creek, particularly in its lower reaches, appears less armored than Eccles Creek and contains reaches dominated by fine-grained material. Therefore, the potential for increased erosion rates in Mud Creek would likely be greater than for Eccles Creek. However, because Mud Creek is a larger watercourse than is Eccles Creek, the addition of 5.57 cfs to the discharge represents a smaller percentage increase to the total stream flow. Thus, this additional water would be more readily accommodated in the channel. Likewise, because of the larger volume of discharge in Mud Creek relative to Eccles Creek, the degradation of water quality in this watercourse would be less.

During dry years, the addition of 5.57 cfs to Scofield Reservoir from Mud Creek would likely not result in any major impacts in terms of the ability of the reservoir to accommodate the additional water. Rather, the increased recharge to the reservoir would likely be considered a positive impact by those who use the water. This would be particularly true during dry years, because as discussed in Section 3.2.3, the inflow of deep, perched groundwater into the mine workings is not related to climate. During extremely wet years, when water is spilling from the reservoir, the addition of this amount of water would be a meager amount relative to the 6,200 cfs capacity of the spillway. During extremely wet years, when there is no available storage capacity in the reservoir, the mine discharge water would increase the high-flow discharge rate in the Price River below the dam by 5.57 cfs. This would constitute a small percentage of the high-flow discharge of the Price River below the reservoir.

If the mine discharge water were redirected to the Upper Huntington Creek drainage, the discharge to Eccles Creek could cease. Under this scenario, the water quality in Eccles Creek would revert to its pre-mining condition, with an

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average TDS concentration of approximately 269 mg/l. Water quality in Mud Creek would also improve to pre-mining levels. As discussed above, there would be a net decrease of approximately 2.8 tons per day of salt loading to Scofield Reservoir. Discharge rates in Eccles Creek would decrease dramatically to pre-mining conditions. This would be particularly noticeable during baseflow conditions, when stream discharge rates would decrease from the current levels in dry years to perhaps less than 100 gpm. The loss of approximately 500 gpm of mine discharge water would represent a loss of approximately 800 acre-feet of water per year in Scofield Reservoir.

5.1.4 Impacts To Water Quantity And Water Quality Of Electric Lake And Downstream Watercourses Resulting From The Discharge Of Intercepted Groundwater

It is proposed in the RFDS that mine water might be discharged to Electric Lake at or below the high water line in Upper Huntington Canyon. The possibility of discharging water some distance out into the lake has also been discussed by USFS personnel and CFC. This section discusses the possible impacts to chemical and physical water quality as a result of discharging mine water to Electric Lake. The chemical water quality impacts are expected to be the same regardless of weather water is discharged near the high water line or father out into the lake. The physical quality of the lake could be impacted if discharge near the high water line results in appreciable entrainment and transport of lake bottom sediments during low stand periods.

As discussed in Section 4.2, it is anticipated that the chemical quality of groundwater encountered during mining in the RFDS area would be similar to that encountered in the Skyline Mine area. Because the anticipated quality of mine discharge water is poorer than that in Upper Huntington Creek, the water quality of Upper Huntington Creek would be degraded by the addition of any mine water. The magnitude of this impact is directly related to the volume of mine water discharged into the receiving water. In the following discussion, water quality impacts to Electric Lake have been analyzed by comparing the water quality of Upper Huntington Creek at UPL-10 to the average quality of Skyline Mine discharge water. However, the water quality impacts to Electric Lake resulting from proposed mining activities in the RFDS area would be less than those occurring in Upper Huntington Creek due to dilution in the lake.

Because the average solute concentrations of major ions in mine discharge water and Upper Huntington Creek water are known, it is possible to use a flow-weighted linear mixing model to estimate the anticipated water quality at UPL-10 (Upper Huntington Creek just above Electric Lake) at different mine water discharge rates. The results of these calculations for an anticipated mine water

discharge rate of 3,000 gpm are shown in Table 5.1. Because there is currently no mine discharge into Upper Huntington Creek, the entire 3,000 gpm would constitute a new impact to the stream. The linear mixing model suggests that TDS concentrations at UPL-10 could increase from approximately 182 mg/l to 502 mg/l (Table 5.1). Much of this increase would be caused by increases in the sulfate concentration in the stream, which could increase from 15 to 194 mg/l. Smaller increases in other solute species would also occur (Table 5.1). As discussed above, these estimates are based on a continuous discharge of 3,000 gpm into the stream. It is more likely that mine water would only be pumped intermittently, and thus, the average pumping rate would be considerably less. Therefore, these estimates should be considered as worst-case estimates. The actual water quality impacts may be considerably smaller than those described above. The results of the flow-weighted mixing calculations are of value in estimating the general magnitude of impacts to Upper Huntington Creek, but as described in Section 5.1.3, it should be noted that there is the potential for error using this technique. Assuming an average TDS concentration of mine discharge water of 916 mg/l, there would be an additional 16.5 tons per day of salt loading to the reservoir.

Huntington Creek and Electric Lake are protected for secondary contact recreation such as boating, wading, or similar uses. These waters are also protected for cold-water species of game fish and other cold-water aquatic life, including the necessary aquatic organisms in their food chain. The waters are also protected for agricultural uses including irrigation of crops and stock watering. Huntington Creek has been designated as protected for domestic purposes with prior treatment by treatment processes as required by the Utah Division of Drinking Water.

Before any mine water could be discharged into these waters, a UPDES discharge permit would be required. In order to receive this permit, it would need to be demonstrated that the beneficial use standards for these waters would not be exceeded. Water quality analyses for the Skyline Mine discharge for important parameters regulated under the beneficial use standards are included in Appendix D. As discussed in Section 5.1.3, the quality of mine discharge water for all parameters regulated under beneficial use standards (with the exception of phenol and possibly total phosphorous) for which data are available is generally acceptable for the designated beneficial uses. As discussed above, all important water quality parameters would be controlled through the UPDES permitting process and are regulated by several Utah State regulatory agencies. Additionally, continuous, automated monitoring equipment has been installed in the Skyline Mine discharge system that ensures that water that is excessively elevated in TDS, pH, turbidity, or oil and grease concentrations would not be

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discharged. If poor quality mine discharge water is detected by this system, it is automatically rerouted to underground storage areas within the Skyline Mine and is not discharged.

Because the mine discharge water is generally of sufficient quality to meet drinking water standards and all of the designated beneficial uses of the receiving waters (for the chemical parameters for which data are available and with the exception of phenol and possibly total phosphorous), it is unlikely that there would be adverse impacts to ecosystems in downstream water courses or that there would be adverse water quality impacts to downstream water users.

The temperature of groundwater from the Skyline Mine has averaged between about 11 and 16°C (Mayo and Associates, 1994). If this water is discharged directly into Electric Lake during the winter months when temperatures of the lake water are near 0°C, there would be an alteration of the thermal regime of the lake. This may locally result in the melting or thinning of the surface ice in the vicinity of the discharge point and may also impact ecosystems in the immediate vicinity of the discharge point.

In the event that mine water is discharged near the high water line of Electric Lake, there is potential for appreciable erosion of lake bed sediments during times of the year when Electric Lake is not at high water. When the lake is not at high water, mine water discharge would first mix with Upper Huntington Creek discharge before flowing in the lake. When the lake is not at high water, Huntington Creek flows in a channel carved into unvegetated lake bed sediments. The addition of approximately 3,000 gpm (6.68 cfs) of mine discharge water to Upper Huntington Creek would constitute a considerable increase in the discharge in the creek. During low-flow periods, discharge from Upper Huntington Creek to Electric Lake is commonly between about 1 and 3 cfs (Mayo and Associates, 1996). Thus, an addition of 6.68 cfs would result in a baseflow discharge that is between about 2.2 and 6.7 times current levels.

The potential for disturbance of lake-bottom sediments would be greatly diminished if discharge water were conveyed via pipeline to a point further out into the lake. Because the mine water discharged into the lake would be essentially sediment free, there would likely not be any perceptible deposition of sediment at the mine discharge point.

During dry years and during the late summer months, the addition of 6.68 cfs of water to Electric Lake may be seen as a beneficial impact. This would be particularly true during drought years, because as discussed in Section 3.2.3, the inflow of deep, perched groundwater into the mine workings is not related to

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climate. During extremely wet years, when water is spilling from the reservoir, the addition of this amount of water would be a meager amount relative to the 2,300 cfs capacity of the spillway. During extremely wet years, when there is no available storage capacity in the reservoir, the mine discharge water would increase the high-flow discharge rate in Huntington Creek below the dam by 6.68 cfs. This would constitute a small percentage of the high-flow discharge of Huntington Creek below the reservoir.

5.1.5 Impairment Of Water Rights Resulting From Decreased Stream Flows

Numerous water rights for creeks are held in the RFDS area by both private land owners and government agencies. As described in Section 5.1.1, perceptible or quantifiable impacts to creek discharge rates are not anticipated. If there are no impacts to creek discharge rates then there should be no impairment of water rights. In the event that there is a mining-related flow diminution of an appropriated surface water source, Utah Code 40-10-18 requires the mine operator to "promptly replace any state appropriated water in existence prior to the application for a surface coal mining and reclamation permit."

5.2 ALTERNATIVE 3: LEASE WITH BLM STANDARD LEASE TERMS AND CONDITIONS ONLY

Under Alternative 3, the SCLS are not applied to the lease. The potential environmental impacts under this alternative include the impacts described under Alternative 2 and the potential impacts described below.

5.2.1 Diversion Of Surface Water From Perennial Creeks And Boulger Reservoir Into The Subsurface As A Result Of Undermining And Subsidence

Perennial streamflow may be impacted if subsidence-related tension fractures caused diversion of surface water into the subsurface. As discussed in Section 2.8, it is believed that low-permeability confining or perching layers exist beneath all of the perennial streams in the RFDS area. This is expected to be the case regardless of the geomorphology. For instance, although Boulger Canyon is wide with a low stream gradient whereas Swens Canyon is narrow and steep, the same bedrock formation underlies the unconsolidated sediments in each canyon. Canyon geomorphology in the study area is a function of erosional process (fluvial and glacial) not the underlying bedrock. It is for this reason that the results of undermining Burnout Canyon with respect to stream dewatering can be extrapolated to all of the perennial drainages in the study area.

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Therefore, in order for surface waters to be diverted from a creek, the integrity of the perching layer(s) would need to be compromised such that downward migration of surface waters into deeper unsaturated rock horizons could occur. The subsidence fractures must be sufficiently extensive and interconnected so as to facilitate the conveyance of stream water out of the drainage. As discussed in Section 6.1.1, it is expected that the integrity of the low-permeability bedrock horizons that support both streams and shallow groundwater systems in the RFDS area would not be compromised. For these reasons, the potential for the direct interception and translocation of surface waters by subsidence fractures is considered remote. The existence of low-permeability layers creates shallow, perched groundwater systems beneath the stream. Were this not the case, the streams in the RFDS area would be losing streams because the groundwater derived baseflow component would flow downward into the unsaturated horizons that exist deeper beneath the surface.

If subsidence fractures were to occur above the impermeable perching layer, these would be of relatively little consequence to the hydrologic regime. Because sediments above the perching layer are believed to be fully saturated, there could be no loss of water to these fractures. As discussed in Section 6.1.1, subsidence fractures that could develop in the Blackhawk Formation would heal rapidly as a fracture plane is wetted due to swelling clays in the Blackhawk Formation. Thus, if subsidence fractures were to damage the perching layer beneath the stream, these fractures would likely remain open for only a short period of time.

The experience of CFC performing longwall extraction beneath Burnout Creek provides support for the idea that perceptible or quantifiable detrimental impacts to perennial streams would not likely occur if these drainages were undermined. As discussed in Section 4.1.3, there have been no quantifiable impacts to baseflow discharge in Burnout Creek after it was undermined that could be attributed to mining activities. It is believed that the geologic conditions in the RFDS area (geologic formation, overburden thickness, and degree of fracturing and faulting) are sufficiently similar to those at Burnout Canyon (less than 1 mile from the RFDS area) to give scientific validity to extrapolating the observed effects of undermining Burnout Creek to those that may occur if perennial surface water drainages in the RFDS area are undermined with longwall mining techniques. Thus, it is probable that no perceptible or quantifiable losses of surface water would occur if surface water drainages in the RFDS area are undermined.

As discussed in Section 6.1.1, there is a potential for localized shifting of groundwater discharge locations as a result of mining-related subsidence. This can result from minor alterations in the attitude of bedrock horizons (i.e. a change

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in the groundwater flow direction) or changes to fracture networks that may support groundwater discharge. However, because the drainages that support surface water in the RFDS area are all well entrenched and the surface gradients are relatively steep, the possibility that minor shifting of groundwater discharge locations could remove perceptible or quantifiable amounts of surface water from the drainage is remote. Rather, it is likely that groundwater entering the stream channel would simply enter slightly higher or lower in the drainage. Under this scenario, there would be no net loss of water from the watercourse.

For the reasons discussed above, it is believed that the potential for diminished baseflow discharge in creeks in the RFDS area under Alternative 3 is negligible. However, if perceptible or quantifiable detrimental impacts to groundwater systems that provide baseflow to streams in the RFDS area do occur, then these impacts would be reflected in decreased baseflow in streams. These potential impacts to perennial streams, were they to occur, would likely be of relatively short duration, likely on the order of one or two seasons. As discussed in Section 6.1.1, tension fractures in the Blackhawk Formation tend to heal rapidly because of the existence of hydrophilic swelling clays in the rocks of the formation. If subsidence fractures were to intercept groundwater, the fractures would rapidly heal as the clays along the fracture planes became wetted and subsequently swelled. If subsidence fractures appear in a stream channel that has a bare bedrock substrate (that may not contain swelling clays) the subsidence fractures would likely fill with sediment transported by the stream. It was evident in the July 2000 stream survey that each of the streams surveyed was actively transporting quantities of sediment that would be sufficient to fill even a relatively large subsidence fracture in a short period of time. Assuming a typical fracture width of 1 inch, a depth of 30 feet, and a length of 50 feet, a fracture volume of 125 cubic feet is calculated. Although no direct measurements of sediment transport in streams in the area are available, it is believed that the quantities of sediment transported annually in perennial streams in the RFDS area greatly exceed this amount. Thus, even if several subsidence fractures occurred in the drainage, the duration of a potential stream-water loss resulting from subsidence fractures physically intersecting a bedrock channel would be relatively short, perhaps on the order of one or two seasons.

In the event that there were a perceptible or quantifiable mining-related diminution of discharge in a creek that has been designated for protection, the application of SCLS #17 would require the lessee to replace any water lost from or adversely affected by mining operations with water from an alternate source in sufficient quality to maintain existing riparian habitat, fishery habitat, or livestock and wildlife use.

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5.2.2 Changes In Stream Morphology Due To Subsidence Of Creeks

Longwall mining commonly results in differential subsidence of the land surface. If longwall mining occurs under a stream drainage, there would be localized changes in channel gradient near the margins of a subsided area. These changes may result in a deepening or a widening of the stream channel. In the interior of a subsided area, the land subsidence is more uniform and changes in stream gradient should theoretically be small. Therefore, the greatest potential for major alterations in stream morphology occurs above panel ends or above longwall gateroads. Although the potential for major changes in stream morphology does exist, the experience of CFC in mining Burnout Canyon suggests that the changes that may occur would not be large enough to cause major detrimental impacts to the streams in the RFDS area.

It was observed by the authors that the subsidence-induced changes in channel gradient at Burnout Canyon, even in the areas of maximum differential subsidence, were not great enough to cause barriers to fish movement in the stream. Rather, as has been observed in other subsided areas in the Wasatch Plateau, the subsidence around the margins of longwall panels occurs in a more distributed, gradual fashion. Thus, it is believed to be unlikely that fish barriers would form as a result of potential longwall mining in the RFDS area.

Sidel et al. (2000) report that changes to the stream morphology in Burnout Creek during the period it underwent longwall mining were minor and consisted primarily in an increase in the percentage of pools along the drainage. However, similar morphological changes occurred in the adjacent James Canyon, which was a mostly non-undermined control for their study. Thus, it is difficult to determine to what extent, if any, the mining activity had on the stream morphology in the drainage. The morphological changes that did occur in both drainages were short-lived. Within a year the drainage had returned to near-pre-mining conditions (Sidel et al., 2000). However, it is possible that there will be an increase in pooling in portions of streams that are undermined using longwall mining techniques.

Thus it is believed that although differential subsidence of perennial drainages above longwall-mined areas would occur under to Alternative 3, these changes would generally be minor. If a major impact to stream morphology were to occur, the impacts would likely be short-lived.

It has been determined in the Geology, Mining, Subsidence, and Seismicity technical report (NorWest, 2000) that in portions of some perennial stream drainages in the RFDS area, there could be moderate changes in the channel gradients. In most sections of the perennial streams in the RFDS area, the stream gradients are steep enough for the stream to adjust to subsidence-induced slope

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changes without any major changes to stream morphology. However, in some perennial drainages, including portions of the Flat Canyon and Boulger Canyon, and the lower reaches of Swens Canyon, there are reaches with relatively low stream gradients that may experience moderate subsidence-induced gradient changes. In these areas, there is the potential for low or possibly even negative stream gradient to occur if the slope changes are sufficiently large. The precise locations where these effects could occur are entirely contingent upon the specific locations, geometries, and orientations of longwall panels. Thus, in the absence of a detailed mine plan, it is difficult to be more specific in predicting locations where these effects may occur. If negative gradients occur in these areas, pooling of water in the subsidence troughs near gradient inflection points may result. This could result in the creation of new ponds or wetland areas in the drainages. If ponding occurs in areas containing thick alluvial deposits (such as those found in the Flat Canyon and lower Boulger Canyon drainages) these ponds or wetlands may persist for a relatively short period of time. This is because the stream has a tendency to actively erode soft sediments in highland areas and deposit the abundant, easily eroded sediment in lowland areas. Thus, the stream would have the tendency to quickly come into equilibrium with its channel in terms of channel gradient. In areas of maximum differential subsidence, there is the potential for head cutting in stream channels that would result in increased sediment loading and temporary changes to stream morphology. Changes in channel width resulting from erosion of stream banks may also occur. In areas directly underlain by bedrock formations, where relatively less sediment is transported and the substrate is less easily eroded, the effects would persist for a longer period.

In areas where subsidence-induced changes to stream gradients could result in local reversals of stream gradient and potential ponding of water or the creation of wetland areas (most notably in Flat Canyon and possibly also in portions of Boulger Canyon and Swens Canyon) there is the potential for flooding of structures that are located near the streambank. The authors have not observed structures in these areas that appear to have the potential to be flooded. Thus, this impact is not anticipated in the RFDS area.

According to the RFDS, Upper Huntington Creek would not be subsided by longwall undermining. However, there is a possibility that Upper Huntington Creek and portions of Electric Lake would be directly undermined for the development of mains. As discussed in the Geology, Mining, Subsidence, and Seismicity technical report (NorWest, 2000), subsidence above regions mined using room and pillar techniques is expected to proceed gradually at a very slow rate, possibly requiring several centuries or even millennia to complete. For these reasons, it is believed that any subsidence fractures that may develop beneath

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Upper Huntington Creek would likely develop slowly and gradually. Because of the presence of thick, soft alluvial sediments in the drainage, any subsidence fractures that develop would likely be filled with sediment at a fast enough rate to keep the fractures continuously and completely filled with sediment as the region subsides. As these sediments are compacted over the centuries, their ability to transmit water would continuously be diminished. The amount of water potentially transmitted in these fractures would be very small relative to the amount of water in the drainage. Therefore, no measurable or perceptible impacts to water quantity in Upper Huntington Creek or Electric Lake are anticipated as a result of room and pillar extraction beneath these areas.

5.2.3 Increased Sediment Loading Resulting From Subsidence Of Creeks

As discussed in Section 5.1.2, differential subsidence of surface water drainages has the potential to increase the sediment load of streams.

Under Alternative 3, the potential for increased sediment loading resulting from subsidence would be the same as those under Alternative 2, with the exception that sediment load increases could occur in perennial drainages. Whereas sediment loading in ephemeral or intermittent drainages is only of consequence for part of the year when these watercourses are transporting water and sediment, if perennial drainages are affected, this impact could occur throughout the year.

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6.0 POTENTIAL ENVIRONMENTAL CONSEQUENCES — GROUNDWATER

6.1 ALTERNATIVE 2: LEASE WITH BLM STANDARD LEASE TERMS AND CONDITIONS AND FOREST SERVICE SPECIAL COAL LEASE STIPULATIONS

6.1.1 Potential Impacts to Groundwater Systems

There are two mechanisms through which underground coal mining has the potential to impact groundwater resources. The first mechanism is the direct interception of groundwater by mine workings. The second mechanism is by interruption or deformation of strata overlying subsided areas. Each of these mechanisms is discussed below.

Direct Interception of Groundwater

Direct interception of groundwater results in the local dewatering of deep groundwater systems. As described in Section 3.3, groundwater that is encountered in underground workings at the Skyline Mine and groundwater that may be encountered in the RFDS area issues from either deep Blackhawk Formation groundwater systems or Star Point Sandstone groundwater systems.

Deep Blackhawk Formation groundwater systems do not have good hydraulic communication with the surface as indicated by radiocarbon ages that are many thousands of years, the lack of tritium, and the rapid decline of inflow rates after a water-bearing feature is encountered. What this suggests is that the dewatering of these horizons should not induce renewed recharge to these systems and therefore there should be no impact to the hydrologic balance in the recharge areas. Because deep Blackhawk Formation groundwater systems drain quickly when encountered, it is doubtful that these systems support perceptible or quantifiable discharge to the surface.

Star Point Sandstone groundwater systems also discharge water to mine workings that is many thousands of years old. Because of the lateral continuity of the Star Point Sandstone, it is possible that there may be hydraulic continuity from the recharge zone to where water is encountered in mine workings. However, pump test analysis (Mayo and Associates, 1997a; Bills, 2000) indicates that the hydraulic conductivity of unfractured Star Point Sandstone is low, and thus recharge to the Star Point Sandstone is largely constrained by the low permeability of the unit. Thus it is unlikely that dewatering of the sandstone would perceptibly or quantifiably impact the hydrologic balance in the recharge

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area. Due to the antiquity of water in the Star Point Sandstone, it is unlikely that discharge from the Star Point Sandstone, wherever that may occur, is important to the hydrologic balance of that area.

Subsidence-Related Impacts to Groundwater

Subsidence-induced interruption and deformation of strata has the potential to impact groundwater systems by 1) enhancing existing or creating new flow pathways for vertical groundwater migration and thereby partially or wholly dewatering a saturated horizon, and/or by 2) locally altering natural groundwater flow directions. In the study area, subsidence has the potential to impact near surface groundwater systems and deep bedrock groundwater systems that exist above the mined horizon.

The potential impacts of mining-related subsidence to dewater near surface groundwater systems are, for the most part, analogous to the potential impacts to perennial creeks (Section 5.2.1). As with perennial creeks, the operation of near surface groundwater systems is fundamentally dependent on the presence of low-permeability bedrock horizons that create perched groundwater conditions. The critical question that must be evaluated, then, is how would subsidence and subsidence-related fracturing affect the bedrock immediately below where these systems operate.

The Geology, Mining, Subsidence, and Seismicity Technical Report (NorWest, 2000) describes the reaction of rock strata above longwall mined areas as a function of overburden thickness. There are four zones of movement above subsided areas. These include the cave zone, fracture zone, flexure zone, and soil zone. In the RFDS area the fracture zone is estimated to extend above the Lower O'Connor B seam up to 375 feet for single seam extraction and up to 675 feet above the Flat Canyon Seam for double seam extraction. The minimum overburden thickness in the RFDS area where longwall mining could occur is about 900 feet for the Lower O'Connor B seam. Most of the surface is more than 1,200 above the Lower O'Connor B seam. Thus, both colluvial/shallow bedrock groundwater systems operate entirely with the flexure zone and soil zone.

The expected response in the flexure zone is that there would be movement along existing joints and bedding planes, which can open up in zones of tension. Vertical movement along fractures typically remains within individual beds and is not vertically extensive unless massive strong beds are in the zone. Weaker rocks in the upper part of the zone may flex without causing failure along joints or tension cracks to form. In the soil zone materials are weak and generally do not fail due to the ability to flex. Tension crack formation does occur in the active tension zone but cracks close again when the compression zone reaches that point.

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Based on the previous discussion, it is expected that the integrity of the low permeability bedrock horizons that are fundamental to the operation of colluvial/shallow bedrock groundwater systems generally would not be compromised. The exception would be the creation of tension cracks in high-strain zones as discussed below.

In zones of permanent tension that form above such features as panel ends, fire barrier pillars, and the outer edge of a block of panels, tension cracks are possible in shallow subsurface strata and may persist for a time. The degree to which these tension cracks impact shallow groundwater systems would be dependant on the degree of interconnectedness of fractures with other fractures or permeable horizons that are capable of receiving water. However, it is anticipated that because of lithologic heterogeneity and the abundance of swelling clays in the Blackhawk Formation, that tension fractures which do form would heal quickly.

Experience in the Skyline Mine area also suggests that shallow bedrock horizons are not compromised to the degree that there is perceptible or quantifiable dewatering of a stream or spring. The experience at Burnout Creek is especially important (Section 4.1.3). The strata underneath Burnout Creek have been subjected, in various locations, to tensile stresses caused by panel ends, stacked double seam fire barrier pillars, and the outer margin of a block of panels. Nevertheless, there has not been a decrease in stream discharge. Second, the response of springs and wells (Section 4.1.1) to undermining and subsidence suggests that subsidence does not result in dewatering of groundwater systems. Lastly, exploration drill holes in the Blackhawk are very unstable, and when left open for a few days, slough badly (Vaughn Hansen Associates, 1982) suggesting that any subsurface openings created by subsidence would heal quickly.

Subsidence also has the potential to locally alter groundwater flow directions. This is caused by slightly altering the attitude of shallow bedrock or by subtle disturbances in unconsolidated material. While this could affect the discharge rate from an individual spring, the total discharge from the groundwater system would remain the same as groundwater is diverted to other nearby existing discharge locations or new discharge locations.

The probability of impacting deep bedrock groundwater systems that exist above the mined horizon decreases with increasing overburden thickness. As noted in Section 4.1.2, subsidence causes water level perturbations in deeper groundwater systems but there is no indication that the groundwater systems monitored by wells have been dewatered. If a saturated horizon in the deeper bedrock were dewatered, it is unlikely that there would be a perceptible or quantifiable impact

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to the hydrologic balance because of the limited recharge and discharge of these systems.

Summary

Although mine workings encounter a large amount of groundwater, sometimes more than 1,000 gpm, this water is derived from storage in the groundwater system. Where groundwater naturally discharges from deep bedrock groundwater systems, it is surmised that the discharge rate is several orders of magnitude less than the rate that water inflows to mine workings. It is estimated that there is a remote probability that direct interception of groundwater by mine workings would cause perceptible or quantifiable impacts to the hydrologic balance at either the recharge or discharge areas of deep groundwater systems.

It is estimated that there is a negligible probability of perceptibly or quantifiably dewatering near surface groundwater systems as a result of mining-related subsidence and fracturing. There is a possibility that there may be some local alterations in groundwater flow direction, which might affect the discharge from an individual spring but not diminish the total discharge from the groundwater system supporting that spring.

In the event that there were a perceptible or quantifiable mining-related diminution of groundwater discharge at a developed spring location in the area, the application of SCLS #17 would require the lessee to replace any water lost from developed groundwater sources with water of similar quality.

6.1.2 Trans-Basin Diversion of Intercepted Groundwater

The potential for transbasin diversions arises if water that is encountered underground is discharged to another drainage other than the one where the water would naturally discharge. The Skyline Mine area and mine workings straddle the surface water divide between two major river basins of the region, the Price River and the San Rafael River basins. Most of the surface area in the RFDS area is within the San Rafael River Basin. The southwest corner of the RFDS area is within the Gooseberry Creek drainage (Figure 2.1), which is tributary to the Price River Basin. It is important to note that the Upper Huntington Creek drainage is a peninsula-like extension of the San Rafael River Basin into the Price River Basin.

At the Skyline Mine, groundwater is encountered underground on both sides of the surface water drainage. However, all water encountered in the mine is currently discharged to Eccles Creek, a tributary to the Price River. It is anticipated that CFC would discharge groundwater encountered by mining in the RFDS area to Eccles Creek, unless a discharge point could be permitted in the Upper Huntington Creek drainage. It presently would not be possible to

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discharge mine water to the Upper Huntington Creek drainage because watercourses within the outer boundary of the National Forest are designated by the State of Utah to be "High Quality Waters – Category 1" and new point source discharges into these waters are prohibited (UAC R317-2-3).

It is important in the analysis of potential transbasin diversion to identify the source of water intercepted by mine workings and the natural discharge locations of intercepted water. As described in the previous section, mining at the Skyline Mine does not appear to have created pathways for the downward migration of water from the surface or near surface to the mine. Thus, water that is intercepted in mine workings is likely groundwater that is naturally resident in the horizons immediately above or below the mined coal seam. It is anticipated that mining in the RFDS area would only encounter water that naturally occurs in the strata immediately above or below the mined coal seams.

As described in Section 3.2.3 and 3.2.4, groundwater in deep Blackhawk Formation groundwater systems and in the Star Point Sandstone groundwater systems does not appear to naturally discharge to the surface within the study area. It is surmised that the East Gooseberry Fault may intercept groundwater flowing westward in the deep bedrock. Where groundwater is conveyed by the East Gooseberry Fault is not known.

Because the natural discharge locations of groundwater potentially encountered by mining in the RFDS area are only speculative, the nature of any transbasin impact cannot be stated with certainty. However, the magnitude of this impact, regardless of where it occurs, can be estimated by considering the mean residence times of groundwater encountered by mining. Mayo and Associates (1996, 1999a) report that the radiocarbon ages of groundwater inflows to the Skyline Mine are many thousands of years. What this means is that the rate of flow through these systems is slow and thus the magnitude of discharge from these systems is likely meager. Thus it would not be correct to assume that the rate of discharge from mine workings in the RFDS area is equivalent to the possible decrease in natural groundwater flow rates at the discharge location. Mining accelerates the rate of groundwater discharge from deep bedrock inactive flow groundwater systems.

A helpful analogy would be a livestock watering trough that is fed by a small trickle. Once the trough is full, water spills from the trough at the same rate that water enters the trough—at a trickle. If the bottom of the trough were punctured, the magnitude of discharge from the trough would be large compared to the trickle that once discharged from the system. What is lost from the pre-punctured

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system is the small trickle, not the large outflow resulting from the trough being breached.

It is highly probable that if water intercepted by mining in the RFDS area is discharged to a basin other than that which the water was naturally tributary, there would be not be a perceptible or quantifiable impact to the hydrologic balance of the basin from which water was diverted.

6.1.3 Impacts to Water Rights Resulting From The Diminution Of Spring Flows

Numerous water rights for springs are held in the RFDS area by both private land owners and the U.S. Forest Service. As described in Section 6.1.1, perceptible or quantifiable impacts to spring discharge rates are not anticipated. If there are no impacts to spring discharge rates then there should be no impairment of water rights. In the event that there was a mining-related flow diminution of an appropriated spring, Utah Code 40-10-18 requires the mine operator to "promptly replace any state appropriated water in existence prior to the application for a surface coal mining and reclamation permit."

A water right has a specified point of diversion. It is possible that if a spring discharge location shifted as a result of subsidence, this impact a water right because water could no longer be diverted at the specified point. If such a situation were to occur, the State Engineer would need to make a finding.

6.1.4 Potential Degradation of Water Quality in the Mine Environment

The quality of water that passes through the mine environment may be degraded by chemical interactions with naturally occurring minerals or materials and equipment introduced into the mine. Potential environmental impacts can occur if degraded water discharges from the mine workings either during active mining or after mining activities cease. These potential impacts are discussed below.

Acid mine drainage is caused by the oxidation and dissolution of naturally occurring sulfide minerals (principally pyrite and marcasite) when these minerals are exposed to the atmosphere in mine openings. Under natural (non-mined) conditions, the lack of available oxygen in the vicinity of the coal seams prohibits this reaction. The oxidation of sulfide minerals results in the release of hydrogen ions (acid), and increased iron and sulfate concentrations. However, acid mine drainage is rarely a problem in western coal mines because free hydrogen ions readily dissolve carbonate minerals (calcite and dolomite), which are abundant in the mine environment, and the sulfur content of coal is low. The dissolution of carbonate minerals results in increased concentrations of bicarbonate, calcium ion, and magnesium ion. Both of these reactions increase the total dissolved solids (TDS) concentration of mine water. Ion exchange of calcium ion and

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magnesium ion for sodium ion is common due to the presence of clay and zeolite minerals (Mayo and Associates, 1994). Ion exchange reactions do not appreciably change the TDS concentration of mine water. The end result of these interrelated and secondary mineral reactions is that after water has passed through the mine environment, it is elevated in sodium ion, bicarbonate, and sulfate relative to groundwater that flows into the mine. Mine discharge water of this type is common from coal mines in the Wasatch Plateau.

Increased iron concentrations resulting from the oxidation of sulfide minerals does not typically result in negative water quality impacts in the Wasatch Plateau. Because most mine discharge waters and receiving waters are basic, dissolved iron is rapidly precipitated as iron hydroxides as the water comes in contact with the atmosphere and microbes at the surface. Water flowing in a surface stream that is fully aerated should not contain more than a few micrograms per liter of uncomplexed iron at equilibrium in the pH range of about 6.5 to 8.5 (Hem, 1985). Fine-grained iron precipitates are sometimes noted at mine water discharge points. These precipitates are generally not prolific enough to cause notable suspended sediment water quality impacts.

The dissolution of gypsum, halite, or other highly soluble minerals, which occur naturally in small quantities in the rocks adjacent to mine openings, may degrade the quality of the water discharging from the mine. The dissolution of gypsum increases the calcium ion, sulfate, and TDS concentrations of mine water. The dissolution of halite increases sodium ion, chloride, and TDS concentrations. These dissolution reactions affect water quality if these minerals are present in abundant quantities along groundwater flowpaths newly created by mining. This impact is generally not observed in Wasatch Plateau coal mines.

Some materials used in mining operations, when brought into contact with groundwater, have the potential to adversely impact the quality of water discharged from the mine. Mayo and Associates (1994) report that in the late 1980s gypsum rock dust was used in the Skyline Mine. This practice resulted in exceedence of TDS limits for mine discharge water because of the high solubility of gypsum. In March 1991, Skyline Mine began using carbonate rock dust, which is considerably less soluble in water. As a result of this change water quality of mine discharge water eventually improved. Mayo and Associates (1994) also note that part of the increase in TDS of mine discharge waters relative to mine inflow waters is a result of the oxidation of longwall emulsion fluid. When fugitive longwall emulsion fluid comes in contact with mine waters, the organic molecules in the fluid are readily oxidized by bacterial action resulting in the production of carbon dioxide gas. Carbon dioxide gas reacts with water to form carbonic acid (H_2CO_3), which dissociates into hydrogen ions and bicarbonate.

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The liberated hydrogen ions are rapidly consumed in reactions with naturally occurring carbonate minerals, resulting in increased calcium ion, magnesium ion, and bicarbonate concentrations in mine water.

During the course of mining operations, many tons of ferrous metals are utilized. Some of the metal objects are removed after mining ceases and, as a necessity, others are left in place. The largest permanent use of metal in mining operations is in roof-support. Thousands of metal roof-bolts are installed at regular spacings in the mine roof to prevent roof collapse. In some locations, wire mesh is also installed. For safety reasons, it is not possible to remove the roof-bolts or wire mesh after mining in an area has ceased. Additionally, metal is used in stoppings and man-doors, overcasts, cribbing, well casings, pipes, and miscellaneous items such as hangers and signs. There is the potential for the metal in these objects to oxidize (rust) as it comes in contact with water in the mine environment.

Oxidation of ferrous materials results in the release of iron into the water. The magnitude and rate of the potential oxidation is constrained by a complex variety of factors, including the temperature, Eh, and pH of the water, the pressure on the system, the presence or absence of bacteria, and the solute chemistry of the mine water. As a result, this potential impact is difficult to quantify. However, discharge water from Wasatch Plateau coal mines has not been degraded by elevated iron concentrations. To what extent the iron concentration in mine discharge water may change after mining operations cease is difficult to determine. However, the concentration would likely remain low because dissolved iron is rapidly precipitated as iron hydroxides as noted previously.

Mining equipment may be abandoned underground as dictated by safety or economic considerations. However, it is Forest Service policy to not allow any new solid waste disposal facilities on National Forest System lands and to not add to existing facilities. Equipment left underground would be considered a solid waste and it would not be consistent with Forest Policy to allow the abandonment of equipment underground. Further, Section 7 of the BLM lease form requires lessees to remove equipment and materials "as required by the authorized officer." In the event that it were necessary to leave equipment underground for safety reasons, it is unlikely that corrosion of abandoned equipment would degrade the quality of water in the mine environment. Mining equipment, such as longwall mining machines, roof bolters, and continuous miners, is made of high quality steel alloy containing chromium. The metal is highly resistant to corrosion. Calculations of the corrosion potential of the steel used in longwall mining machines have been performed by the University of Utah Metallurgy Department (BLM, 1998). They determined that it would take thousands of years for the metal to corrode away, and that the metal would need to be ground to a fine

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particulate for chromium to be dissolved. The University of Utah (BLM, 1998) report indicates that the general conditions required to hasten the corrosion of this metal do not exist in the Utah coal mining environment.

Petroleum, oils, and lubricants are regularly used in mining operations. These materials may degrade discharge water quality if they are mishandled or abandoned underground and exposed to water passing through the mine. Any toxic or hazardous materials which are used underground would have to be removed from the mine prior to closure.

Although the impacts to water quality are expected to minimal, the application of SCLS #19 would require that the operator remove mine equipment and materials that are not needed for continued operations, roof support, and mine safety from underground workings prior to abandonment of mine sections.

6.2 ALTERNATIVE 3: LEASE WITH BLM STANDARD LEASE TERMS AND CONDITIONS ONLY

The potential impacts to groundwater resources under this alternative are the same as under Alternative 2, except that the area of potential impact increases as a result of not applying stipulations that preclude the subsidence of perennial creeks, paved roads, and structures.

By not applying the SCLS under this alternative, impact mitigation dictated by SCLS #17 and SCLS #19 would not be required.

Under this alternative, the operator would not be specifically required to remove equipment that is not incorporated into the mine. However, as noted, it is Forest Service policy to not allow any new solid waste disposal facilities on National Forest System lands and to not add to existing facilities. Equipment left underground would be considered a solid waste and it would not be consistent with Forest Policy to allow the abandonment of equipment underground. Further, Section 7 of the BLM lease form requires lessees to remove equipment and materials "as required by the authorized officer."

Nevertheless, if mine equipment were left underground, it is unlikely that ferrous equipment such as longwall shields, longwall shears, or continuous miners would perceptibly or quantifiably impact water quality even if these pieces of equipment were abandoned in areas that subsequently flooded. As noted in the previous section, the general conditions facilitating oxidation of metals do not exist in Utah coal mines. Minor water quality impacts could occur if lubricants were not

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drained from the equipment prior to abandonment. The magnitude of this impact would depend on the amount of organic materials, the volume of water in a flooded section, and the rate of intrinsic bioremediation. Computerized controls on equipment may contain lead, cadmium, mercury, and chromium and could cause water quality impacts if located in a flooded section. However, the magnitude of this impact is estimated to be minimal because of the small amount of controls relative the volume of water likely to be impounded and the slow oxidation rates of these materials in the mine environment.

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7.0 RECOMMENDATIONS FOR MONITORING AND MITIGATION

7.1 SURFACE WATER

CFC has monitored stream discharges and water quality at eight sites in the RFDS area. For the SMCRA mining permit, an operational monitoring program that would need to be approved by UDOGM would be developed that builds on the baseline monitoring. It is recommended that, where possible, long-term discharge measurement devices be installed at locations selected for operational monitoring. This would facilitate greater accuracy and consistency in the flow measurements, which greatly increases the usefulness of these data. It is recommended that continuous recording devices be installed at surface-water monitoring stations on critical drainages.

Additionally, it is recommended that those stream reaches that have been classified as likely being perennial be monitored periodically in the future to refine the delineation of perennial reaches in the RFDS area.

Perceptible or quantifiable impacts to surface water discharge rates are not expected as a result of mining in the RFDS area. Therefore, no measures are recommended to decrease the likelihood of a perceptible or quantifiable impact. If surface water discharge rates were to be impacted, mitigation would be required by SMCRA for culinary drinking water sources and Utah State Code 40-10-18 for state appropriated waters. If SCLS #17 is applied to the lease, the lessee would be required to replace any water lost from creeks designated for protection with water of similar quality.

It is recommended that if mine water is discharged directly into Electric Lake that consideration be given to the placement of the discharge point. If the water is allowed to flow rapidly over the shoreline of the lake, appreciable erosion and sediment redistribution may occur. It may be advantageous to install an energy dissipating system that would decrease the discharge velocity and erosion potential of the discharging water.

Site-specific pre-mining investigations and planning should be carried out before mining proceeds in those areas where it is determined that there is high potential for subsidence-induced stream gradient reversal and pond or wetland formation. The precise locations of areas of potential stream gradient change would be a function of the implemented mining plan. Therefore, where possible, mining plans should be designed to minimize the potential for this occurrence.

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7.2 GROUNDWATER

CFC has monitored 24 springs in the RFDS area for baseline water quality and discharge. It is expected that an operational monitoring program that builds on this baseline monitoring would be required under the SMCRA permit administered by UDOGM. The most critical data that can be collected are spring discharge measurements and emphasis should be placed on collection of flow data over water quality data. No additional monitoring of groundwater resources is recommended.

Perceptible or quantifiable impacts to groundwater resources are not expected as a result of mining in the RFDS area. No measures are recommended to decrease the likelihood of a perceptible or quantifiable impact. If groundwater resources were to be impacted, mitigation would be required by SMCRA for culinary drinking water sources and Utah State Code 40-10-18 for state appropriated waters. If SCLS #17 is applied to the lease, the lessee would be required to replace any water lost from developed groundwater sources with water of similar quality.

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APPENDIX A

EIS SUMMARY

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EIS SUMMARY
SURFACE-WATER AND GROUNDWATER RESOURCES

AFFECTED ENVIRONMENT

This summary describes groundwater and surface water resources in the Flat Canyon Coal Lease Tract and the adjacent fee lands. Together the tract and the private lands are described as the 'RFDS area' in this summary. The study area for this investigation extends beyond the RFDS as shown in Figure 1. This investigation relies on data, information, and experience from the existing Skyline Mine permit area (Figure 1), which is east of and contiguous with the RFDS area. This area is referred to throughout this report as the Skyline Mine area.

SURFACE WATER

All surface waters in the study area, with a single exception, drain into Upper Huntington Creek, which is a tributary of the San Rafael River. The San Rafael River flows into the Green River approximately 80 miles southeast of the study area. A small portion (< 6%) of the study area is in the Upper Gooseberry Creek drainage. Upper Gooseberry Creek flows into Fish Creek above the Scofield Reservoir on the Price River. The Price River flows into the Green River approximately 60 miles southeast of the study area. The region of investigation for this analysis is an area of approximately 12.7 square miles. Perennial stream reaches have been identified in Boulger, Flat, Swens, Little Swens, and Cunningham Canyons. Upper Huntington Creek, which defines the northern and eastern boundaries of the study area, is also a perennial stream. In order to simplify the characterization and analysis of surface water systems in the study area, the surface water drainages have been divided into sub-basins. These sub-basins are shown on Figure 2. Also shown on Figure 2 are the reaches of the individual streams that have been classified as perennial for this analysis.

Several drainages that have not previously been classified as perennial were determined to possibly be perennial as a part of this study. These reaches are indicated on Figure 1.2. Determinations of possibly perennial reaches were based on field observations of streamflow and vegetation types and through inspection of aerial photographs.

The specific characteristics of each sub-basin in the study area are described below.

Flat Canyon Sub-Basin

The Flat Canyon sub-basin includes an area of 1.76 square miles, which is approximately 13.8% of the study area. The gradient in Flat Canyon, approximately 0.93%, is the lowest of any of the sub-basins in the RFDS area. Flat Canyon is so called because of the broad, flat-bottomed valley floor through which Flat Canyon Creek flows. The broad riparian corridor in Flat Canyon is up to 1,000 feet wide. Flat Canyon Creek in its upper reaches, where it meanders through the broad alluvial valley, is a Rosgen (1996) E5 type stream. This reach is dominated by run features. The channel substrate underlying the creek in Flat Canyon consists primarily of thick, saturated

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glacio-lacustrine sediments. The sediments along the margin of the canyon are approximately 80 feet thick, consisting mostly of sand.

In the lower reaches of Flat Canyon Creek, the channel is more deeply incised and the gradient is much steeper (3%). This reach is a Rosgen (1996) B3 type, which consists primarily of riffles with less than 5% pools. The banks in this reach are well vegetated and stable. The substrate in lower Flat Canyon Creek consists primarily of cobbles and boulders. It appears well armored and stable.

The north-facing canyon walls in Flat Canyon are vegetated with dense conifer forests. Portions of these conifer stands have recently undergone logging. The south facing canyon walls are vegetated primarily with scattered, dense stands of quaking aspen. Flat Canyon creek is separated from the underlying coal seams by 1,000 to 1,800 feet of overburden.

Discharge and water quality at Flat Canyon Creek have were monitored in October 1999 and July 2000 (NorWest, 2000a). The October discharge measurement was 91 gpm while the July measurement was 215 gpm. The water in Flat Canyon Creek during October was of the calcium-bicarbonate chemical type with a TDS concentration of 169 mg/l.

Boulger Canyon Sub-Basin

The Boulger Canyon sub-basin, which occupies approximately 3.92 square miles, or 30.8% of the study area, is the largest of the sub-basins. Included in this area are the upper drainage (above Boulger Reservoir), which is approximately 3.22 square miles in area, and the lower drainage, which occupies an area of approximately 0.70 square miles (Figure 2). Boulger Creek is a third order stream that flows to the northeast where it joins Flat Canyon Creek and then flows into Electric Lake. The gradients on Boulger Creek are steeper than are those of the adjacent Flat Canyon creek. The gradient on the main reach below the confluence of the two forks and above the reservoir averages 1.7%.

The reach of Boulger Creek extending from below the upper forks to Electric Lake contains reaches that are Rosgen (1996) type C3 and B3. The stream in this area, which meanders tightly, is 8-10 feet wide and is dominated by riffles and runs with a channel depth ranging from 6 inches to 2 feet. The substrate in areas of low gradient appears stable and well armored. It is composed of approximately 50% cobbles, 15% gravel, and 35% sand/silt. The stream banks in this portion of the drainage are well vegetated and appear stable. The drainage in this area supports a moderately wide strip of riparian vegetation up to approximately 350 feet wide along the valley bottom. Much of the riparian vegetation along the margins of the valley bottom appears to be supported by inflows of alluvial and colluvial groundwater from the lower canyon walls. This groundwater also provides recharge to the creek.

Approximately 1,800 feet above the confluence with Electric Lake, a small unnamed tributary to Boulger Creek enters from the south side of the canyon (Figure 2). This stream appears to be perennial based on the narrow corridor of riparian vegetation that exists along and adjacent to the stream channel. Discharge and field parameters were measured in this drainage by Mayo and Associates during October 1999 and July 2000. On both occasions water was flowing in the

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stream. The stream was flowing at 32.8 gpm during July 2000. Inspection of aerial photographs suggests that the stream has the appearance of being perennial for a distance of approximately one-half mile above the confluence with Boulger Creek.

The right (north) fork of Boulger Creek has an average gradient of approximately 4.3%. There is a narrow strip of riparian vegetation associated with this reach of the creak. For the first approximately 1,800 feet of this drainage, the stream is a Rosgen (1996) type B3 stream. The channel substrate in this reach is made up of material ranging from 2-inch gravels to 12-inch and greater cobble/boulder material. Runs and riffles make up approximately 60% of the stream, with approximately 40% pools. Raleigh Consultants (1992) noted sedimentation in the right fork of Boulger Creek that was attributed potentially to inactive beaver dams. The next approximately 2,000 feet of the right fork consists of a meandering Rosgen (1996) C3 type stream. The channel in this reach is approximately 10 feet wide and 6 inches deep. The stream contains approximately 80% riffles and runs and 20% pools and the substrate in this reach is made up of approximately 50% cobbles, 20% sand and silt, and 35% gravel. The stream banks appear stable. The final approximately 5,000 feet in the uppermost portion of the drainage is a steep, Rosgen (1996) type A2 or B2 stream with riffles comprising about 90% and pools 10%. The width of the stream in this reach is approximately 5 feet, with depths ranging from 4 inches in the riffles to 1 foot in the pools. The substrate in this reach is dominated by large cobbles, boulders, and bedrock.

The left (south) fork of Boulger Creek is a steep drainage with an average gradient of approximately 7.5%. The channel in the lower reach of the left fork is a Rosgen (1996) type A3 channel, while the upper, headwaters area is a Rosgen (1996) C5 or E5 type. The channel substrate in the lower part of the south fork is comprised of large cobbles and boulders. In the headwaters region of the left fork a large meadow is present in a glacial cirque. The stream channel substrate in this region consists primarily of fine-grained alluvial material. Much of the baseflow of the left fork of Boulger Creek originates from springs along the margins of this meadow.

The depth of cover separating Boulger Creek from the coal seams that may be mined ranges from 700 feet in the lower reaches near Electric Lake to more than 2,200 feet in the headwaters areas.

Discharge and water quality in Boulger Creek have been monitored at C-4, C-7, and C-8 (Figure 2; NorWest, 2000a). Discharge has been measured at C-4 (below the confluence with Flat Canyon creek) since 1997. The maximum recorded discharge, 3,120 gpm, occurred during July 1999. A minimum flow of 450 gpm was measured during October 1999. Streamwater in Boulger Creek is of the calcium-bicarbonate chemical type. TDS concentrations at C-4 have remained relatively constant during the baseline monitoring period, ranging from 140 to 190 mg/l.

Boulger Reservoir is a man-made water body with a surface area of approximately 4.52 acres with a storage capacity of 45 acre-feet. The reservoir is a popular recreation site for fishing, swimming, and rafting. Boulger Reservoir is separated from the underlying coal seams by approximately 1,200 feet of cover. Comparison of discharge and water quality measurements

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from C-8 (immediately above the reservoir) and C-7 (immediately below the reservoir) suggests that the water quality of Boulger Creek is not degraded as a result of being in the reservoir.

Swens Canyon Sub-Basin

The Swens Canyon sub-basin occupies 2.33 square miles or 18.4% of the study area. The stream drains westward into Upper Huntington Creek, with a gradient averaging 3.1%. Swens Canyon Creek is a third order stream that meanders tightly, particularly in the lower reaches of the drainage. The stream banks and adjacent areas are heavily vegetated with riparian vegetation and appear to be relatively stable. Swens Canyon Creek appears to be a gaining stream over its entire reach. It is apparent that much of the riparian vegetation along the margins of the valley bottom in Swens Canyon Creek is not sustained by direct recharge from the stream. Rather, these vegetated areas appear to be sustained by discharge from shallow, colluvial groundwater systems discharging low on the canyon walls.

Along the length of Swens Canyon Creek, there is evidence that the hillsides have periodically encroached into the stream channel resulting in impounding of the stream. These encroachments appear to be the result of mass movement (i.e. hillside slumping) of the Blackhawk Formation sediments that compose the hillsides. The fact that the lowermost canyon slopes are commonly wet from groundwater seepage may be a contributing factor to the frequency of mass movements. It is evident that the drainage has also been periodically dammed in many locations by beavers. As a result of these occurrences, thick sections of sediment have been emplaced by stream deposition in the backwater areas that existed when the stream was dammed, while adjacent areas have not experienced that degree of sedimentation. These conditions, in conjunction with changes in geologic formation or geologic structure underlying the stream bottom, have resulted in a somewhat stair-stepped topography in the canyon bottom.

The lower 5,000 feet of the stream channel in Swens Canyon is comprised of fine-grained material interspersed with gravel, cobbles, and occasional boulders. This reach is a Rosgen (1996) C3 type. This reach of the stream consists of approximately 80-90% runs and riffles, and 10-20% pools. In this reach the stream meanders tightly and the stream channel is well incised in its channel. Groundwater inflows are apparent along much of the extent of this reach of the drainage. These commonly consist of small springs or seepage fronts that emerge near the transition between the valley bottom and the canyon walls.

A small tributary to Swens Canyon Creek enters from the south approximately 1,000 feet above the confluence with Upper Huntington Creek. This tributary, which extends for approximately one-half mile, appears to possibly be perennial based upon the well-established riparian vegetation along the stream banks. No baseline discharge data are available for this tributary. However, it was noted by Mayo and Associates that there was appreciable flow in the drainage during October 1999 and again in July 2000.

The North Fork enters Swens Canyon Creek approximately 3,000 feet above the confluence with Upper Huntington Creek (Figure 2.1). This tributary is approximately 2,500 feet in length and is very steep. The average channel gradient is approximately 13.8%. This stream reach appears to possibly be perennial based upon the well-established riparian vegetation along the stream banks.

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No baseline discharge data are available for this tributary. However, it was noted by Mayo and Associates that there was appreciable flow in the drainage during October 1999 and again in July 2000. Much of the baseflow discharge to the stream originates from a series of springs discharging from colluvial groundwater systems in its headwaters region.

In the reach of Swens Canyon Creek extending from the confluence with the North Fork and upstream for approximately 3,500 feet the stream channel narrows considerably. In this reach, the channel substrate is dominated by cobbles and boulders. In some locations, bedrock outcrops are visible in the channel bottom. The channel, which meanders slightly in this reach, contains many active and inactive beaver dams.

In the headwaters reaches of Swens Canyon Creek, the valley broadens into a region of wide meadows and grasslands. The stream channel in this reach is a narrow Rosgen (1996) A2 type. Much of the baseflow to Swens Canyon Creek appears to originate in this region. Many springs and groundwater seepages enter the stream channel from the lower hillsides adjacent to the stream.

Swens Canyon Creek is separated from the underlying coal seams by 800 feet of cover at the confluence with Upper Huntington Creek to approximately 2,400 feet of cover in its headwaters area.

Swens Canyon Creek has been monitored by CFC at C-3 since 1997 (Figure 2; NorWest, 2000a). Discharge has ranged from 30 gpm during October 1998 to 300 gpm during both July 1998 and July 1999. The water in Swens Canyon Creek is of the calcium-bicarbonate chemical type. Baseline TDS concentrations in Swens Canyon Creek have ranged from 177 to 213 mg/l.

Little Swens Sub-Basin

Little Swens Creek flows northeast from highland areas toward its confluence with Upper Huntington Creek. The basin encompasses an area of 0.98 square miles, which is 7.7% of the study area. The drainage is steep, with a stream gradient of approximately 5.9%. Little Swens Canyon Creek is a tightly meandering stream with relatively stable, well-vegetated stream banks. Like the adjacent Swens Canyon drainage, there is evidence of a long history of encroachment of hillsides by mass movement onto valley floor. There is also evidence of a long history of beaver dam construction in the drainage. These conditions have resulted in accumulation of sediment in some areas with considerably less sediment in other areas resulting in a somewhat stair-stepped topography on along the canyon bottom.

The stream channel in the lower approximately one-half mile of the drainage is a Rosgen (1996) B3 type. The valley bottom in this reach is approximately 30 feet wide. The channel substrate in this reach consists of gravel, cobbles and boulders. Generally, the stream channel in Little Swens Canyon is more dominated by rocky material and appears to have less fine-grained material in the substrate than does the adjacent Swens Canyon. The stream banks in this reach are heavily vegetated and appear stable.

In the next 1,000 feet of the drainage, the channel narrows slightly and the channel substrate is dominated by boulders and bedrock. This reach appears to have been impacted considerably by beaver dams and encroachment of the lower canyon walls into the drainage by mass movement. This reach of the drainage is a Rosgen (1996) A2 type.

A small reservoir has been constructed in the upper reaches of this drainage. This pond has a surface area of approximately 3.15 acres and is used for recreation purposes by a privately owned girl's camp that surrounds the pond.

The Little Swens Canyon drainage is separated from the underlying coal seams by 1,100 feet of overburden near the confluence of the stream with Upper Huntington Creek. In the headwaters regions, the overburden is approximately 2,100 feet. The overburden between the reservoir at the girls camp and the coal seams ranges from about 1,900 to 2,000 feet

Baseline water quality and discharge measurements have been performed on Little Swens Canyon Creek at C-2 from 1998 to 2000 (Figure 2; NorWest, 2000a). Discharge at C-2 has varied from 16 gpm during October 1998 to 211 gpm during July 1998. Discharge in the creek is of the calcium-bicarbonate chemical type. TDS concentrations have ranged from 151 to 214 mg/l.

Cunningham Canyon Sub-Basin

The Cunningham Canyon sub-basin, with an area of 0.92 square miles, is a relatively small drainage located near the southern margin of the RFDS area. Cunningham Canyon Creek is an easterly flowing drainage that flows into Electric Lake in the Upper Huntington Creek drainage. The drainage has a steep gradient, averaging 8.0%. The channel substrate in the upper reaches is dominated by cobbles and boulders. In the lower reaches, near the confluence with electric lake, the channel substrate is dominated by fine-grained materials including silt and soil. The stream is entrenched below the land surface by approximately 1 to 2 feet in the lower reaches of the drainage. Riparian vegetation along the stream banks and adjacent flood plain in the lower reaches of the canyon is dense and the stream channel appears stable.

Water quality and discharge have been monitored by CFC at C-5 (Figure 2; NorWest, 2000a) from 1997 to 2000. Discharge at C-5 has varied from 20 gpm in October 1998 to 162 gpm during October 1997. TDS concentrations at C-5 have varied from 118 to 165 mg/l.

The Cunningham Canyon drainage is separated from the coal seams by 700 feet in its lower reaches near Electric Lake to approximately 1,900 feet in the headwaters area.

Upper Huntington Creek Sub-Basin

Within the RFDS area there are a series of unnamed small, east and northeast facing ephemeral drainages to Upper Huntington Creek (Figure 2). These drainages, which all exist on the steep, western slope of Upper Huntington Creek, range in size from 0.4 to 0.78 square miles. Gradients of the unnamed Upper Huntington Creek sub-basins are all very steep, ranging from approximately 17% to 32%.

None of these drainages are known to support perennial streams. One intermittent stream located immediately south of Little Swens Canyon (Figure 2) was monitored for discharge and field parameters by CFC in July 2000. Discharge from this stream was meager at 7 gpm.

The overburden separating the unnamed Upper Huntington Creek drainages from the coal seams ranges in thickness from approximately 700 feet near Electric Lake to more than 2,000 feet in the highland areas above Huntington Canyon

Upper Gooseberry Creek Sub-Basin
A small portion (0.73 square miles, less than 6%) of the RFDS area drains to the Upper Gooseberry Creek drainage. Gooseberry Creek drains to the north-northwest and flows into Fish Creek which discharges to Scofield Reservoir. While Upper Gooseberry Creek near the RFDS area may possibly be perennial, the stream itself is beyond the RFDS area and would not be undermined. For this reason, this stream has not been investigated.

All of the Upper Gooseberry Creek sub-basin within the RFDS area is separated from the coal seams by more than 1,500 feet of cover.

Summary of General Characteristics of Surface-Water Systems in the RFDS Area
Both ephemeral and perennial drainages in the RFDS area are supported in the late winter and spring months by the annual snowmelt event. Because of the large quantities of snowmelt water relative to the amount of groundwater that can be stored and discharged from shallow groundwater systems in the area, perennial streams commonly have high-flow discharge rates that exceed their low-flow baseflow discharge rates by many times.

Perennial streams in the RFDS area exist where 1) there is adequate groundwater recharge and subsurface storage capacity in the drainage basins to sustain discharge from shallow groundwater systems throughout the year and 2) there is a low-permeability confining layer beneath the stream that prevents downward percolation of water in the stream channel (i.e. the stream is perched).

Field observations by the principal authors during 1997-2000 suggest that the perennial streams in the RFDS area are generally gaining streams. Observations of stream conditions in the springtime and late fall suggest that this condition persists throughout the year. The streams gain flow from discharge from shallow groundwater systems in the form of springs, seeps, and discharge directly to the stream channel. These are common along the lengths of the perennial drainages.

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Climatic Setting

The study area is located in an area of subalpine climate. Precipitation is measured at the Skyline Mine surface facility in Eccles Canyon west of the study area. Between 1985 and 1995 the average annual (calendar year) precipitation ranged from 17.2 to 29.4 and averaged 23.9 inches (Mayo and Associates, 1996). Monthly average temperatures at the mine range from 8.0 to 74.4 °F (CFC, 1999).

The National Resource Conservation Service (NRCS) maintains two high elevation precipitation stations east of the study area. During the period 1961-1990 (NRCS, 1995) the average annual precipitation was 29 inches at the Mammoth-Cottonwood Station (elevation 8,800 feet), and 33 inches at the Red Pine Ridge Station (elevation 9,200).

The study area is in a region that has experienced several extremely wet years during the early and mid 1980s, followed by an extended drought from 1987 to 1993. Since 1993 the region has enjoyed mostly wet conditions. However, beginning in January 2000 the region entered a drought period. It is important to note that most baseline hydrologic collection by CFC occurred during the moderately wet period in the late 1990s.

Geologic Setting

The geology of the study area has been described in the Geology, Mining, Subsidence, and Seismicity Technical Report (NorWest, 2000b) prepared concurrently with this report. Five bedrock formations of concern to coal mining activities in the study area are, in descending stratigraphic order, the North Horn Formation, Price River Formation, Castlegate Sandstone, Blackhawk Formation, and Star Point Sandstone. These rocks are composed of interbedded shale, mudstone, siltstone, and sandstone layers that are laterally discontinuous. The heterogeneity and lateral discontinuity of these rocks have a profound effect on water-bearing and water-transmitting properties. Water is not generally transmitted great distances either vertically or horizontally, and the many low-permeability units create perched conditions. Unconsolidated alluvial, colluvial, and glacial deposits as well as soil are important hydrogeologic units in the study area.

Groundwater Systems

The concept of a groundwater system refers to 1) where and how recharge occurs, 2) how flow is accommodated, and 3) where and how groundwater discharges. Five types of groundwater systems are defined in the study area. These systems are:

- colluvial/shallow bedrock groundwater systems;
- Boulger Canyon alluvial groundwater system;

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- Flat Canyon groundwater system;
- deep Blackhawk Formation groundwater systems; and
- Star Point Sandstone groundwater systems

These five systems have been defined because stratigraphic, lithologic, and structural constraints cause each type of system to operate differently. The concept of a groundwater system is limited to how a system operates and does not indicate or preclude hydraulic communication among the systems of a given type. This concept is useful in places such as the study area where groundwater commonly occurs in localized areas, and where aquifers, in which there is hydraulic communication over a greater expanse, do not exist.

Each type of groundwater system is described below.

Colluvial/Shallow Bedrock Groundwater Systems

Colluvial/shallow bedrock groundwater systems occur throughout the study area. This type of system occurs in the thick soil mantle, slope wash colluvial deposits, and shallow bedrock in which the porosity has been enhanced by weathering or fracturing. Groundwater in shallow alluvial deposits is alsoincluded in this type of system. The abundance of relatively low-permeability horizons in bedrock formations of the study area hinders appreciable migration of groundwater to deeper stratigraphic horizons and creates perched groundwater conditions in colluvium and shallow bedrock.

The depth of colluvial/shallow bedrock groundwater systems has not been investigated but is estimated to range from several tens of feet to perhaps over 100 feet in some areas. Data from the Skyline Mine area indicate that a water monitoring well (W79-14-2a) completed in the Blackhawk Formation at a depth of 102 to 122 feet exhibits seasonal water level responses (Mayo and Associates, 1996), which, as discussed below, is a characteristic of colluvial/shallow bedrock groundwater systems. However, two wells completed at depths ranging from 150 to 200 feet do not show seasonal water level responses.

Colluvial/shallow bedrock groundwater systems are directly recharged by snowmelt, especially snow that melts relatively slowly in dense wooded stands common in the study area. Groundwater flow follows topographic gradient and flow path lengths are relatively short: no more than from the top of a ridge to a canyon bottom.

Groundwater in colluvial/shallow bedrock systems supports discharge from nearly all of the springs in the study area. Discharge from this type of system directly to creeks is indicated by gaining stream flows. Groundwater discharge from this type of system occurs primarily along the bottoms of canyons. Some groundwater discharge occurs higher on a number of hillsides because of 1) local breaks in slope such as in the head of Swens Canyon where glacial moraine materials create a less steep slope, or 2) groundwater in permeable shallow bedrock, such as a sandstone paleochannel or the Castlegate Sandstone, encounters a less permeable bedrock horizon.

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Storage in colluvial/shallow bedrock groundwater systems is small because of the generally limited depth of colluvial and shallow bedrock materials, short flow path lengths, relatively large hydraulic conductivities, and relatively steep hydraulic gradients. Consequently, this type of groundwater system is acutely sensitive to seasonal and climatic variations in precipitation. Seasonal and climatic dependence is demonstrated by variations in spring discharge rates. Discharge from springs is typically greatest in the springtime and declines appreciably during the summer and fall months. A number of springs had lower discharges in springtime 2000 than during previous springtimes. This reflects sensitivity to climatic changes such as the drought conditions that the region has seen since the beginning of 2000.

Spring and seep survey data also indicate the dependence on seasonal recharge. The total discharge from all of the springs located in the Fall 1997 survey was 1,073 gpm. During the following spring the total discharge was 2,895 gpm, a nearly three-fold increase. Although these data were not collected during the same snowmelt recharge cycle, both surveys were conducted during similar moderately wet climatic conditions.

That springs respond quickly to season and climate suggests that time between recharge and discharge in colluvial/shallow bedrock groundwater systems is less than one year. As noted, much of the baseline discharge data for these springs have been collected during a lengthy wet-spell. Because of the heavy climatic dependence of these springs, it is expected that many of the springs in the study area would have much lower discharge rates or dry up in drought years.

CFC has collected unstable isotopic data from five springs in the study area (NorWest 2000a). All spring waters sampled in the study area contain anthropogenic carbon and abundant tritium. These compositions indicate that recharge to the groundwater systems supporting discharge from these springs occurred within the last approximately 50 years.

Boulger Canyon Alluvial Groundwater System

Alluvial sediments deposited in the relatively broad-bottomed portions of Boulger Canyon support groundwater. A distinct groundwater system has been designated for these sediments because of the comparatively larger depth and extent of these deposits relative to other, much steeper canyons in the RFDS area. The depth of this alluvium is known in one location where exploration drilling (drill hole 99-4-1; Figure 1.2) encountered 40 feet of alluvial sediments.

Groundwater in these sediments is recharged largely by interflow from colluvial/shallow bedrock groundwater systems. During dry times Boulger Creek could also provide recharge. However, visual observations of the creek by the principal authors suggest that Boulger Creek is a gaining creek year round, suggesting that discharge from the alluvial groundwater system is predominately to the creek.

Flat Canyon Groundwater System

Exploration drilling by CFC in the Flat Canyon area has revealed that there is a thick deposit of unconsolidated sediments in the canyon. Drill logs for wells 98-32-1 and 95-33-1 were provided for review by CFC. The locations of these two wells are indicated on Figure 1.2. The drill logs indicate that these sediments are 70 to 90 feet thick on the margins of Flat Canyon. These sediments consist primarily of sand and gravel with only minor fine-grained materials, and thus

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are expected to be fairly permeable. Inspection of geomorphology in air photos and in the field suggests that these alluvial sediments were likely deposited in an impoundment created by the glacier(s) in Boulger Canyon and the lateral and terminal moraine deposits of the Boulger Canyon glacier(s). Glacial moraine deposits typically have low hydraulic permeabilities (Freeze and Cherry, 1979). Consequently, water is largely impounded in glacio-lacustrine sediments behind the lateral and end moraines at the confluence of Flat and Boulger Canyons. Because of the thickness, lateral extent, and saturation of these deposits, the Flat Canyon glacio-lacustrine sediments have been designated as a distinct groundwater system.

Discharge from colluvial/shallow bedrock groundwater systems provides the bulk of recharge to the Flat Canyon glacio-lacustrine sediments.

A large portion of the discharge from the Flat Canyon groundwater system occurs directly to Flat Canyon Creek. Flat Canyon Creek does not appear to be fed by perennial creeks in any of the side drainages. Rather, Flat Canyon Creek appears to gradually gain flow throughout the year along its course due to discharge from springs and groundwater discharge directly to the creek.

A limited amount of water is also transmitted from the Flat Canyon alluvium through the glacial moraine deposits. This water supports several small wet areas on the hillslope west of Boulger Reservoir. Groundwater discharge from the Flat Canyon alluvium at this location has not been quantified or monitored. It is believed that this groundwater discharge is largely consumed by transpiration due to the presence of phreatophytes on the hillside. It is expected that because of the large storage volume in the Flat Canyon glacio-lacustrine sediments, that discharge in this location will be essentially constant even during drier climatic cycles.

Discharge from the Flat Canyon groundwater system may also occur via underflow through the basal moraine deposits or bedrock underlying the moraine deposits. Any underflow would recharge the glacial/alluvial sediments below the moraine and would ultimately discharge to either Boulger Creek below the reservoir or via groundwater inflow to Electric Lake. A small amount of water may also migrate downward and recharge underlying bedrock. However, there is no evidence suggesting that discharge occurs via these two mechanisms.

Deep Blackhawk Formation Groundwater Systems

Deep Blackhawk Formation groundwater systems occur at depths greater than about 150 feet where the Blackhawk Formation is the exposed at the surface. Deep Blackhawk Formation groundwater systems have been encountered in underground workings at the Skyline Mine and have been encountered by exploration drilling in the RFDS area (CFC, 1999). These systems occur in paleochannel sandstones that are encased in three dimensions by relatively impermeable mudstones and shales. Consequently there is poor hydraulic communication between sandstones both laterally and vertically. Groundwater in these sandstone channels may occur under unconfined or confined conditions. Confined conditions in the underlying Star Point Sandstone attest to the ability of fine-grained units in the Blackhawk Formation to act as substantial barriers to vertical groundwater flow.

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Experience at Skyline Mine and other mines in the Wasatch Plateau indicates that coal seams themselves do not bear water; in fact, water must be used to control dust as coal is cut by mining equipment.

The mechanics of deep Blackhawk Formation groundwater systems are not as well understood as the mechanics of near surface groundwater systems described above. Mining encounters groundwater in these systems at a point along the flow path but recharge and discharge locations are not obvious. Groundwater flow direction is estimated to be in the direction of bedrock dip(westward).

Mayo and Associates (1996) have determined that groundwaters in the deep Blackhawk Formation groundwater system have radiocarbon ages of 2,500 to 18,500 years and contain essentially no tritium. This suggests that these systems are hydraulically isolated from the surface and that groundwater flow is likely slow. The stable isotopic ratios of mine inflow waters are considerably more negative than shallow subsurface groundwaters, suggesting that these waters likely recharged anciently under cooler paleoclimatic conditions such as glacial periods.

Mayo and Associates (1996) cite several other lines of evidence to demonstrate that deep Blackhawk Formation groundwater systems are discontinuous and hydraulically isolated from the surface (and recharge sources). First, a 192-foot long upward well was constructed in the roof of the Lower O'Connor A Seam (Hydrometrics, 1987). The well only encountered groundwater at the 40-, 100-, and 120-foot intervals while all other horizons were dry. Similarly, a 128-foot deep well in the floor of the mine intercepted water at 98 feet. From the bottom of the mine to 98 feet the rock was not saturated. Second, discharge rates decline rapidly in newly exposed roof drips. Lastly, the total mine water discharge rate does not increase appreciably with time despite the fact that the total mined area continues to increase. The rate of discharge from mine workings is dependent on the rate of coal production and the timing of the encounter of large water-bearing features.

Faults do not appear to be important in the conveyance of water in the deep Blackhawk Formation groundwater system. CFC (1999) reports that of the 44 individual fault planes that were encountered prior to 1999, groundwater inflows occurred from only five. Four of the five appeared to intersect water-saturated sandstone paleochannels in the mine roof. Indeed, experience has indicated that most water-bearing faults encountered in Wasatch Plateau coal mines are associated with sandstone paleochannels. Thus, it is not anticipated that in the RFDS area, large volumes of water would be encountered in faults in the Blackhawk Formation. Recently large groundwater inflows have occurred in the Skyline Mine from two faults; however, these appear to be connected with the Star Point Sandstone and are discussed in the next section.

Potential discharge locations of deep Blackhawk Formation groundwater systems have not been identified. Due to the estimated low flow rates in this type of groundwater system, groundwater discharge at the natural discharge location is not expected to be large in magnitude and thus would be difficult to identify. Nevertheless, because of the westward dip of rocks in the Skyline Mine area and the RFDS area, groundwater in deep perched bedrock groundwater systems likely

discharges, under natural conditions, west of the RFDS area. However, there are no outcrops of the lower Blackhawk Formation west of the RFDS area. Instead, the lower Blackhawk Formation is dissected by the East Gooseberry Fault west of the study area (Figure 1), which likely hinders further westward groundwater flow.

Experience in the Wasatch Plateau suggests that large-offset faults are generally barriers to lateral flow across a fault due to the presence of low-permeability fault gouge. If the East Gooseberry Fault is indeed a barrier to horizontal flow across the fault, then groundwater flow is diverted at the fault in some direction along the fault. The damage zone (rock on either side of the fault that is fractured due to faulting) likely facilitates and supports groundwater flow along the fault. It is doubtful that groundwater from deep Blackhawk Formation groundwater systems discharges to the surface along the surface trace of the East Gooseberry Fault because deep perched systems would not have sufficient hydraulic head.

Star Point Sandstone Groundwater Systems

As described in the Geology, Mining, Subsidence, and Seismicity Technical Report (NorWest, 2000b), the Star Point Sandstone is comprised of two sandstone members, the upper Storrs Tongue and the lower Panther Tongue. Mining at the Skyline Mine has encountered water associated with both the Storrs Tongue and the Panther Tongue. Because of the westward dip of the bedrock, there is a high probability that mining in the RFDS area would encounter additional inflows of water from the Star Point Sandstone.

The Storrs Tongue interfingers with the Blackhawk Formation and divides the Lower O'Connnor A Seam from the Flat Canyon Seam. However, in the western portion of the RFDS area, the Storrs Tongue pinches out and the Lower O'Connor A Seam and the Flat Canyon Seam merge. The Panther Tongue underlies the Flat Canyon Seam, the lower-most seam where mining would occur in the RFDS area. The Flat Canyon Seam is separated from the Panther Sandstone by 15-30 feet of shale, mudstone, and thin coals.

The tongues of the Star Point Sandstone are laterally more extensive than individual sandstones in the overlying Blackhawk Formation. It is anticipated that over larger areas, such as the Skyline Mine and RFDS areas, each tongue operates as a single groundwater system. However, it is not believed that the Star Point Sandstone is a regional aquifer in the sense that there is hydraulic continuity throughout the Wasatch Plateau.

The mechanics of Star Point Sandstone groundwater systems are not well understood. The Star Point Sandstone is exposed in Pleasant Valley east of the Skyline Mine area and the RFDS area and dips westward. This suggests that recharge occurs in the east and groundwater flow is to the west. Because of the inclination of the formation and the low hydraulic conductivity of Blackhawk Formation shales and mudstones overlying the Star Point Sandstone members, confined groundwater conditions are created. Similar confined conditions in the Star Point Sandstone have been observed at other coal mines in the Wasatch Plateau such as the Trail Mountain Mine.

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Large groundwater inflows from faults have recently been encountered in the workings of the Flat Canyon Seam in the Skyline Mine. CFC (1999) reports that a fault with approximately 8 feet of offset was encountered during development of the 14L Headgate. The fault initially produced water from the roof and the floor at a rate of 1,200 to 1,400 gpm. Discharge from the roof ceased after a short period but water still continues to be produced from the floor. A second fault along the same trend was encountered in the 16L Headgate. This fault produces 300 gpm of water from the floor. It is believed that this water discharges from the Panther Tongue of the Star Point Sandstone.

Mayo and Associates (1999a) report that groundwater inflows to the Skyline Mine from the Star Point Sandstone have radiocarbon ages greater than 13,000 years and contain no tritium. This suggests that groundwater flow through the Star Point Sandstone is slow and that there is limited hydraulic communication with the surface. Slow flow rates in the Star Point Sandstone are substantiated by the measurement of hydraulic conductivity in other areas of the Wasatch Plateau. At the Crandall Canyon Mine in the Huntington Canyon area, slug testing revealed a hydraulic conductivity of 4.8×10^{-8} to 7.4×10^{-8} ft/s (Mayo and Associates, 1997a). Bills (2000) determined a hydraulic conductivity of 4.06×10^{-6} ft/s for the Star Point Sandstone in the Straight Canyon area. This latter result is higher than the first because of fracturing associated with the Straight Canyon syncline.

The Star Point Sandstone does not crop out west of Pleasant Valley. Consequently discharge locations for Star Point Sandstone groundwater systems have not been observed in the study area. The Storrs Tongue pinches out in the RFDS area indicating that groundwater is not transmitted westward beyond the study area by the Storrs Tongue. As noted in the previous section, the East Gooseberry Fault truncates the bedrock formations west of the RFDS area. This fault is presumed to be a barrier to lateral flow across the fault. This being the case, groundwater flow is diverted at the fault in some direction along the fault and flow is accommodated in the damage zone of the fault. Potentiometric levels in two monitoring wells, 99-21-1, and 99-28-1 (Figure 1), in the RFDS area that are completed in the first sandstone below the Flat Canyon Seam (which may be the Panther Tongue) suggest that the hydraulic head in the Panther Sandstone (elevation 8,419 and 8,515 feet, respectively) is not sufficient to cause water to discharge at the surface trace of the East Gooseberry Fault (elevation greater than about 8,800 feet, directly west of the RFDS area).

Although it is not known where groundwater in the Star Point Sandstone in the study area ultimately discharges, it can be surmised with some certainty that groundwater in the Star Point Sandstone in the study area is not in hydraulic communication with the Star Point Sandstone groundwater systems that supply water to the large-discharge culinary water supply springs in Huntington Canyon (Big Bear, Little Bear, or Birch springs). First, as noted above, the radiocarbon ages of Panther tongue water encountered at the Skyline Mine is 13,000 years. The radiocarbon ages of groundwater that discharges from the Huntington Canyon Springs (Mayo and Associates, 1997b; Mayo and Associates, 1999b) are summarized below.

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Spring	Radiocarbon Age
Birch Spring	1,700-3,600 years
Big Bear Spring	Mixed; 3,500-4,500 years
Little Bear Spring	Modern

Because water in the Star Point Sandstone in the study area has appreciably greater radiocarbon ages, it is unlikely that this water is hydraulically connected to the Star Point Sandstone in the Huntington Canyon. Second, the East Gooseberry Fault, the surmised location for groundwater discharge from the Panther Tongue, is not structurally connected to fault systems in the vicinity of the Huntington Canyon springs. The Huntington Canyon springs discharge in and near the Pleasant Valley Graben and associated faults whereas the Gooseberry Graben is on the same trend as the Joes Valley Graben.

Water Quality

Groundwater discharge from springs in the study area is low-TDS, calcium-bicarbonate water. For springs that have been monitored for baseline water quality, the average TDS ranges from 60 to 280 mg/l and the average TDS is 180 mg/l (NorWest, 2000a). Concentrations of sodium ion and sulfate are very low. Groundwater quality meets State of Utah drinking water standards for the parameters that have been analyzed. Untreated spring water is used throughout the study area at cabins and campgrounds for culinary uses. Additionally, groundwater discharge supports baseflow to creeks that have been classified as "High Quality Waters – Category 1" by the State of Utah (UAC R317-2).

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POTENTIAL ENVIRONMENTAL CONSEQUENCES

ISSUES AND EVALUATION CRITERIA

Hydrologic issues have been identified by the agencies and are analyzed in this technical report. Issues are listed below together with evaluation criteria.

- Subsidence could change the flow of springs and seeps, affecting spring discharge rates and groundwater contribution to streams. This could, in turn, affect agricultural, domestic, and industrial water supplies as well as ecosystems.

  Evaluation Criteria: Description of effects and duration, % probability.

- Subsidence of perennial streams and the Boulger Dam and Reservoir could intercept flowing/impounded water and divert it underground, changing the hydrologic balance. Changes in stream gradient could cause changes in stream morphology.

  Evaluation Criteria: Description of potential flow changes by quantity and duration of baseflow and % probability; description of bedload/sediment transport associated with change in stream gradient.

- Interception of ground water in underground mine workings and subsequent discharge to Eccles Creek (the existing mine water discharge point) or discharge Electric Lake could cause transbasin diversions of surface and ground water. This could affect agricultural, domestic, and industrial water supplies as well as ecosystems.

  Evaluation Criteria: Description of potential diversions, estimates of amount of water that may be encountered, amount and location of discharge to surface waters, % probability. Change in mine water discharge to each watershed, expected change in flow duration and base flows in Eccles and Upper Huntington Creeks (gpm, acre-feet, %), expected change to inflow and discharge (%, acre-feet) to/from Scofield Reservoir and Electric Lake.

- Discharge of mine water into Eccles Creek or Electric Lake could change quality of receiving waters. This could affect agricultural, domestic, and industrial water supplies as well as ecosystems.

  Evaluation Criteria: Water quality of the discharge water vs. water quality standards associated with the most restrictive of the designated beneficial uses of the receiving waters (meets/does not meet), change in receiving stream water quality (parameters with and without limits specific to beneficial use standards including TDS, RCRA metals, oil and grease, TMDL, and drinking water standards) addressed in part by estimating volume of discharge water as percentage of resulting total flows and determining whether discharge water is being diluted or receiving waters are being "contaminated", change in lake chemistry, including water column and lake bed sediments.

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- Equipment and materials spilled, used, and/or abandoned in underground mine workings could change ground water quality and any connected surface water sources. This could affect agricultural, domestic, and industrial water supplies as well as ecosystems.

  Evaluation Criteria: Description of potential changes in quality by affected parameter and duration.

SURFACE WATER

Alternative 2: Lease with BLM Standard Lease Terms and Conditions and Forest Service Special Coal Lease Stipulations

Potential Decreases In Baseflow Discharge Of Creeks
Under this alternative, the application of SCLS #9, perennial streams would not be undermined and thus the potential for direct impacts to perennial creeks is avoided.

However, creek discharge could be indirectly impacted if there were a diminution of discharge from groundwater systems that supply baseflow to perennial streams. As discussed below in the groundwater section, the potential for diminution of discharge from shallow groundwater systems is considered negligible. This is largely because of the existence of low-permeability rocks that create perched conditions in the groundwater systems that provide baseflow to creeks. Therefore, the probability of decreased baseflow in creeks in the RFDS area under Alternative 2 is negligible.

If, in the unlikely event, there were a perceptible or quantifiable decrease in streamflow as an indirect result of subsidence, SCLS #17 would require that the operator replace, at his expense, any surface water identified for protection that may be lost or adversely affected with water from an alternate source in sufficient quality and quantity to maintain existing riparian habitat, fishery habitat, livestock and wildlife use, or other land uses.

Increased Sediment Loading Resulting From Subsidence
Because perennial streams would not be subsided under Alternative 2, the potential for a direct increase sediment loading under this alternative would only occur in ephemeral or intermittent drainages. However, when there is sufficient water in these drainages, the sediment in the ephemeral or intermittent streams may be transported into perennial streams, lakes, or reservoirs.

Differential subsidence of surface water drainages has the potential to increase the sediment load of streams. Differential subsidence of the land surface can locally cause increased stream gradients, which increases stream velocity and erosion potential. This increased erosion potential may result in increased sediment loading of the stream. Differential subsidence of surface-water drainages can also locally result in decreases in sediment loading. If there is an overall increase in the frequency of pools in a watercourse, bed-load sediment carried by the stream may be deposited in these low-energy reaches, resulting in a decrease in sediment loading downstream of the pools.

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Both of these impacts, if they were to occur, are likely to be short-lived. This is because the erosion of steep-gradient regions and the deposition of material in low-gradient regions result in a gradual bringing of the stream into equilibrium with its channel. Sediment loading may result from either 1) erosion anddeepening of the streambed, or 2) a widening of the stream channel as a result of bank erosion. As the stream reaches equilibrium with the channel, the sediment loading in the stream would likely return to near pre-mining conditions. The rate at which this would occur is a function of the type and resistance to erosion of the subsided sediments. If the sediments are soft and easily eroded (i.e. soil horizons or soft, weathered sedimentary rocks common in the RFDS area) the stream would rapidly come into equilibrium and the increased sediment loading in the stream would rapidly cease. If the channel substrate consists of resistant bedrock, then the stream would take much longer to achieve equilibrium with its channel, but because the rock is not easily eroded, there would be minimal or no increases in sediment loading of the stream.

It should be noted that the north facing slopes of Flat, Cunningham, and Swens Canyons have recently experienced considerable logging activities including the associated road construction and soil and vegetation disturbances. Because of these disturbances, there is a likelihood of increased sediment yield from the logged areas in the near future whether or not mining occurs.

Impacts To Water Quantity And Water Quality Of Eccles Creek And Downstream Watercourses Resulting From The Discharge Of Intercepted Groundwater

Skyline Mine currently discharges about 500 gpm. CFC estimates that mine discharge could be as high as 3,000 gpm if mining were to occur in the RFDS area. This rate would not be sustained continuously but represents a maximum occasional discharge. The actual discharge rate of water from mine workings would be dependant on the amount of water encountered, the amount of water that would be impounded underground, and cycles of the water handling system. The impact of additional discharge to Eccles Creek is discussed in this section.

It is anticipated that the chemical quality of groundwater encountered during mining in the RFDS area would be similar to that encountered in the Skyline Mine area (NorWest, 2000a). Therefore, if mine water discharge rates were to remain at current levels (approximately 500 gpm), and mine water were to continue to be discharged into Eccles Creek, there would be no new impacts to water quality or quantity beyond those currently occurring. Assuming that future discharge rates from the mine increased from current levels to 3,000 gpm (an approximate six-fold increase) then greater impacts to water quantity and quality in Eccles Creek and downstream watercourses would be anticipated.

The overall quality of Skyline Mine discharge water has been appreciably lower than of Eccles Creek (Mayo and Associates, 1996). Therefore there is a direct relationship between the percentage contribution of mine water to the creek and the overall quality of creek water below the mine discharge point. The greater the relative contribution of mine water to the creek, the greater would be the degradation of water quality in the creek.

Because the average solute concentrations of mine discharge water and Eccles Creek water are known, it is possible to use a flow-weighted linear mixing model to estimate the anticipated water quality at CS-2 (Eccles Creek below the mine discharge point) if additional mine discharge

water enters the creek. Because the Skyline Mine is currently discharging approximately 500 gpm into the creek, a total mine discharge of 3,000 gpm would represent an increase of 2,500 gpm above current levels. The linear mixing model suggests that TDS concentrations at CS-2 on Eccles Creek would average approximately 877 mg/l. Currently, with a 500-gpm mine discharge, TDS concentrations average approximately 554 mg/l. A substantial portion of the TDS increase would result from increases in sulfate concentrations, which would average approximately 400 mg/l. Currently, with a 500-gpm discharge, sulfate concentrations at CS-2 average 193 mg/l. Most other solute species would have smaller increases because the concentrations of these species in mine water are nearer those of the receiving water. It should be noted that these estimates are based on a continuous mine discharge of 3,000 gpm. It is likely that pumping of mine water would occur intermittently and the long-term average pumping rate would be considerably less than 3,000 gpm. Thus, these estimates should be considered as worst-case estimates. The magnitude of the potential water quality impacts may be considerably less than those estimated above.

The results of the flow-weighted mixing calculations are acceptable for estimating the general order of impacts to Eccles Creek because of the relatively low concentrations of solute species in both mine water and receiving water. However, it should be noted that, because this technique does not consider thermodynamic factors, there is the potential for error in the calculations, particularly in non-dilute solutions.

Currently, Skyline Mine is permitted to discharge 7.1 tons per day of dissolved solids. Assuming that discharge increases to 3,000 gpm total mine discharge (6.68 cfs) and the average mine discharge TDS concentration of 916 mg/l remains the same, there would be a salt loading of 16.5 tons per day, an increase of 9.4 tons per day.

Scofield Reservoir and the Price River and its tributaries have been designated as protected by the Utah Division of Drinking Water (UAC R317-2) for 1) domestic purposes with prior treatment by treatment processes, 2) secondary contact recreation such as boating, wading, or similar uses, 3) cold-water species of game fish and other cold-water aquatic life, including the necessary aquatic organisms in their food chain, and 4) agricultural uses including irrigation of crops and stock watering.

Before any mine water could be discharged into these waters, the current UPDES discharge permit may need to be modified. In order to receive a new or modify an existing UPDES permit, it must be demonstrated that beneficial use standards would not be exceeded in the receiving water. When a UPDES discharge permit is issued or modified, the water quality of the proposed discharge water is evaluated by the Utah Division of Water Quality (Personal Communication, Mike Herkimer, 2000). WET testing is performed to ensure that the water is not toxic (either chronic or acute) to aquatic organisms. If harmful constituents are identified in the proposed discharge water, then an approved water treatment plan must be implemented before any water may be discharged. If constituents are found in the water that are regulated under TMDL or which may cause the receiving water to not meet the quality standards for the designated beneficial uses, then specific discharge limits are placed on these constituents. Routine water quality monitoring of the discharge water is required for all parameters requested by the Division of Water Quality to demonstrate compliance with the UPDES permit.

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As demonstrated by many years of continuous water quality monitoring, the quality of raw mine discharge water from the Skyline Mine, in terms of TDS, sulfate and pH, is acceptable for all of the protected beneficial uses and is within the drinking water standards set fourth by the Utah Division of Drinking Water (UAC 317-2). Limited chemical data are available for most other chemical parameters controlled by the designated beneficial use standards.

With a few exceptions discussed below, the quality of the mine discharge water has generally been acceptable for all of the designated beneficial uses of the receiving water (in terms of the chemical constituents for which water quality data are available). Concentrations of total boron, cyanide, dissolved lead, total phosphorous, and TDS have on at least one occasion exceeded the concentration limits specified by one or more of its beneficial use standards. Concentrations of cyanide from CS-12 on one occasion exceeded the beneficial use standard for aquatic wildlife. On each of the other 12 monitoring events, no cyanide was detected. During the single cyanide-monitoring event from the UPDES outfall, the concentration of cyanide also slightly exceeded the standard. The concentration of total phosphorous has occasionally been exceeded in discharge from CS-12 and CS-14, and was exceeded in the single phosphorous-monitoring event from the UPDES outfall. The average concentration of total phosphorous from CS-12 discharge is within the beneficial use standards, while those standards are somewhat exceeded in the average CS-14 discharge. The concentration of total mercury also exceeded the beneficial use standards during the single mercury-monitoring event from the UPDES outfall. Concentrations of phenol, an organic compound, have exceeded the beneficial use standards on a few occasions at both CS-12 and CS-14, while on all other occasions, there was no phenol detected in the discharge water. The causes of the occasional elevated phenol concentrations in the mine discharge water are not known.

It is important to note that for each of the chemical parameters discussed above, (with the exception of phenol and possibly total phosphorous) although certain beneficial use standards have occasionally been exceeded in the discharge water from either CS-12 or CS-14, the average concentration of mine discharge water, which is a combination of water from these two sources, is generally suitable for each of the beneficial uses. As discussed above, important chemical parameters of potential mine discharge water would be strictly controlled through the UPDES permitting process and would be monitored by several Utah State regulatory agencies. Additionally, continuous, automated monitoring equipment has been installed in the Skyline Mine discharge system that ensures that water that is excessively elevated in TDS, ph, turbidity, or oil and grease concentrations would not be discharged. If poor quality mine discharge water is detected by this system, it is automatically rerouted to underground storage areas within the Skyline Mine and is not discharged.

The addition of approximately 2,500 gpm (5.57 cfs) of mine discharge water to Eccles Creek above current levels (about 500 gpm) would constitute a considerable increase to the natural discharge in the creek. During low-flow periods, discharge in Eccles Creek measured at CS-2 is commonly between about 0.1 and 2 cfs. Thus, an addition of 5.57 cfs would result in a discharge between 2.8 and 56 times current levels. The addition of this amount of sediment-free water during low-flow periods would cause increased sediment transport. The magnitude of this impact has not been quantified. The data necessary to perform a rigorous and meaningful analysis have not been collected. However, the erosion potential would be mitigated in part

because of the well-armored nature of the stream channel. The stream channel in Eccles Creek is dominated by cobbles and boulders and appears to be relatively stable. During periods of high flow in the creek, when current discharges commonly exceed 10 to 50 cfs, the addition of 5.57 cfs of mine discharge water would constitute a relatively smaller impact.

Eccles Creek is a tributary of Mud Creek, which is a tributary of Scofield Reservoir. Therefore an increase in the mine water discharge rate to Eccles Creek would also impact downstream watercourses including Mud Creek and Scofield Reservoir. Unlike Eccles Creek, the channel substrate in Mud Creek, particularly in its lower reaches, appears less armored than Eccles Creek and contains reaches dominated by fine-grained material. Therefore, the potential for increased erosion rates in Mud Creek would likely be greater than for Eccles Creek. However, because Mud Creek is a larger watercourse than is Eccles Creek, the addition of 5.57 cfs to the discharge represents a smaller percentage increase to the total stream flow. Thus, this additional water would be more readily accommodated in the channel. Likewise, because of the larger volume of discharge in Mud Creek relative to Eccles Creek, the degradation of water quality in this watercourse would be less.

During dry years, the addition of 5.57 cfs to Scofield Reservoir from Mud Creek would likely not result in any major impacts in terms of the ability of the reservoir to accommodate the additional water. Rather, the increased recharge to the reservoir would likely be considered a positive impact by those who use the water. This would be particularly true during dry years because the inflow of deep, perched groundwater into the mine workings is not related to climate. During extremely wet years, when water is spilling from the reservoir, the addition of this amount of water would be a meager amount relative to the 6,200 cfs capacity of the spillway. During extremely wet years, when there is no available storage capacity in the reservoir, the mine discharge water would increase the high-flow discharge rate in the Price River below the dam by 5.57 cfs. This would constitute a small percentage of the high-flow discharge of the Price River below the reservoir.

If the mine discharge water were redirected to the Upper Huntington Creek drainage, the discharge to Eccles Creek could cease. Under this scenario, the water quality in Eccles Creek would revert to its pre-mining condition, with an average TDS concentration of approximately 269 mg/l. Water quality in Mud Creek would also improve to pre-mining levels. As discussed above, there would be a net decrease of approximately 2.8 tons per day of salt loading to Scofield Reservoir. Discharge rates in Eccles Creek would decrease dramatically to pre-mining conditions. This would be particularly noticeable during baseflow conditions, when stream discharge rates would decrease from the current levels in dry years to perhaps less than 100 gpm. The loss of approximately 500 gpm of mine discharge water would represent a loss of approximately 800 acre-feet of water per year in Scofield Reservoir.

Impacts to Water Quantity and Water Quality of Electric Lake and Downstream Watercourses Resulting from the Discharge of Intercepted Groundwater

It is proposed in the RFDS that mine water might be discharged to Electric Lake at or below the high water line in Upper Huntington Canyon. The possibility of discharging water some distance out into the lake has also been discussed by USFS personnel and CFC. This section

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discusses the possible impacts to chemical and physical water quality as a result of discharging mine water to Electric Lake. The chemical water quality impacts are expected to be the same regardless of weather water is discharged near the high water line or father out into the lake. The physical quality of the lake could be impacted if discharge near the high water line results in appreciable entrainment and transport of lake bottom sediments during low stand periods.

It is anticipated that the chemical quality of groundwater encountered during mining in the RFDS area would be similar to that encountered in the Skyline Mine area. Because the anticipated quality of mine discharge water is poorer than that in Upper Huntington Creek, the water quality of Upper Huntington Creek would be degraded by the addition of any mine water. The magnitude of this impact is directly related to the volume of mine water discharged into the receiving water. In the following discussion, water quality impacts to Electric Lake have been analyzed by comparing the water quality of Upper Huntington Creek at UPL-10 to the average quality of Skyline Mine discharge water. However, the water quality impacts to Electric Lake resulting from proposed mining activities in the RFDS area would be less than those occurring in Upper Huntington Creek due to dilution in the lake.

Because the average solute concentrations of mine discharge water and Upper Huntington Creek water are known, it is possible to use a flow-weighted linear mixing model to estimate the anticipated water quality at UPL-10 (Upper Huntington Creek just above Electric Lake) at different mine water discharge rates. The results of these calculations for an anticipated mine water discharge rate of 3,000 gpm are shown in Table 5.1. Because there is currently no mine discharge into Upper Huntington Creek, the entire 3,000 gpm would constitute a new impact to the stream. The linear mixing model suggests that TDS concentrations at UPL-10 could increase from approximately 182 mg/l to 502 mg/l. Much of this increase would be caused by increases in the sulfate concentration in the stream, which could increase from 15 to 194 mg/l. Smaller increases in other solute species would also occur. As discussed above, these estimates are based on a continuous discharge of 3,000 gpm into the stream. It is more likely that mine water would only be pumped intermittently, and thus, the average pumping rate would be considerably less. Therefore, these estimates should be considered as worst-case estimates. The actual water quality impacts may be considerably smaller than those described above. The results of the flow-weighted mixing calculations are of value in estimating the general magnitude of impacts to Upper Huntington Creek, but as described in Section 5.1.3, it should be noted that there is the potential for error using this technique. Assuming an average TDS concentration of mine discharge water of 916 mg/l, there would be an additional 16.5 tons per day of salt loading to the reservoir.

Huntington Creek and Electric Lake are protected for secondary contact recreation such as boating, wading, or similar uses. These waters are also protected for cold-water species of game fish and other cold-water aquatic life, including the necessary aquatic organisms in their food chain. The waters are also protected for agricultural uses including irrigation of crops and stock watering. Huntington Creek has been designated as protected for domestic purposes with prior treatment by treatment processes as required by the Utah Division of Drinking Water.

Before any mine water could be discharged into these waters, a UPDES discharge permit would be required. In order to receive this permit, it would need to be demonstrated that the beneficial

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use standards for these waters would not be exceeded. Water quality analyses for the Skyline Mine discharge for important parameters regulated under the beneficial use standards are included in Appendix D. As discussed above, the quality of mine discharge water for all parameters regulated under beneficial use standards (with the exception of phenol and possibly total phosphorous) for which data are available is generally acceptable for the designated beneficial uses. As discussed above, all important water quality parameters would be controlled through the UPDES permitting process and are regulated by several Utah State regulatory agencies. Additionally, continuous, automated monitoring equipment has been installed in the Skyline Mine discharge system that ensures that water that is excessively elevated in TDS, pH, turbidity, or oil and grease concentrations would not be discharged. If poor quality mine discharge water is detected by this system, it is automatically rerouted to underground storage areas within the Skyline Mine and is not discharged.

Because the mine discharge water is generally of sufficient quality to meet drinking water standards and all of the designated beneficial uses of the receiving waters (for the chemical parameters for which data are available and with the exception of phenol and possibly total phosphorous), it is unlikely that there would be adverse impacts to ecosystems in downstream water courses or that there would be adverse water quality impacts to downstream water users.

The temperature of groundwater from the Skyline Mine has averaged between about 11 and 16°C (Mayo and Associates, 1994). If this water is discharged directly into Electric Lake during the winter months when temperatures of the lake water are near 0°C, there would be an alteration of the thermal regime of the lake. This may locally result in the melting or thinning of the surface ice in the vicinity of the discharge point and may also impact ecosystems in the immediate vicinity of the discharge point.

In the event that mine water is discharged near the high water line of Electric Lake, there is potential for appreciable erosion of lake bed sediments during times of the year when Electric Lake is not at high water. When the lake is not at high water, mine water discharge would first mix with Upper Huntington Creek discharge before flowing in the lake. When the lake is not at high water, Huntington Creek flows in a channel carved into unvegetated lake bed sediments. The addition of approximately 3,000 gpm (6.68 cfs) of mine discharge water to Upper Huntington Creek would constitute a considerable increase in the discharge in the creek. During low-flow periods, discharge from Upper Huntington Creek to Electric Lake is commonly between about 1 and 3 cfs (Mayo and Associates, 1996). Thus, an addition of 6.68 cfs would result in a baseflow discharge that is between about 2.2 and 6.7 times current levels.

The potential for disturbance of lake-bottom sediments would be greatly diminished if discharge water were conveyed via pipeline to a point further out into the lake. Because the mine water discharged into the lake would be essentially sediment free, there would likely not be any perceptible deposition of sediment at the mine discharge point.

During dry years and during the late summer months, the addition of 6.68 cfs of water to Electric Lake may be seen as a beneficial impact. This would be particularly true during drought years, because as discussed in Section 3.2.3, the inflow of deep, perched groundwater into the mine workings is not related to climate. During extremely wet years, when water is spilling from the

reservoir, the addition of this amount of water would be a meager amount relative to the 2,300 cfs capacity of the spillway. During extremely wet years, when there is no available storage capacity in the reservoir, the mine discharge water would increase the high-flow discharge rate in Huntington Creek below the dam by 6.68 cfs. This would constitute a small percentage of the high-flow discharge of Huntington Creek below the reservoir.

Impairment Of Water Rights Resulting From Decreased Stream Flows
Numerous water rights for creeks are heldexist in the RFDS area by both private land owners and government agencies. As described in Section 5.1.1, perceptible or quantifiable impacts to creek discharge rates are not anticipated. If there are no impacts to creek discharge rates then there should be no impairment of water rights. In the event that there is a mining-related flow diminution of an appropriated surface water source, Utah Code 40-10-18 requires the mine operator to "promptly replace any state appropriated water in existence prior to the application for a surface coal mining and reclamation permit."

Alternative 3: Lease with BLM Standard Lease Terms and Conditions Only

Under Alternative 3, the SCLS are not applied to the lease. The potential environmental impacts under this alternative include the impacts described under Alternative 2 and the potential impacts described below.

Diversion of Surface Water from Perennial Creeks and Boulger Reservoir into the Subsurface as a Result of Undermining and Subsidence
Perennial streamflow may be impacted if subsidence-related tension fractures caused diversion of surface water into the subsurface. It is believed that low-permeability confining or perching layers exist beneath all of the perennial streams in the RFDS area. This is expected to be the case regardless of the geomorphology. For instance, although Boulger Canyon is wide with a low stream gradient whereas Swens Canyon is narrow and steep, the same bedrock formation underlies the unconsolidated sediments in each canyon. Canyon geomorphology in the study area is a function of erosional process (fluvial and glacial) not the underlying bedrock. It is for this reason that the results of undermining Burnout Canyon with respect to stream dewatering can be extrapolated to all of the perennial drainages in the study area.

Therefore, in order for surface waters to be diverted from a creek, the integrity of the perching layer(s) would need to be compromised such that downward migration of surface waters into deeper unsaturated rock horizons could occur. The subsidence fractures must be sufficiently extensive and interconnected so as to facilitate the conveyance of stream water out of the drainage. It is expected that the integrity of the low-permeability bedrock horizons that support both streams and shallow groundwater systems in the RFDS area would not be compromised (NorWest, 2000a). For these reasons, the potential for the direct interception and translocation of surface waters by subsidence fractures is considered remote. The existence of low-permeability layers creates shallow, perched groundwater systems beneath the stream. Were this not the case, the streams in the RFDS area would be losing streams because the groundwater derived baseflow component would flow downward into the unsaturated horizons that exist deeper beneath the surface.

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If subsidence fractures were to occur above the impermeable perching layer, these would be of relatively little consequence to the hydrologic regime. Because sediments above the perching layer are believed to be fully saturated, there could be no loss of water to these fractures. Subsidence fractures that could develop in the Blackhawk Formation would heal rapidly as a fracture plane is wetted due to swelling clays in the Blackhawk Formation. Thus, if subsidence fractures were to damage the perching layer beneath the stream, these fractures would likely remain open for only a short period of time.

The experience of CFC performing longwall extraction beneath Burnout Creek (NorWest, 2000a) provides support for the idea that perceptible or quantifiable detrimental impacts to perennial streams would not likely occur if these drainages were undermined. As reported by NorWest (2000a), there have been no quantifiable impacts to baseflow discharge in Burnout Creek after it was undermined that could be attributed to mining activities. It is believed that the geologic conditions in the RFDS area (geologic formation, overburden thickness, and degree of fracturing and faulting) are sufficiently similar to those at Burnout Canyon (less than 1 mile from the RFDS area) to give scientific validity to extrapolating the observed effects of undermining Burnout Creek to those that may occur if perennial surface water drainages in the RFDS area are undermined with longwall mining techniques. Thus, it is probable that no perceptible or quantifiable losses of surface water would occur if surface water drainages in the RFDS area are undermined.

There is a potential for localized shifting of groundwater discharge locations as a result of mining-related subsidence. This can result from minor alterations in the attitude of bedrock horizons (i.e. a change in the groundwater flow direction) or changes to fracture networks that may support groundwater discharge. However, because the drainages that support surface water in the RFDS area are all well entrenched and the surface gradients are relatively steep, the possibility that minor shifting of groundwater discharge locations could remove perceptible or quantifiable amounts of surface water from the drainage is remote. Rather, it is likely that groundwater entering the stream channel would simply enter slightly higher or lower in the drainage. Under this scenario, there would be no net loss of water from the watercourse.

For the reasons discussed above, it is believed that the potential for diminished baseflow discharge in creeks in the RFDS area under Alternative 3 is negligible. However, if perceptible or quantifiable detrimental impacts to groundwater systems that provide baseflow to streams in the RFDS area do occur, then these impacts would be reflected in decreased baseflow in streams. These potential impacts to perennial streams, were they to occur, would likely be of relatively short duration, likely on the order of one or two seasons. As discussed in Section 6.1.1, tension fractures in the Blackhawk Formation tend to heal rapidly because of the existence of hydrophilic swelling clays in the rocks of the formation. If subsidence fractures were to intercept groundwater, the fractures would rapidly heal as the clays along the fracture planes became wetted and subsequently swelled. If subsidence fractures appear in a stream channel that has a bare bedrock substrate (that may not contain swelling clays) the subsidence fractures would likely fill with sediment transported by the stream. It was evident in the July 2000 stream survey that each of the streams surveyed was actively transporting quantities of sediment that would be sufficient to fill even a relatively large subsidence fracture in a short period of time. Assuming a typical fracture width of 1 inch, a depth of 30 feet, and a length of 50 feet, a fracture volume of

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125 cubic feet is calculated. Although no direct measurements of sediment transport in streams in the area are available, it is believed that the quantities of sediment transported annually in perennial streams in the RFDS area greatly exceed this amount. Thus, even if several subsidence fractures occurred in the drainage, the duration of a potential stream-water loss resulting from subsidence fractures physically intersecting a bedrock channel would be relatively short, perhaps on the order of one or two seasons.

In the event that there were a perceptible or quantifiable mining-related diminution of discharge in a creek that has been designated for protection, the application of SCLS #17 would require the lessee to replace any water lost from or adversely affected by mining operations with water from an alternate source in sufficient quality to maintain existing riparian habitat, fishery habitat, or livestock and wildlife use.

Changes In Stream Morphology Due To Subsidence Of Creeks

Longwall mining commonly results in differential subsidence of the land surface. If longwall mining occurs under a stream drainage, there would be localized changes in channel gradient near the margins of a subsided area. **These changes may result in a deepening or a widening of the stream channel.** In the interior of a subsided area, the land subsidence is more uniform and changes in stream gradient should theoretically be small. Therefore, the greatest potential for major alterations in stream morphology occurs above panel ends or above longwall gateroads. Although the potential for major changes in stream morphology does exist, the experience of CFC in mining Burnout Canyon suggests that the changes that may occur would not be large enough to cause major detrimental impacts to the streams in the RFDS area.

It was observed by the authors that the subsidence-induced changes in channel gradient at Burnout Canyon, even in the areas of maximum differential subsidence, were not great enough to cause barriers to fish movement in the stream. Rather, as has been observed in other subsided areas in the Wasatch Plateau, the subsidence around the margins of longwall panels occurs in a more distributed, gradual fashion. Thus, it is believed to be unlikely that fish barriers would form as a result of potential longwall mining in the RFDS area.

Sidel et al. (2000) report that changes to the stream morphology in Burnout Creek during the period it underwent longwall mining were minor and consisted primarily in an increase in the percentage of pools along the drainage. However, similar morphological changes occurred in the adjacent James Canyon, which was a mostly non-undermined control for their study. Thus, it is difficult to determine to what extent, if any, the mining activity had on the stream morphology in the drainage. The morphological changes that did occur in these drainages were short-lived. Within a year the drainage had returned to near-pre-mining conditions (Sidel et al., 2000). However, it is possible that there will be an increase in pooling in portions of streams that are undermined using longwall mining techniques.

Thus it is believed that although differential subsidence of perennial drainages above longwall-mined areas would occur under to Alternative 3, these changes would generally be minor. If a major impact to stream morphology were to occur, the impacts would likely be short-lived.

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It has been determined in the Geology, Mining, Subsidence, and Seismicity technical report (NorWest, 2000b) that in portions of some perennial stream drainages in the RFDS area, there could be moderate changes in the channel gradients. In most sections of the perennial streams in the RFDS area, the stream gradients are steep enough for the stream to adjust to subsidence-induced slope changes without any major changes to stream morphology. However, in some perennial drainages, including portions of the Flat Canyon and Boulger Canyon, and the lower reaches of Swens Canyon, there are reaches with relatively low stream gradients that may experience moderate subsidence-induced gradient changes. In these areas, there is the potential for low or possibly even negative stream gradient to occur if the slope changes are sufficiently large. The precise locations where these effects could occur are entirely contingent upon thespecific locations, geometries, and orientations of longwall panels. Thus, in the absence of a detailed mine plan, it is difficult to be more specific in predicting locations where these effects may occur. If negative gradients occur in these areas, pooling of water in the subsidence troughs near gradient inflectionpoints may result. This could result in the creation of new ponds or wetland areas in the drainages. If ponding occurs in areas containing thick alluvial deposits (such as those found in the Flat Canyon and lower Boulger Canyon drainages) these ponds or wetlands may persist for a relatively short period of time. This is because the stream has a tendency to actively erode soft sediments in highland areas and deposit the abundant, easily eroded sediment in lowland areas. Thus, the stream would have the tendency to quickly come into equilibrium with its channel in terms of channel gradient. In areas of maximum differential subsidence, there is the potential for head cutting in stream channels that would result in increased sediment loading and temporary changes to stream morphology. Changes in channel width resulting from erosion of stream banks may also occur. In areas directly underlain by bedrock formations, where relatively less sediment is transported and the substrate less easily eroded, the effects would persist for a longer period.

In areas where subsidence-induced changes to stream gradients could result in local reversals of stream gradient and potential ponding of water or the creation of wetland areas (most notably in Flat Canyon and possibly also in portions of Boulger Canyon and Swens Canyon) there is the potential for flooding of structures that are located near the streambank. The authors have not observed structures in these areas that appear to have the potential to be flooded. Thus, this impact is not anticipated in the RFDS area.

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According to the RFDS, Upper Huntington Creek would not be subsided by longwall undermining. However, there is a possibility that Upper Huntington Creek and portions of Electric Lake would be directly undermined for the development of mains. As discussed in the Geology, Mining, Subsidence, and Seismicity technical report (NorWest, 2000b), subsidence above regions mined using room and pillar techniques is expected to proceed gradually at a very slow rate, possibly requiring several centuries or even millennia to complete. For these reasons, it is believed that any subsidence fractures that may develop beneath Upper Huntington Creek would likely develop slowly and gradually. Because of the presence of thick, soft alluvial sediments in the drainage, any subsidence fractures that develop would likely be filled with sediment at a fast enough rate to keep the fractures continuously and completely filled with sediment as the region subsides. As these sediments are compacted over the centuries, their ability to transmit water would continuously be diminished. The amount of water potentially transmitted in these fractures would be very small relative to the amount of water in the drainage.

Therefore, no measurable or perceptible impacts to water quantity in Upper Huntington Creek or Electric Lake are anticipated as a result of room and pillar extraction beneath these areas.

Increased Sediment Loading Resulting From Subsidence Of Creeks

Under Alternative 3, the potential for increased sediment loading resulting from subsidence would be the same as those under Alternative 2, with the exception that sediment load increases could occur in perennial drainages. Whereas sediment loading in ephemeral or intermittent drainages is only of consequence for part of the year when these watercourses are transporting water and sediment, if perennial drainages are affected, this impact could occur throughout the year.

GROUNDWATER

Alternative 2: Lease with BLM Standard Lease Terms and Conditions and Forest Service Special Coal Lease Stipulations

Potential Impacts to Groundwater Systems

There are two mechanisms through which underground coal mining has the potential to impact groundwater resources. The first mechanism is the direct interception of groundwater by mine workings. The second mechanism is by interruption or deformation of strata overlying subsided areas. Each of these mechanisms is discussed below.

Direct interception of groundwater results in the local dewatering of deep groundwater systems. Groundwater that is encountered in underground workings at the Skyline Mine and groundwater that may be encountered in the RFDS area issues from either deep Blackhawk Formation groundwater systems or Star Point Sandstone groundwater systems (NorWest, 2000a).

Deep Blackhawk Formation groundwater systems do not have good hydraulic communication with the surface as indicated by radiocarbon ages that are many thousands of years, the lack of tritium, and the rapid decline of inflow rates after a water-bearing feature is encountered. What this suggests is that the dewatering of these horizons should not induce renewed recharge to these systems and therefore there should be no impact to the hydrologic balance in the recharge areas. Because deep Blackhawk Formation groundwater systems drain quickly when encountered, it is doubtful that these systems support perceptible or quantifiable discharge to the surface.

Star Point Sandstone groundwater systems also discharge water to mine workings that is many thousands of years old. Because of the lateral continuity of the Star Point Sandstone, it is possible that there may be hydraulic continuity from the recharge zone to where water is encountered in mine workings. However, pump test analysis (Mayo and Associates, 1997a; Bills, 2000) indicates that the hydraulic conductivity of unfractured Star Point Sandstone is low, and thus recharge to the Star Point Sandstone is largely constrained by the low permeability of the unit. Thus it is unlikely that dewatering of the sandstone would perceptibly or quantifiably

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impact the hydrologic balance in the recharge area. Due to the antiquity of water in the Star Point Sandstone, it is unlikely that discharge from the Star Point Sandstone, wherever that may occur, is important to the hydrologic balance of that area.

Subsidence-induced interruption and deformation of strata has the potential to impact groundwater systems by 1) enhancing existing or creating new flow pathways for vertical groundwater migration and thereby partially or wholly dewatering a saturated horizon, and/or by 2) locally altering natural groundwater flow directions. In the study area, subsidence has the potential to impact near surface groundwater systems and deep bedrock groundwater systems that exist above the mined horizon.

The potential impacts of mining-related subsidence to dewater near surface groundwater systems are, for the most part, analogous to the potential impacts to perennial creeks. As with perennial creeks, the operation of near surface groundwater systems is fundamentally dependent on the presence of low-permeability bedrock horizons that create perched groundwater conditions. The critical question that must be evaluated, then, is how would subsidence and subsidence-related fracturing affect the bedrock immediately below where these systems operate.

The Geology, Mining, Subsidence, and Seismicity Technical Report (NorWest, 2000b) describes the reaction of rock strata above longwall mined areas as a function of overburden thickness. There are four zones of movement above subsided areas. These include the cave zone, fracture zone, flexure zone, and soil zone. In the RFDS area the fracture zone is estimated to extend above the Lower O'Connor B seam up to 375 feet for single seam extraction and up to 675 feet above the Flat Canyon Seam for double seam extraction. The minimum overburden thickness in the RFDS area where longwall mining could occur is about 900 feet for the Lower O'Connor B seam. Most of the surface is more than 1,200 above the Lower O'Connor B seam. Thus, both colluvial/shallow bedrock groundwater systems operate entirely with the flexure zone and soil zone.

The expected response in the flexure zone is that there would be movement along existing joints and bedding planes, which can open up in zones of tension. Vertical movement along fractures typically remains within individual beds and is not vertically extensive unless massive strong beds are in the zone. Weaker rocks in the upper part of the zone may flex without causing failure along joints or tension cracks to form. In the soil zone materials are weak and generally do not fail due to the ability to flex. Tension crack formation does occur in the active tension zone but cracks close again when the compression zone reaches that point.

Based on the previous discussion, it is expected that the integrity of the low permeability bedrock horizons that are fundamental to the operation of colluvial/shallow bedrock groundwater systems generally would not be compromised. The exception would be the creation of tension cracks in high-strain zones as discussed below.

In zones of permanent tension that form above such features as panel ends, fire barrier pillars, and the outer edge of a block of panels, tension cracks are possible in shallow subsurface strata and may persist for a time. The degree to which these tension cracks impact shallow groundwater systems would be dependant on the degree of interconnectedness of fractures with

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other fractures or permeable horizons that are capable of receiving water. However, it is anticipated that because of lithologic heterogeneity and the abundance of swelling clays in the Blackhawk Formation, that tension fractures which do form would heal quickly.

Experience in the Skyline Mine area also suggests that shallow bedrock horizons are not compromised to the degree that there is perceptible or quantifiable dewatering of a stream or spring. The experience at Burnout Creek is especially important (NorWest, 2000a). The strata underneath Burnout Creek have been subjected, in various locations, to tensile stresses caused by panel ends, stacked double seam fire barrier pillars, and the outer margin of a block of panels. Nevertheless, there has not been a decrease in stream discharge. Second, the response of springs and wells (NorWest, 2000a) to undermining and subsidence suggests that subsidence does not result in dewatering of groundwater systems. Lastly, exploration drill holes in the Blackhawk are very unstable, and when left open for a few days, slough badly (Vaughn Hansen Associates, 1982) suggesting that any subsurface openings created by subsidence would heal quickly.

Subsidence also has the potential to locally alter groundwater flow directions. This is caused by slightly altering the attitude of shallow bedrock or by subtle disturbances in unconsolidated material. While this could affect the discharge rate from an individual spring, the total discharge from the groundwater system would remain the same as groundwater is diverted to other nearby existing discharge locations or new discharge locations.

The probability of impacting deep bedrock groundwater systems that exist above the mined horizon decreases with increasing overburden thickness. As noted by NorWest (2000a), subsidence causes water level perturbations in deeper groundwater systems but there is no indication that the groundwater systems monitored by wells have been dewatered. If a saturated horizon in the deeper bedrock were dewatered, it is unlikely that there would be a perceptible or quantifiable impact to the hydrologic balance because of the limited recharge and discharge of these systems.

In summary, although mine workings encounter a large amount of groundwater, more than 1,000 gpm, this water is derived from storage in the groundwater system. Where groundwater naturally discharges from deep bedrock groundwater systems, it is surmised that the discharge rate is several orders of magnitude less than the rate that water inflows to mine workings. It is estimated that there is a remote probability that direct interception of groundwater by mine workings would cause perceptible or quantifiable impacts to the hydrologic balance at either the recharge or discharge areas of deep groundwater systems.

It is estimated that there is a negligible probability of perceptibly or quantifiably dewatering near surface groundwater systems as a result of mining-related subsidence and fracturing. There is a possibility that there may be some local alterations in groundwater flow direction, which might affect the discharge from an individual spring but not diminish the total discharge from a groundwater system.

In the event that there were a perceptible or quantifiable mining-related diminution of groundwater discharge at a developed spring location in the area, the application of SCLS #17

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would require the lessee to replace any water lost from developed groundwater sources with water of similar quality.

Transbasin Diversion of Intercepted Groundwater

The potential for transbasin diversions arises if water that is encountered underground is discharged to another drainage other than the one where the water would naturally discharge. The Skyline Mine area and mine workings straddle the surface water divide between two major river basins of the region, the Price River and the San Rafael River basins. Most of the surface area in the RFDS area is within the San Rafael River Basin. The southwest corner of the RFDS area is within the Gooseberry Creek drainage, which is tributary to the Price River Basin. It is important to note that the Upper Huntington Creek drainage is a peninsula-like extension of the San Rafael River Basin into the Price River Basin.

At the Skyline Mine, groundwater is encountered underground on both sides of the surface water drainage. However, all water encountered in the mine is currently discharged to Eccles Creek, a tributary to the Price River. It is anticipated that CFC would discharge groundwater encountered by mining in the RFDS area to Eccles Creek, unless a discharge point could be permitted in the Upper Huntington Creek drainage. It presently would not be possible to discharge mine water to the Upper Huntington Creek drainage because watercourses within the outer boundary of the National Forest are designated by the State of Utah to be "High Quality Waters – Category 1" and new point source discharges into these waters are prohibited (UAC R317-2-3).

It is important in the analysis of potential transbasin diversion to identify the source of water intercepted by mine workings and the natural discharge locations of intercepted water. As described in the previous section, mining at the Skyline Mine does not appear to have created pathways for the downward migration of water from the surface or near surface to the mine. Thus, water that is intercepted in mine workings is likely groundwater that is naturally resident in the horizons immediately above or below the mined coal seam. It is anticipated that mining in the RFDS area would only encounter water that naturally occurs in the strata immediately above or below the mined coal seams.

As described in the Affected Environment section, groundwater in deep Blackhawk Formation groundwater systems and in the Star Point Sandstone groundwater systems does not appear to naturally discharge to the surface within the study area. It is surmised that the East Gooseberry Fault may intercept groundwater flowing westward in the deep bedrock. Where groundwater is conveyed by the East Gooseberry Fault is not known.

Because the natural discharge locations of groundwater potentially encountered by mining in the RFDS area are only speculative, the nature of any transbasin impact cannot be stated with certainty. However, the magnitude of this impact, regardless of where it occurs, can be estimated by considering the mean residence times of groundwater encountered by mining. Mayo and Associates (1996, 1999a) report that the radiocarbon ages of groundwater inflows to the Skyline Mine are many thousands of years. What this means is that the rate of flow through these systems is slow and thus the magnitude of discharge from these systems is likely meager. Thus it would not be correct to assume that the rate of discharge from mine workings in the

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RFDS area is equivalent to the possible decrease in natural groundwater flow rates at the discharge location. Mining accelerates the rate of groundwater discharge from deep bedrock inactive flow groundwater systems.

A helpful analogy would be a livestock watering trough that is fed by a small trickle. Once the trough is full, water spills from the trough at the same rate that water enters the trough—at a trickle. If the bottom of the trough were punctured, the magnitude of discharge from the trough would be large compared to the trickle that once discharged from the system. What is lost from the pre-punctured system is the small trickle, not the large outflow resulting from the trough being breached.

It is highly probable that if water intercepted by mining in the RFDS area is discharged to a basin other than that which the water was naturally tributary, there would be not be a perceptible or quantifiable impact to the hydrologic balance of the basin from which water was diverted.

Impacts to Water Rights Resulting From The Diminution Of Spring Flows
Numerous water rights for springs are held in the RFDS area by both private land owners and the U.S. Forest Service. As described in Section 6.1.1, perceptible or quantifiable impacts to spring discharge rates are not anticipated. If there are no impacts to spring discharge rates then there should be no impairment of water rights. In the event that there was a mining-related flow diminution of an appropriated spring, Utah Code 40-10-18 requires the mine operator to "promptly replace any state appropriated water in existence prior to the application for a surface coal mining and reclamation permit."

A water right has a specified point of diversion. It is possible that if a spring discharge location shifted as a result of subsidence, this impact a water right because water could no longer be diverted at the specified point. If such a situation were to occur, the State Engineer would need to make a finding.

Potential Degradation of Water Quality in the Mine Environment
The quality of water that passes through the mine environment may be degraded by chemical interactions with naturally occurring minerals or materials and equipment introduced into the mine. Potential environmental impacts can occur if degraded water discharges from the mine workings either during active mining or after mining activities cease. These potential impacts are discussed below.

Acid mine drainage is caused by the oxidation and dissolution of naturally occurring sulfide minerals (principally pyrite and marcasite) when these minerals are exposed to the atmosphere in mine openings. Under natural (non-mined) conditions, the lack of available oxygen in the vicinity of the coal seams prohibits this reaction. The oxidation of sulfide minerals results in the release of hydrogen ions (acid), and increased iron and sulfate concentrations. However, acid mine drainage is rarely a problem in western coal mines because free hydrogen ions readily dissolve carbonate minerals (calcite and dolomite), which are abundant in the mine environment, and the sulfur content of coal is low. The dissolution of carbonate minerals results in increased concentrations of bicarbonate, calcium ion, and magnesium ion. Both of these reactions increase

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the total dissolved solids (TDS) concentration of mine water. Ion exchange of calcium ion and magnesium ion for sodium ion is common due to the presence of clay and zeolite minerals (Mayo and Associates, 1994). Ion exchange reactions do not appreciably change the TDS concentration of mine water. The end result of these interrelated and secondary mineral reactions is that after water has passed through the mine environment, it is elevated in sodium ion, bicarbonate, and sulfate relative to groundwater that flows into the mine. Mine discharge water of this type is common from coal mines in the Wasatch Plateau.

Increased iron concentrations resulting from the oxidation of sulfide minerals does not typically result in negative water quality impacts in the Wasatch Plateau. Because most mine discharge waters and receiving waters are basic, dissolved iron is rapidly precipitated as iron hydroxides as the water comes in contact with the atmosphere and microbes at the surface. Water flowing in a surface stream that is fully aerated should not contain more than a few micrograms per liter of uncomplexed iron at equilibrium in the pH range of about 6.5 to 8.5 (Hem, 1985). Fine-grained iron precipitates are sometimes noted at mine water discharge points. These precipitates are generally not prolific enough to cause notable suspended sediment water quality impacts.

The dissolution of gypsum, halite, or other highly soluble minerals, which occur naturally in small quantities in the rocks adjacent to mine openings, may degrade the quality of the water discharging from the mine. The dissolution of gypsum increases the calcium ion, sulfate, and TDS concentrations of mine water. The dissolution of halite increases sodium ion, chloride, and TDS concentrations. These dissolution reactions affect water quality if these minerals are present in abundant quantities along groundwater flowpaths newly created by mining. This impact is generally not noted in Wasatch Plateau coal mines.

Some materials used in mining operations, when brought into contact with groundwater, have the potential to adversely impact the quality of water discharged from the mine. Mayo and Associates (1994) report that in the late 1980s gypsum rock dust was used in the Skyline Mine. This practice resulted in exceedence of TDS limits for mine discharge water because of the high solubility of gypsum. In March 1991, Skyline Mine began using carbonate rock dust, which is considerably less soluble in water. As a result of this change water quality of mine discharge water eventually improved. Mayo and Associates (1994) also note that part of the increase in TDS of mine discharge waters relative to mine inflow waters is a result of the oxidation of longwall emulsion fluid. When fugitive longwall emulsion fluid comes in contact with mine waters, the organic molecules in the fluid are readily oxidized by bacterial action resulting in the production of carbon dioxide gas. Carbon dioxide gas reacts with water to form carbonic acid (H_2CO_3), which dissociates into hydrogen ions and bicarbonate. The liberated hydrogen ions are rapidly consumed in reactions with naturally occurring carbonate minerals, resulting in increased calcium ion, magnesium ion, and bicarbonate concentrations in mine water.

During the course of mining operations, many tons of ferrous metals are utilized. Some of the metal objects are removed after mining ceases and, as a necessity, others are left in place. The largest permanent use of metal in mining operations is in roof-support. Thousands of metal roof-bolts are installed at regular spacings in the mine roof to prevent roof collapse. In some locations, wire mesh is also installed. For safety reasons, it is not possible to remove the roof-bolts or wire mesh after mining in an area has ceased. Additionally, metal is used in stoppings

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and man-doors, overcasts, cribbing, well casings, pipes, and miscellaneous items such as hangers and signs. There is the potential for the metal in these objects to oxidize (rust) as it comes in contact with water in the mine environment.

Oxidation of ferrous materials results in the release of iron into the water. The magnitude and rate of the potential oxidation is constrained by a complex variety of factors, including the temperature, Eh, and pH of the water, the pressure on the system, the presence or absence of bacteria, and the solute chemistry of the mine water. As a result, this potential impact is difficult to quantify. However, discharge water from Wasatch Plateau coal mines has not been degraded by elevated iron concentrations. To what extent the iron concentration in mine discharge water may change after mining operations cease is difficult to determine. However, the concentration would likely remain low because dissolved iron is rapidly precipitated as iron hydroxides as noted previously.

Mining equipment may be abandoned underground as dictated by safety or economic considerations. However, it is Forest Service policy to not allow any new solid waste disposal facilities on National Forest System lands and to not add to existing facilities. Equipment left underground would be considered a solid waste and it would not be consistent with Forest Policy to allow the abandonment of equipment underground. Further, Section 7 of the BLM lease form requires lessees to remove equipment and materials "as required by the authorized officer." In the event that it were necessary to leave equipment underground for safety reasons, it is unlikely that corrosion of abandoned equipment would degrade the quality of water in the mine environment. Mining equipment, such as longwall mining machines, roof bolters, and continuous miners, is made of high quality steel alloy containing chromium. The metal is highly resistant to corrosion. Calculations of the corrosion potential of the steel used in longwall mining machines have been performed by the University of Utah Metallurgy Department (BLM, 1998). They determined that it would take thousands of years for the metal to corrode away, and that the metal would need to be ground to a fine particulate for chromium to be dissolved. The University of Utah (BLM, 1998) report indicates that the general conditions required to hasten the corrosion of this metal do not exist in the Utah coal mining environment.

Petroleum, oils, and lubricants are regularly used in mining operations. These materials may degrade discharge water quality if they are mishandled or abandoned underground and exposed to water passing through the mine. Any toxic or hazardous materials which are used underground would have to be removed from the mine prior to closure.

Although the impacts to water quality are expected to minimal, the application of SCLS #19 would require that the operator remove mine equipment and materials that are not needed for continued operations, roof support, and mine safety from underground workings prior to abandonment of mine sections.

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Alternative 3: Lease with BLM Standard Lease Terms and Conditions Only

The potential impacts to groundwater resources under this alternative are the same as under Alternative 2, except that the area of potential impact increases as a result of not applying stipulations that preclude the subsidence of perennial creeks, paved roads, and structures.

By not applying the SCLS under this alternative, impact mitigation dictated by SCLS #17 and SCLS #19 would not be required.

Under this alternative, the operator would not be specifically required to remove equipment that is not incorporated into the mine. However, as noted, it is Forest Service policy to not allow any new solid waste disposal facilities on National Forest System lands and to not add to existing facilities. Equipment left underground would be considered a solid waste and it would not be consistent with Forest Policy to allow the abandonment of equipment underground. Further, Section 7 of the BLM lease form requires lessees to remove equipment and materials "as required by the authorized officer."

Nevertheless, if mine equipment were left underground, it is unlikely that ferrous equipment such as longwall shields, longwall shears, or continuous miners would perceptibly or quantifiably impact water quality even if these pieces of equipment were abandoned in areas that subsequently flooded. As noted in the previous section, the general conditions facilitating oxidation of metals do not exist in Utah coal mines. Minor water quality impacts could occur if lubricants were not drained from the equipment prior to abandonment. The magnitude of this impact would depend on the amount of organic materials, the volume of water in a flooded section, and the rate of intrinsic bioremediation. Computerized controls on equipment may contain lead, cadmium, mercury, and chromium and could cause water quality impacts if located in a flooded section. However, the magnitude of this impact is estimated to be minimal because of the small amount of controls relative the volume of water likely to be impounded and the slow oxidation rates of these materials in the mine environment.

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RECOMMENDATIONS FOR MONITORING AND MITIGATION

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SURFACE WATER

CFC has monitored stream discharges and water quality at eight sites in the RFDS area. For the SMCRA mining permit, an operational monitoring program that would need to be approved by UDOGM would be developed that builds on the baseline monitoring. It is recommended that, where possible, long-term discharge measurement devices be installed at locations selected for operational monitoring. This would facilitate greater accuracy and consistency in the flow measurements, which greatly increases the usefulness of these data. It is recommended that continuous recording devices be installed at surface-water monitoring stations on critical drainages.

Additionally, it is recommended that those stream reaches that have been classified as likely being perennial be monitored periodically in the future to refine the delineation of perennial reaches in the RFDS area.

Perceptible or quantifiable impacts to surface water discharge rates are not expected as a result of mining in the RFDS area. Therefore, no measures are recommended to decrease the likelihood of a perceptible or quantifiable impact. If surface water discharge rates were to be impacted, mitigation would be required by SMCRA for culinary drinking water sources and Utah State Code 40-10-18 for state appropriated waters. If SCLS #17 were applied to the lease, the lessee would be required to replace any water lost from creeks designated for protection with water of similar quality.

It is recommended that if mine water is discharged directly into Electric Lake that consideration be given to the placement of the discharge point. If the water is allowed to flow rapidly over the shoreline of the lake, appreciable erosion and sediment redistribution may occur. It may be advantageous to install an energy dissipating system that would decrease the discharge velocity and erosion potential of the discharging water.

Site-specific pre-mining investigations and planning should be carried out before mining proceeds in those areas where it is determined that there is high potential for subsidence-induced stream gradient reversal and pond or wetland formation. The precise locations of areas of potential stream gradient change would be a function of the implemented mining plan. Therefore, where possible, mining plans should be designed to minimize the potential for this occurrence.

GROUNDWATER

CFC has monitored 24 springs in the RFDS area for baseline water quality and discharge. It is expected that an operational monitoring program that builds on this baseline monitoring would be required under the SMCRA permit administered by UDOGM. The most critical data that can be collected are spring discharge measurements and emphasis should be placed on collection of

flow data over water quality data. No additional monitoring of groundwater resources is recommended.

Perceptible or quantifiable impacts to groundwater resources are not expected as a result of mining in the RFDS area. No measures are recommended to decrease the likelihood of a perceptible or quantifiable impact. If groundwater resources were to be impacted, mitigation would be required by SMCRA for culinary drinking water sources and Utah State Code 40-10-18 for state appropriated waters. If SCLS #17 is applied to the lease, the lessee would be required to replace any water lost from developed groundwater sources with water of similar quality.

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APPENDIX B

TECHNICAL REPORT SUMMARY TABLE

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RESOURCE/ISSUE	EFFECTS BY ALTERNATIVE		
Alternative	**Alternative 1** No Action	**Alternative 2** Std. Terms and Conditions with Special Stipulations to Protect Resources. No Subsidence of Sensitive Resource Areas or Facilities	**Alternative 3** Standard Terms and Conditions Only
Surface Water			
Diminution of creek flows due to impacts to groundwater discharge that provides baseflow	No Effect	The probability of a perceptible or quantifiable diminution of discharge from springs that provide baseflow to streams in the RFDS area is remote.	Same as Alternative 2
Diversion of water from perennial creeks into subsurface	No Effect	No Effect	Negligible effect. It is very unlikely that water would be diverted. Any pathways potentially created into the subsurface would rapidly be healed when wetted.
Increased sediment loading resulting from subsidence	No Effect	Minor, temporary effect. Increases or decreases in sediment loading of ephemeral drainages may result from differential subsidence. These would be short lived because drainages naturally have the tendency to return to equilibrium with substrate.	Same as Alternative 2, except the temporary increases or decreases in sediment loading would occur in perennial drainages. The effect could therefore occur throughout the year.
Impacts to morphology of perennial streams due to subsidence	No Effect	No Effect	Minor effect. There could be localized changes in stream gradients where differential subsidence occurs. In areas with naturally low stream gradients, there is the possibility of the creation of small ponds or wetland areas.
Impacts to water quality and quantity in Eccles Creek and downstream watercourses	No Effect	Addition of 4,840 ac-ft/yr to watercourse. Minor increase in downstream flooding potential. Average TDS in	Same as Alternative 2

		Eccles Creek increases from about 550 mg/l to 880 mg/l. Total mine water salt loading to Scofield Reservoir of 16.5 tons per day, or an increase of 9.4 tons per day above current permitted discharge levels.	
Impacts to water quality and water quantity in Electric Lake and downstream watercourses	No Effect	Addition of 4,840 acft/yr to watercourse. Minor increase in downstream flooding potential. Average TDS in uppermost Electric Lake increases from about 180 mg/l to 500 mg/l. Because of dilution, average TDS increase in all of Electric Lake would be lower. Total mine water salt loading to Electric Lake of 16.5 tons per day.	Same as Alternative 2

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Groundwater			
Dewatering of deep bedrock groundwater systems due to direct interception	No Effect	Deep bedrock groundwater systems would be locally dewatered. Remote possibility of impacting the hydrologic balance in either the recharge area or the discharge area.	Same as Alternative 2
Dewatering of groundwater in shallow horizons that support spring discharges in the RFDS area	No Effect	The probability of a perceptible or quantifiable diminution of discharge from spring in the RFDS area is remote.	Same as Alternative 2.
Potential for transbasin diversion of groundwater	No Effect	The specific nature of potential transbasin diversions cannot be ascertained. However, the magnitude of the impact is expected to not be perceptible or quantifiable.	Same as Alternative 2.
Water quality impacts associated with interactions of groundwater materials in the mine environment.	No Effect	Water quality is not expected to be impaired by interactions with either naturally occurring minerals or introduced materials. All equipment would be required to be removed prior to mine closure.	Same as Alternative 2 except that equipment might be allowed to be abandoned underground. However, no impairment of water quality expected

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APPENDIX C

RESUMES

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NAME James D. Alto, P. E.

TITLE Manager, Environmental Services

SUMMARY OF EXPERIENCE

Over 17 years experience in a variety of engineering roles in the mining and environmental fields. Licensed professional engineer and registered environmental manager with more than seven years management experience in environmental and engineering consulting. Extensive background in environmental compliance auditing, preparation of Plans and Operations, site reclamation design and bond calculations, financial analysis, project feasibility justification, project management, proposal development, NEPA, RCRA, and CERCLA. Proven leadership abilities with commitment toward the quality process and team management principles.

ACADEMIC AND PROFESSIONAL QUALIFICATIONS

B.S., Mining Engineering, University of Utah
Licensed Engineer, State of Utah
Registered Environmental Manager
Certified Environmental Auditor
Member Elect - Mining and Metallurgical Society of America (MMSA)
Past Chair - Utah Section, Society of Mining Engineers (SME of AIME)

PROFESSIONAL HISTORY

1997-Present
NorWest Mine Services, Inc., Salt Lake City, UT
MANAGER, ENVIRONMENTAL SERVICES: Responsible for project management and engineering for a wide variety of mining and environmental projects.

1990 - 1997
JBR Environmental Consultants, Salt Lake City, Utah
MANAGER, ENGINEERING & INVESTIGATION TEAM LEADER: Senior level management responsibility for all contracted environmental engineering projects including: tailings impoundment and heap each design, permitting and project management; ancillary facilities design and construction management; and design, installation and operation of environmental remediation systems. Directed engineering marketing efforts and long-range and short-range strategic planning. Staff totaled nine full time engineers, geologists, designers and drafters with annual revenues of over $900,000.

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- Manager of Engineering for multi-phased tailings impoundment retrofit project resulting in client savings of more than $6 million in capital expenditures.
- Co-author of Utah's Division of Water Quality's Guidelines for Design, Construction and Operation of Heap Leach Facilities.
- Project Manager for renewal of three discharge permits for a major gold mine in central Nevada. Permit renewals submitted to and approved by Nevada's DEP.

1990 - 1991
Plexus Resources Corporation, Salt Lake City, Utah
MANAGER, PERMITTING AND ENVIRONMENTAL AFFAIRS:
Directed evaluations of environmental and regulatory requirements for properties and projects presented to company for purposes of joint ventures and acquisition consideration. Responsible for coordination of company's efforts for acquisition of permits for underground polymetallic mine which included cooperative involvement with federal (USFS) state and county agencies. Responsible for environmental compliance auditing of 110,000 ounce/yr gold operation in western Nevada.

1988 - 1990
Plexus Resources Corporation, Salt Lake City, Utah
MINING ENGINEER: Responsible for all ore reserve calculations,, mine planning, metallurgical evaluation, capital and operating expense cost estimation, and feasibility analysis for preparation of recommendations for future of properties and projects. Responsible for review, analysis and reporting of findings of mine plan efficiencies and operating performance of 110,000 ounce/yr gold mine in western Nevada.

1981 - 1988
Arentz Mining Engineers, Salt Lake City, Utah
MINING ENGINEER: Directed development and on-site implementation of gold tailings retreatment heap leaching project in Sonora, Mexico. Performed ore reserve calculations, mine planning and feasibility analysis on numerous national and international consulting assignments.

1980
Ranchers Exploration & Development Corp., Escalante Silver Mine
JUNIOR MINING ENGINEER

1979
Black Butte Coal Company, Black Butte Mine
JUNIOR MINING ENGINEER

DIV OF OIL GAS & MINING

NAME Dr. C.B. (Conrad) Houser

TITLE Vice President

SUMMARY OF EXPERIENCE Internationally experienced mining engineer and manager with broad engineering, environmental, legal, marketing, planning, and financial experience as well as focussed skills in surface and underground mining of coal, oil shale and trona.

ACADEMIC AND PROFESSIONAL QUALIFICATIONS

M.S. (civil engineering - Rice University, Houston, Texas, 1969
B.S., U.S. Air Force Academy, Colorado Springs, Colorado, 1967
MBA course work, University of Utah, Salt Lake City, Utah, 1977
J.D. (Cum Laude), J. Reuben Clark Law School at BYU, Provo, Utah, 1975
Member of Utah State Bar
U.S. Patent License
Registered Professional Engineer in Colorado and Wyoming
Certificated in Total Quality Management, Financial Analysis of Investments, Project Management, International Finance, Industrial Relations, Safety Supervision, Negotiation Techniques

PROFESSIONAL HISTORY

1996 - Present
NorWest Mine Services, Inc., Salt Lake City, Utah
VICE PRESIDENT: Provides mining, financial services, and project management. Recent assignments include preparing final EPC and contract mining documents for an Indian coal project; due diligences studies and appraisals; and project manager on Brazilian underground mining project.

1995 - 1996
Rocky Mountain Leadership Institute, Casper, Wyoming
PRESIDENT: Consulting and training for businesses and governmental entities. Acquisition analysis and due diligence. Asset maximization. Marketing realignment. Strategic planning.

1993 - 1995
Wold Trona Company, Inc., Casper, Wyoming
VICE PRESIDENT, CHIEF OPERATING OFFICER: Overall responsibility for integration of $200 million new mineral process technology development, design, financing, permitting, marketing, administration, and legal affairs.

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MARKETING: Pre-sold 80% of initial 10 year's production via letters of intent: established strategy, introduced new project to market, initiated revision of industry specifications, established customer relations all leading to project revenue base loading.

ADMINISTRATION: Organized all office functions from ground zero to produce synergistic MIS, planning, accounting, budgeting, and associated functions.

PERMITTING: Orchestrated all aspects of permit preparation, review, and approval at minimal cost and record speed to clear the way for project construction.

ENGINEERING: Participated in process development, capital and operating cost reduction, process and mine design and engineering, construction of demonstration plant, preparation of bid packages, leading to success ful posturing of Engineering Procurement - Construction contract.

LEGAL: Developed in-house and through outside counsel partnership agreements (Limited Liability companies and Limited Partnerships) sales, contracts, Interior Board of Land Appeals defence, patent applications, engineering contracts, and the project financial prospectus.

1992
Drummond, Gillette, Wyoming
ENGINEERING & ENVIRONMENTAL MANAGER: After purchase of Mobil operations by Drummond, responsibilities included development of plans and permits to transition the Caballo Rojo Mine from truck and shovel to dragline operations.

1977 - 1991
Mobil Corporation
VICE PRESIDENT - ENGINEERING MANAGER, DENVER, COLORADO (1988 - 1991): Operations in Wyoming's Powder River Basin and Indonesia. Complete engineering, environmental, strategic planning and financial responsibility. Key participant in Booz, Allen, Hamilton strategic posturing project in New York City to determine whether Mobil should remain in the coal business. Recommended Mobil discontinue its coal focus unless it was willing to become a major player. Played a major role in the solicitation of buyers and the sale of Mobil's coal interests, netting $80 million in asset recovery. Quarterbacked lawsuit defending Mobil's integrity against claims of tortuous contract interference by a competitor.

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ENGINEERING & ENVIRONMENTAL MANAGER, GILLETTE, WYOMING (1985 - 1987): Created $3 million unanticipated profit enhancement by changing mining location to better optimize returns from the operation - requires complete revision of both short and long term mining plans as well as major permit revision in record time. Made major operating changes to match coal quality to customer needs - necessitated changing both vertical and horizontal mining orientations. Development drilling techniques were significantly enhanced. Developed special software for selection of coal to yield increased profits though proper shipment scheduling. Truck and shovel operations were optimized.

Negotiated a win-win agreement out of deadlocked conflict saving over $1.3 million. Actively participated in marketing of coal. Led an environmental team to the only perfect record (zero notices of violation) in U.S. fossil fuelled mining history (over 280 inspections). Revitalized and empowered a stagnant engineering and environmental staff.

1982 - 1985
Mobil Synfuels, Denver, Colorado
VENTURE SERVICES ADVISOR: Led matrix organization including all reserve definition and underground mine planning supporting $6 billion project. Complete infrastructure alignment with mining and processing operations.

1980 - 1981
Mobil Corporation, Ndola, Zambia
MANAGING DIRECTOR/GENERAL MANAGER: Originated program for converting wasted flare-gas into replacement fuel for transportation with national hard currency savings estimated at $4 million per year. Pioneered transfer of wholesale metered distribution system into developing country, saving over $180,000 in annual operating cost. Coordinated legal, financial, and engineering activities for EPC blending and packaging plant in Zambia with revenue contribution projected at $8 million per year.

1977 - 1980
Australia Marketing Operations; Manager, Queensland, Brisbane
TERMINAL MANAGER: Dramatically improved customer and marketing support services and responsiveness. Resolved hot union conflicts and sustained peaceful and productive relationships, avoiding work stoppages and their attendant loss of revenue and market share. Reorganized production practices to dramatically reduce losses and costs.

1975 - 1977
Spafford, Nixon & Houser; Salt Lake City, Utah
LAW FIRM PARTNER

1971 - 1973
Nelson, Haley, Patterson & Quirk; Greeley, Colorado
ENGINEERING COORDINATOR

1968 - 1971
Captain, US Air Force; Tokyo, Japan
Headquarters Fifth Air Force
BASE ENGINEER

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NAME T.W.P. (Tim) Peterson

TITLE Senior Geotechnical Engineer

SUMMARY OF EXPERIENCE

Tim Peterson has over 25 years of engineering experience in geotechnical and civil engineering. He has been responsible for numerous geotechnical site investigations for thermal and hydroelectric power plants, dams, open cast mines, light to heavy industrial complexes, gas plants, low and high rise residential, hospital, educational, and commercial buildings, roads, bridges, port facilities, off-shore platforms, small and large diameter water, sulphur and gas pipelines and transmission lines. His experience includes the design of pad, raft and most types of piled foundations including foundation analyses for offshore platforms in the North Sea and Indian Ocean; the design of earth, tailings and water retaining structures; detailed settlement analyses; seismic analyses; and stability analyses of open pit mines, road and rail cuttings and embankments, earth and rockfill dams, and excavated marine slopes. He has specialized experience in the field of geotechnical engineering in permafrost regions, and has been responsible for conducting numerous geotechnical failure investigations for insurers. He has worked on several projects worldwide including major hydroelectric studies in Pakistan and Bolivia; open pit mines in Indonesia, Thailand, the Philippines, Colombia and Australia; industrial and commercial projects in the Middle East and the U.K. and spent most of 1994 managing field investigations for four high head hydroelectric schemes in Bolivia. He provides ongoing mining assistance to a major Canadian Utility, including design and monitoring of highwalls, waste dumps and tailings impoundments and geotechnical input to mine planning.

ACADEMIC AND PROFESSIONAL QUALIFICATIONS

B.Sc., (Civil Eng.), Portsmouth, U.K., 1973
H.N.D., (Civil Eng.), North East London Polytechnic, U.K., 1971
Member, Association of Professional Engineers, Geologists and Geophysicists of Alberta (P.Eng.)
Chartered Engineer, U.K. (C.Eng.).
Member, Institution of Civil Engineers (M.I.C.E.).
Fellow, Geological Society of London, U.K. (F.G.S.).
Member, British Geotechnical Society.
Member, International Society for Soil Mechanics and Foundation Engineering.

PROFESSIONAL HISTORY

1996 - Present
NorWest Mine Services Ltd., Calgary, Alberta
SENIOR GEOTECHNICAL ENGINEER: Consulting services to a major

Canadian utility for civil and mining related work. Dam safety evaluations of ash lagoons and cooling ponds and design of incremental construction of ash tailings impoundments. Ongoing pit stability monitoring and input to mine planning. Remediation work associated with mine subsidence.

1980 - 1996
Monenco Agra, Calgary, Alberta
SENIOR SUPERVISING GEOTECHNICAL ENGINEER: Civil Engineering Department (1995 - October 1996). Responsible for mining, hydroelectric and process related projects. Specific projects include the design of the Snare Cascades Hydroelectric Project, Northwest Territories; design and reconstruction of Whiteman's Dam, Canmore, Alberta; Plant 4 Emergency Tailings at Suncor; design of a new sewage lagoon at Sundance Thermal Plant, Alberta; design of headpond impoundments, Miguillas Valley, Bolivia; upgrading power canal dykes, Brazeau, Alberta; seismic analysis of high head hydro developments, Zongo Valley, Bolivia, settlement monitoring and remediation of Highvale Mine Services Building, Alberta; geotechnical assessment of Highvale Mine long range plan area; dam safety assessment of the Wabamun Ash Lagoon, Alberta; and ongoing pit slope stability monitoring at Highvale and Whitewood Coal Mines.

MANAGER OF OPERATIONS: Miguillas Valley Hydroelectric Feasibility Study, Bolivia (1994 - 1995). Responsible for management and supervision of a nine month program of field investigations for four high head hydro schemes in the high Andes, including core drilling, geological mapping, hydrology, topographic, hydrographic and geophysical surveys, environmental and archaeological studies.

SENIOR SUPERVISING GEOTECHNICAL ENGINEER: Civil Engineering Department, Calgary (1989 - 1993). Responsible for mining, hydroelectric, and industrial projects. Geotechnical project coordination for open pit mine stability monitoring, groundwater monitoring and dewatering, mine design and planning at Highvale and Whitewood Mines, Alberta. Coordination, management and supervision of field investigations for Pasir Coal Project, Kalimantan, Indonesia; site selection and supervision of site investigations associated with Himalian and Panian Mine Feasibility Studies on Semirara Island, Philippines; geotechnical audits of a proposed coal mine in Colombia; and geotechnical assessment and coordination of investigations and review of geotechnical criteria for LP-2 coal project, Thailand. Designs for Three Sisters Dam, Spray Canal, Glenmore Causeway and Ghost Dam, Alberta. Geotechnical Project Engineer involved with design of the Husky Bi-Provincial Upgrader at Lloydminster, the LNS pilot project at Cold lake and road upgrading at CFB Suffield.

SENIOR SUPERVISING GEOTECHNICAL ENGINEER: Civil Engineering Department, Calgary (1987-1989). Responsible for project coordination and geotechnical input to hydroelectric, mining and industrial projects including North Fork, Bearspaw, Bighorn, Ghost, Glenmore and Three Sisters Dam safety assessments and upgrading; Highvale and Whitewood Mine geotechnical assessments and stability monitoring, and foundation analysis for the LRT Crowchild Bridge, Calgary.

SUPERVISING GEOTECHNICAL ENGINEER: Civil Engineering Department, Calgary (1984 - 1987). Responsible for mining, hydroelectric and industrial projects. These include dam safety evaluations; the design of new spillway structures; slope stability analyses of mines in Alberta, Nova Scotia and Australia, including Leigh Creek and Lochiel in South Australia; foundation recommendations for industrial and gas plants in Alberta and Saskatchewan; settlement analysis of piled foundations for multi-storey structures in Alberta; substation site preparation and foundation design in upper New York state; bridge foundation and abutment design for county roads at Whitewood, Entwistle and Brazeau, Alberta.

DIRECTOR OF FIELD INVESTIGATIONS, Basha, Pakistan (1982 - 1984). CIDA funded feasibility study of a hydro site on the Indus river at Basha, Pakistan, where the construction of a 200 m high rockfill dam and 50 mile long reservoir was proposed. Responsible for managing the site office and all site activities including over 4000 metres of drilling in rock and overburden, topographical and hydrological surveys, geological mapping of outcrops, organization and supervision of the site soil testing laboratory, preparation of all site related data for input to the Feasibility Study Report and the general Hydroelectric Studies Report prepared by MCL in Lahore, Pakistan.

MANAGER SPECIAL DESIGN GROUP, Calgary (1981 - 1982). Seconded to the Yukon Pipeline Design Joint Venture, Calgary, for the design of the Yukon Section of the Alaska Highway Gas Pipeline for Foothills Pipelines. Responsibilities included the coordination of all geotechnical input to the pipeline design, together with supervising all special design aspects required for the 48 and 56 inch diameter warm and chilled sections of the line to be constructed in intermittent permafrost, including geotechnical, geothermal, hydrological, drainage and erosion control and insulation. Specific geotechnical concerns included detailed analyses of frost heave and thaw settlement, pipeline restraint criteria and the stability of frozen and unfrozen excavated and natural slopes. An appraisal of site investigation methods in cold regions was carried out, together with a review of terrain analysis techniques and data from over one thousand boreholes along the entire route in the Yukon.

SENIOR GEOTECHNICAL SPECIALIST: Civil Engineering Department, Calgary (1980 - 1981). Responsible for investigation works, stability analysis using the Slope II computer model of existing hydroelectric developments for TransAlta Utilities. Foundation studies and recommendations for the Keephills Thermal Plant, Alberta, and recommendations involved in the planning and operating of the Highvale and Whitewood Coal Mines, Alberta.

1969 - 1980

Pell Frischmann and Partners, London, U.K.

SENIOR GEOTECHNICAL ENGINEER (1977 - 1980). Responsible for the planning, management and interpretation of site investigations; the design of foundations, deep basements and earth retaining structures for projects in the U.K., U.S.A., Nigeria and the Middle East, including multi-storey offices, hotels and hospitals, housing, industrial and civil engineering developments and offshore structures; the design and site supervision of land reclamation for British Steel Corporation's new Ore Terminal and direct Reduction Plant at Hunterston, Scotland; investigation and design of land reclamation for a Water Pollution Control Centre at Tubli, Bahrain; analyses of foundation design and operational behaviour of the Production Platform Jacket in the North Sea Brent Field for Shell; foundation design checking for the Bombay High Field Platform; state of the art study report on Containership Berthing Facilities with DMJM of Los Angeles for the Los Angeles Harbor Department; failure investigation of the fourteen berth extensions to the Port of Bandar Shahpour, Iran; slope stability analysis associated with deep excavations, embankments and dredged marine slopes; the investigation of and reporting on geotechnical failures for Insurers, and the completion of numerous feasibility studies for office and industrial developments in the U.K. and overseas.

GEOTECHNICAL ENGINEER (1973 - 1977). Responsible for the interpretation of site investigations, stability and settlement analyses, and the design of foundations.

ASSISTANT ENGINEER (1969 - 1973). Involved with site supervision of various large contracts in the U.K. and the design of multi-storey office and hospital buildings.

PAPERS PUBLISHED

1996 *"Collapse settlement of wetted mine waste - two case histories"*, with N.H. Wade, to be presented at Tailings and Mine Waste '97, Fort Collins, Colorado, January 1997.

1996 *"Whiteman's Earthfill Dam Internal Erosion"*, with L. Courage, A. Rothbauer, B. Pelz, to be presented at ICOLD, Florence, Italy, May 1997.

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1993 *"Collapse and Consolidation Settlement in Mine Spoil Due to Saturation and Preloading"*, with N.H. Wade; 46th Canadian Geotechnical conference, Saskatoon, Saskatchewan, October.

1991 *"Graphical Database for Pit Slope Monitoring"*, with N.H. Wade, 2nd Canadian Conference on Computer Applications in the Mineral Industry, Vancouver, B.C.; Sept.

1991 *"Interpretation of Geophysical Logs Using a Scanning Routine"*, with N.H. Wade; ibid.

1988 *"Evaluation of Two Hydraulic Fill Dams in Alberta"*, with N.H. Wade, L. Courage, and R. Keys; Hydraulic Fill Structures '88 ASCE Speciality Conference in Fort Collins, Colorado, August, 1988.

1987 *"Interdisciplinary Mine Planning - The Geotechnical Component"*, with N.H.Wade, F. Naderi, CIM 3rd District Five Meeting, Fort McMurray, Alberta, September 1987.

1986 *"Highwall Monitoring, Instrumentation and Stability Analysis at Highvale Coal Mine, Alberta"*, with N.H. Wade, Symposium on Geotechnical Stability in Surface Mining, University of Calgary, Alberta, November 1986.

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NAME	Richard Wright, C. Eng.
TITLE	Senior Mining Engineer
SUMMARY OF EXPERIENCE	Mr. Wright has over 20 years of mining related experience in operations, engineering and consultancy associated with both underground and surface mines in the USA, Canada, South Africa, Mexico and the U.K. His last two years were spent as project manager assisting an underground longwall coal expansion program in Mexico. He has spent five years in the USA progressing coal prospects from the feasibility phase through to operations planning and engineering, including a mine that has recently been setting world longwall production records. In addition he has about 10 years of consultancy experience covering geotechnical, mining and ventilation engineering for a variety of projects and clients, including design, engineering and planning applications and associated public inquiries.
ACADEMIC AND PROFESSIONAL QUALIFICATIONS	M.Sc. (Mining/Geotechnical), University of Alberta, 1981. B.Sc. (Mining Engineering), Royal School of Mines, London, UK, 1977. B.Sc. (Engineering Science), University of Leicester, UK, 1974. European Engineer (Registration No: UK/IMM/EE/94/8852) Chartered Engineer (No.410430), Member of the Institution of Mining and Metallurgy
PROFESSIONAL HISTORY	**1998 - Present** **NorWest Mine Services Ltd., Calgary, Alberta, Canada** SENIOR MINING ENGINEER: Engineering and Management of underground mining and geotechnical projects. Providing operational and planning assistance with emphasis on underground coal mine design and planning, mine rehabilitation, stability of underground openings and blasting vibrations impact analysis **1989 - 1998** **Wright Technical Services, Redruth, Cornwall, England** MINING / GEOTECHNICAL CONSULTANT: Independent Mining and Geotechnical Engineering Consultant with emphasis on coal mining, underground construction and radioactive waste disposal. Projects included: • Project Manager for operations and engineering assistance for upgrading of existing and new underground coal mines for

MICARE, Coahuila, Mexico;

- design, data evaluation and shaft/tunnel surveying for the planned Sellafield underground radioactive waste repository in the UK;
- geotechnical site investigations and evaluation of the stability of foundations, slopes and underground openings for a number of clients;
- ventilation design and monitoring for construction of the UK side of the Channel Tunnel; and
- various coal and metal mine engineering and planning studies for a number of clients.

1987 - 1989
Jay Mineral Services Limited, Truro, Cornwall, England
MINING CONSULTANT: Responsible for a variety of mining engineering projects including;

- various economic evaluations of underground and surface coal and metal mines in the UK and overseas;
- prediction of blasting vibrations for surface coal mines and preparation of expert witness evidence for the Smotherfly planning inquiry in the UK;
- pillar design of coal and salt mines in the UK and Ireland;
- shaft winding and headframe design for underground coal mines and preparation of expert witness evidence for the Hawkhurst Moor public inquiry in the UK;
- market study for full face hard rock boring of tunnels and shafts; and
- electricity tariff study for gold mining in Ghana..

1986 - 1987
Battelle Project Management Division, Columbus, Ohio, USA
SENIOR GEOTECHNICAL ENGINEER: Assistant Project Manager of a $10 million contract for underground geotechnical testing as part of the site characterization for a proposed underground nuclear waste repository in salt strata. This included planning for major long term tests on the rock mass and engineered barriers in an exploratory shaft facility in Texas, USA. The tests were designed to assess the mechanical, thermal, chemical and hydraulic performance under nuclear safety requirement for containment over 10,000 years.

1983 - 1986
Twentymile Coal Company, Colorado, USA
CHIEF MINING ENGINEER: responsible for the mine planning and engineering department of an underground coal mine. This involved detailed planning for

a 3.2 Mtpa operation with both longwall and room and pillar operations. This included ventilation survey and design, geology, geotechnical, hydrology, coal quality, construction, equipment selection, environmental, permitting, financial evaluations, surveying, sequencing and subsidence prediction and monitoring.

1981 - 1983
Getty Mining Company, Salt Lake City, Utah, USA
PROJECT ENGINEER: responsible for underground coal mine planning, mine design, feasibility studies and exploration programmes for new projects and operating coal mines. Developed geotechnical programs for rock characterization and hazard analysis for mine design and strata control studies.

1977 - 1978
Anglo Power Collieries, Kriel, Transvaal, South Africa
MINE ENGINEER: responsible for an underground coal production section and surface mine planning and engineering of an opencast coal mine (pit design, sequencing, geology, coal quality, etc.).

1974 - 1975
Anglo American Corporation, Welkom, Orange Free State, South Africa
MINE OFFICIAL: Practical experience in production, preparation, ventilation, surveying, sampling and other service departments of deep underground gold mines.

PUBLICATIONS

1988 Blasting Vibes I and II, J.Stocks and R.Wright, Mineral Planning, UK.
1982 Technology Management for Risk Minimization, J.D.Spalding, E.N.Thurmond, J.M.Mercier and R.Wright, International Conference on Coal Research (ICCR), London.
1981 Stability Analysis in Room and Pillar Coal Mining, M.Sc. Thesis, University of Alberta, Canada.

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NAME	Kelly L. Payne
TITLE	Hydrogeologist
EDUCATION	M.S. Hydrogeology, Expected Graduation Date December 2000 Brigham Young University, Provo, Utah, Usa Thesis Title: *Occurrence and Geochemical Evolution of Shallow Groundwater in the Northern Altiplano, Bolivia: Implications for Groundwater Resource Development* B.S. Geology, 1994 Brigham Young University, Provo, Utah, USA
WORK EXPERIENCE	NorWest Mine Services, Inc, Salt Lake City, Utah, June 2000 to present. Mayo and Associates, LC, Lindon, Utah, April 1994 to June 2000, hydrogeologist, project manager, office manager
PROJECT EXPERIENCE	**Coal Mine Permitting** Supervised the preparation of Chapter 6 (Geology) and Chapter 7 (Hydrology) of the Mining and Reclamation Plan (MRP) for the new West Ridge Mine. Work was performed for WEST RIDGE Resources, Price, Utah. Supervised the investigation of groundwater systems, preparation of a statement of Probable Hydrologic Consequences (PHC), and a surface water and groundwater monitoring plan for existing coal leases and new properties acquired by the C.W. Mining Company, Huntington, Utah. Made a presentation at an Informal Conference before the director of UDOGM when the permit was protested. Characterized groundwater systems and evaluated the impacts of underground coal mining on surface water and groundwater at a number of mines in the Wasatch Plateau and Book Cliffs Coal Fields. Prepared a statement of the Probable Hydrologic Consequences (PHC) and a surface water and groundwater monitoring program, as required for a Mining and Reclamation Permit (MRP) by the Utah Division of Oil, Gas and Mining. These mines include:

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Soldier Canyon Mine, Soldier Creek Coal Company, Wellington, Utah.
Skyline Mines, Canyon Fuel Company, Scofield, Utah
SUFCO Mine, Canyon Fuel Company, Salina, Utah
PacifiCorp Mines (Deer Creek, Cottonwood, and Trail Mountains), Huntington, Utah
Crandall Canyon Mine, GENWAL Resources, Inc, Huntington, Utah
Willow Creek Mine, Plateau Mining Corp., Helper, Utah

Supervised the investigation of potential impacts of longwall mining at the SUFCO Mine to the hydrologic balance of Box Canyon Creek, a perennial stream. Prepared a report summarizing impacts to cultural resources, riparian ecosystems, and hydrologic balance. The purpose of the investigation was to gain U.S. Forest Service consent to use longwall extraction to undermine the perennial stream. Evaluation performed for Canyon Fuel Company, Salina, Utah.

Investigated the source of large volume groundwater in-flows from faults in the West Elk Mine in order to predict future encounters and assess the hydrologic impacts of intercepting fault waters. This investigation was undertaken for Mountain Coal Company, Somerset, Colorado.

NEPA

Managed the preparation of technical reports and groundwater resource sections of Environmental Impact Statements for both The Pines and the Cottonwood Coal Lease Tracts. Work was performed for the Manti-La Sal National Forest as a third-party NEPA contractor.

Water Supply, Water Resources, and Water Rights

Performed a preliminary evaluation of the shallow groundwater resources and assessed the potential for contamination of shallow water wells in the northern Altiplano, Bolivia for the Benson Institute, a non-governmental organization based in Provo, Utah.

Managed the evaluation of background water quality and infiltration potential for a new sewage treatment facility in Cedar Valley, Utah. The project included the installation and sampling of monitoring wells and soil borings and in situ permeability tests.

Prepared Delineation Reports for the Drinking Water Source Protection Plan, required by the State of Utah for all public culinary water supplies. Work was completed for Skyline Mines and SUFCO Mine.

Preparing the Delineation Report and Drinking Water Source Protection Plan for Alpine Cove Water Company's culinary wells.

Characterized groundwater conditions in the New Harmony, Utah Area in order to help defend water rights held by the LDS Church. Gave oral testimony in deposition and at trial.

Hazardous Materials Investigations

Conducted geophysical investigations at several UST sites in Provo, Utah. The research evaluated the response of electrical resistivity (ER), very low frequency electromagnetic (VLF), and ground-penetrating radar (GPR) geophysical methods to shallow gasoline contamination.

Performed a characterization of groundwater flow regimes and the fate of hydrocarbon contamination in the Big Piney Oil and Natural Gas Field, Wyoming for Mobil Exploration and Producing, U.S.

Characterized the hydrogeology and extent of natural gas condensate contamination and prepared a groundwater monitoring plan for a natural gas production well site near Big Piney, Wyoming. Work was completed for Mobil Exploration and Producing, U.S. and Williams Field Services.

Provided technical and logistical support to the investigation of heavy metal contamination caused by irrigation with raw sewage in the Mezquital Valley north of Mexico City. This investigation was conducted by Brigham Young University and the University of Hidalgo in Pachuca, Hidalgo, Mexico. Performed initial project reconnaissance and provided verbal translation for BYU faculty.

Prepared a site characterization and groundwater monitoring plan for a hydrocarbon contaminated site at a natural gas compressor station in Wyoming. The project included the installation of monitoring wells, water quality sampling, and the review and analysis of historical data.

Managed the hydrogeologic characterization and hydrocarbon contamination evaluation at the Foundation Creek Natural Gas Compressor Station, Rangely, Colorado. This project involved the installation of monitoring wells and soil borings, chemical sampling, and preparation of final report. Work was completed for Williams Field Services.

Forensic Hydrogeology and Litigation

Participated in the hydrogeologic characterization and evaluation of the extent of Cr^{6+} contamination of an alluvial aquifer at Hinkley, California. The work was performed in support of the lawsuit Anderson v. PG&E and Aguyo v. PG&E. Complied a database from more than 80,000 pages of documents produced by the defendant. Produced maps, graphs, and interpretations that were used in the presentation of expert testimony.

Currently participating in the hydrologeologic characterization of evaluation of the extent of TCE and perchlorate contamination of aquifers supplying domestic water to the City of Redlands, California. Work is being performed in support of a class-action and direct-action lawsuit brought against Lockheed-Martin Corporation.

PUBLICATIONS

Benson, A.K., Payne, K.L., and Stubben, M.A., 1995, Detecting organic groundwater contamination using electrical resistivity and VLF surveys *in* Hinchee, R.E., Douglas, G.S., and Ong, S.K., eds., Monitoring and verification of bioremediation: Battelle Press, Columbus, p. 105-113.

Benson, A.K., Payne, K.L., and Stubben, M.A., 1997, Mapping groundwater contamination using dc resistivity and VLF geophysical methods—A case study: Geophysics, v. 62, n. 1, p. 80-86.

Mayo, A.L., Morris, T.H., Petersen, E.C., and Payne, K.L., 1997, Groundwater flow systems in the Utah Coal District: Proceedings Rocky Mountain Ground Water Conference, Boise, Idaho.

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David Alan Newman

Education:

Doctor of Philosophy - Mining Engineering
The Pennsylvania State University, 1985
Master of Science - Mining Engineering
The Pennsylvania State University, 1980
Bachelor of Arts - Geology
Vassar College, 1977

Employment Background:

Present-1985	President, **Appalachian Mining and Engineering, Inc./Geolab** Lexington, Kentucky
Present-1989	President, **Newman Engineering, PSC.** Lexington, Kentucky
1988-1984	Assistant Professor of Mining Engineering, Director of Weekend/Evening Graduate Program **University of Kentucky** Lexington, Kentucky
1984-1978	Graduate Research Assistant **The Pennsylvania State University** University Park, Pennsylvania
1978-1977	Assistant Drill Manager, **American Testing and Engineering Company**, Indianapolis, Indiana

Professional Registration:

Commonwealth of Kentucky, Registered Professional Engineer, No. 14,891
Commonwealth of Kentucky, Registered Professional Geologist, No. 2,601
State of West Virginia, Registered Professional Engineer, No. 11,656
Commonwealth of Virginia, Licensed Professional Engineer, No. 023660
State of Indiana, Registered Professional Engineer, No. PE19300222

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Professional Experience:

Present-1985 **Appalachian Mining and Engineering, Inc./Geolab,** *President*
Engineering consulting firm specializing in rock and soil mechanics investigations, geotechnical engineering, subsidence prediction and abatement, blast design and evaluation, mine design and ground control, slope stability, mine property valuation and reserve analysis, coal refuse impoundment design and stability assessment, rock and soil property testing through **Geolab** a state-of-the-art materials testing laboratory using a computer controlled 200,000 pound capacity SATEC load frame.

Present-1988 **Newman Engineering, PSC.,** *President*
Municipal engineering projects involving urban hydrologic analysis and design, storm sewer design and evaluation, detention pond design, review of subdivision construction plans, highway design, and blasting projects.

1988-1984 **University of Kentucky**, *Assistant Professor - Mining Engineering*
Dr. Newman directed five externally funded research projects, conducted internally funded research while overseeing M.S. theses. He developed and directed the weekend/evening graduate program with Friday evening/Saturday morning courses at the Southeast Community College campus in Cumberland, Ky. Teaching responsibilities included undergraduate and graduate courses in rock mechanics, slope stability, and mine valuation. Dr. Newman developed and taught, the "Elements of Coal Mining" and "SUBSIDE" short courses.

1984-1978 **The Pennsylvania State University**, *Graduate Research Assistant*
Dr. Newman carried out research on four major research grants involving; development of a rock mass classification system for assessing mine roof stability,

- yield pillar design,
- longwall gateroad stability,
- coal pillar design for room-and-pillar mining,
- in-situ stress measurements,
- in-mine seismic refraction, and
- numerical simulation of roof behavior

1978-1977 Assistant drill manager, **ATEC Drilling**
Responsibilities included scheduling drilling crews, the maintenance of repair shop inventory, and geotechnical core logging. Projects included geotechnical drilling and conducting a seismic surveys

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Professional Societies:

Society for Mining, Metallurgy, and Exploration, Inc. (SMME)
- Rock Mechanics Award Committee
- Professional Engineering Examination Committee
- Student Activities Committee

Central Appalachian Section, SMME
American Society for Testing and Materials
Order of the Engineer
National Coal Association - Acid Mine Drainage Committee

Listings and Recognitions:

Who's Who in the South and Southwest
Phi Kappa Phi Honor Society
Mineral Research Institute Fellowship
U.S. Office of Education Mining, Mineral, Mineral Fuel Conservation Fellowship

Patents and Inventions:

"A Flexible Wire Rope Roof Bolt for Use in Thin Seam Coal Mines," Patent disclosure document No. 246721

"An In-situ Coal Face Sampling Device," Patent disclosure document No. 177846

"A Method of Increasing the Bulk Density of Coal in Underground Haulage Equipment," Patent disclosure document No. 180682

Grants and Contracts:

1988-1986 **U.S. Bureau of Mines**, Generic Research Program Mine Systems Design and Ground Control Virginia Polytechnic Institute, Blacksburg, Va. Principal Investigator "Field Investigation of the Post-Failure Behavior of Coal Pillars"

1988-1986 **Arch of Kentucky**, Lynch, Kentucky Principal Investigator "Rock and Coal Property Testing for Proposed Multiple Seam Mining Operation"

1986 **Arch of Kentucky**, Lynch, Kentucky Principal Investigator "In-situ Stress Measurements at Mine 37"

1986 **U.S. Bureau of Mines**, Mining and Mineral Resources Research Institute Seed Grant Program Principal Investigator "Laboratory Investigation of the Post-Failure Behavior of Coal"

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Grants and Contracts (continued):

1984 **University of Kentucky** - Graduate School Major Research Equipment Fund
Strain extensometers for post-failure research

1984- **SOHIO Center For Scientific Excellence in Mining Technology**, Researcher
1982 "Longwall Pillar Design and Gateroad Stability Assessment"

1984- **U.S. Bureau of Mines**, Mining and Mineral Resources Institute Grant,
1982 Contract No. G5105083, Researcher
"Design Procedures for Coal Mine Tunnels"

1983 G.A.I. Consultants, Inc., Monroeville, Pennsylvania
U.S. Dept. of Energy, Contract No. DE-AC22-80PC30120 Contract Researcher
"Characterization of Subsidence Over Pillar Extraction Panels"

1983- **U.S. Dept. of Energy**, Contract No. ET-78-G-01-3427 Researcher
1981 "Improved Design of Room-and-Pillar Coal Mining"

1980- **U.S. Dept. of Energy**, Contract No. ET-77-C-01-9144 Researcher
1978 "Geotechnical Investigation of Roof Conditions in the Area Mined by the Automated Extraction System"

Publications:

Newman, D.A., "The Role of Engineering and Geology in Analyzing Ground Control Conditions," 18th Int. Conf. on Ground Control in Mining, 1999, pp. 64 - 71.

Newman, D.A., "Landslide Occurrence in Steep Slope Areas of Appalachia," 17th Int. Conf. on Ground Control in Mining, 1998, pp. 309-316.

Newman, D.A., "Surface Subsidence and Structural Damage," Chapter 5 in: An Investigation of High Extraction Mining and Related Valley Fill Practices in Southwestern Pennsylvania, Audubon Society of Western Pennsylvania, 1998, pp. B-85 - B-120.

Newman, D.A., "Subsidence Prediction Techniques," Chapter 6 in: An Investigation of High Extraction Mining and Related Valley Fill Practices in Southwestern Pennsylvania, Audubon Society of Western Pennsylvania, 1998, pp. B-121 - B-131.

Newman, D.A., "Integration of Geology and Engineering Design in Mining: Multiple Seam Mining in the Southern Appalachian Coal Field," Milestones in Rock Engineering: A Jubilee Collection, Bieniawski, ed. A.A. Balkema, 1996.

Newman, D.A., "Planning and Design for Barrier Pillar Recovery - Three Case Histories," 14th Int. Conf. on Ground Control in Mining, West Virginia Univ., 1995, pp. 72-79.

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Publications (continued):

Newman, D.A. and Hoelle, J.L., "The Impact and Variability in Coal Strength on Mine Planning and Design - A Case History," West Virginia Univ., 12th Int. Conf. on Ground Control in Mining, 1993, pp. 237-243.

Artrip. P.S., Nelson, J.S., and Newman, D.A., "Modern Geotechnical Exploration and Mine Design,"West Virginia Univ., 12th Int. Conf. on Ground Control in Mining, 1993, pp. 249-260.

Newman, D.A. and Bennett, D.G., "The Effect of Specimen Size and Stress Rate for the Brazilian Test - A Statistical Analysis," Rock Mechanics and Rock Engineering, Vol. 23, 1990, pp. 123-134.

Newman, D.A., "In-Situ Yield Behavior of a Coal Pillar," International Journal of Mining and Geological Engineering, No. 2, Vol. 7, May, 1989, pp. 163-170.

Leonard, J.W. and Newman, D.A., "Volumetric Efficiency and the Potential for Increased Productivity in Underground Haulage Units" AIME-Society of Mining Engineers Annual Transactions, 1989, pp. 1202-1203.

Newman, D.A., "Yield Pillar Behavior in Deep Coal Mines," Proc. Sixth Annual Technical Workshop of the Generic Mineral Technology Center, Univ. of Alaska, 1988, pp. .

Newman, D.A., "Automated Data Acquisition System for Remote Monitoring of Pillar and Roof Deformation on a Longwall Panel," AIME-Society of Mining Engineers Annual Meeting, Preprint 88-64, Phoenix, Arizona, January, 1988.

Newman, D.A. and Bennett, D.B., "A Microcomputer Based System for the Prediction of Mining Costs and Mine Property Valuation," AIME-Society of Mining Engineers Annual Meeting, Preprint 88-63, Phoenix, Arizona, January, 1988.

Martin, J.S. and Newman, D.A., "The Characterization and Redesign of a Failing Highwall in Eastern Kentucky," AIME-Society of Mining Engineers Annual Meeting, Phoenix, Preprint 88-80, Arizona, January, 1988.

Newman, D.A., "Evaluation of Stability in Longwall Chain Pillars - A Technical Note," AIME-SME Transactions, Vol. 281, 1987.

Newman, D.A., "Automated Monitoring of the Stress-Strain Behavior of a Yield Pillar," Proc. Fifth Annual Technical Workshop of the Generic Mineral Technology Center, Univ. of Alabama, 1987, pp. 94-100.

Newman, D.A., "A Laboratory Investigation of the Post-Failure Behavior of Coal," IMMR Highlights, University of Kentucky Institute for Mining and Minerals Research, Vol. 6, No. 5, 1987, pp. 1-2.

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Publications (continued):

Newman, D.A. and Bieniawski, Z.T., "A Modified Version of the Geomechanics Classification for Roofspan Design in Underground Coal Mines," AIME-SME Transactions, Vol. 280, 1986, pp. 2134-2138.

Newman, D.A. and Bieniawski, Z.T., "A Modified Version of the Geomechanics Classification for Roofspan Design in Underground Coal Mines," Preprint No. 85-313, AIME-SME Fall Meeting, Albuquerque, 1985.

Newman, D.A., "Mine Drainage and Pumping," in: **Kentucky Coal Mine Reference Book**, Cameron ed., Dept. of Mines and Minerals and Kentucky Mining Institute, 1985, pp. 89-99.

Snodgrass, J.J. and Newman, D.A., "An In-Situ Technique for the Assessment of Failure in Coal Pillars," Proc. 26th U.S. Symp. on Rock Mech., Ashworth ed., Univ. of S. Dakota, Rapid City, 1985, pp. 1181-1188.

Newman, D.A., "A Modified Version of the Geomechanics Classification for Use in Coal Mines," Proc. 2nd Conf. on Ground Control in the Illinois Basin, Chugh, ed., S. Ill. Univ., Carbondale, 1985, pp. 64-72.

Newman, D.A., "Coal Mine Ground Control - The Effect of Geology," Proc. 12th Ann. Meeting Eastern Sec. Amer. Assoc. Petrol. Geol., S. Ill. Univ., Carbondale, 1983, pp. 68-74.

Bieniawski, Z.T., Rafia, F., and Newman, D.A., "Ground Control Investigations for Assessment of Roof Conditions in Coal Mines," Proc. 21st U.S. Symp. on Rock Mech., Missouri-Rolla, 1980, pp. 693-700.

Bieniawski, Z.T., Rafia, F., and Newman, D.A., "Performance Evaluation of Automated Extraction System, Vol. 5, Geotechnical Investigations of the Roof Conditions in the Area Mined by the AES Machine," Final Technical Report, DOE Contract ET-77-C-01-9144, 1980, 73 p.

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APPENDIX D

SKYLINE MINE DATA

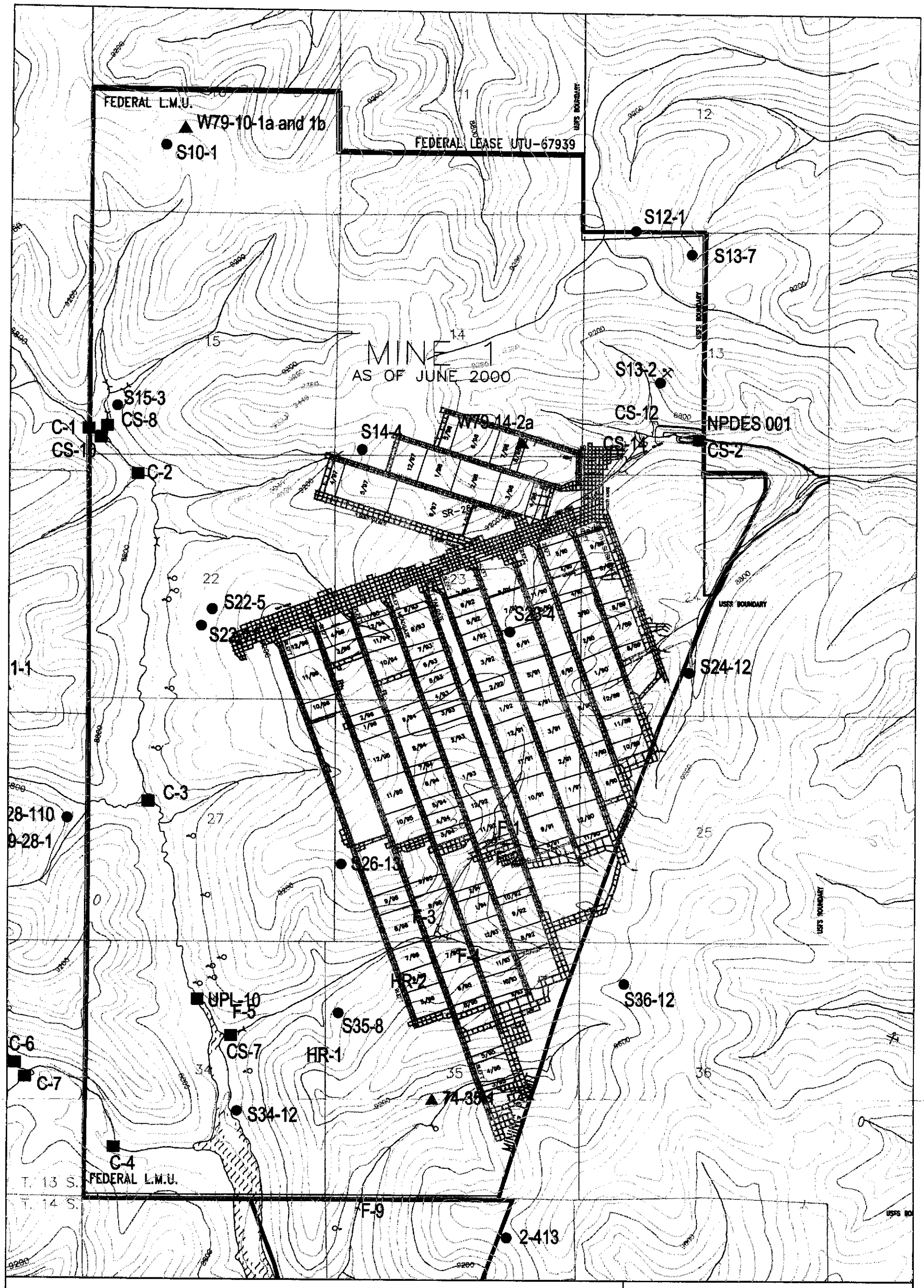

FIGURE D.1
MINE 1 WORKINGS AND
HYDROLOGIC MONITORING POINTS

FILE: DFIG.DWG	SCALE 1" = 2000'	NorWest
DATE: 10/20/2000		

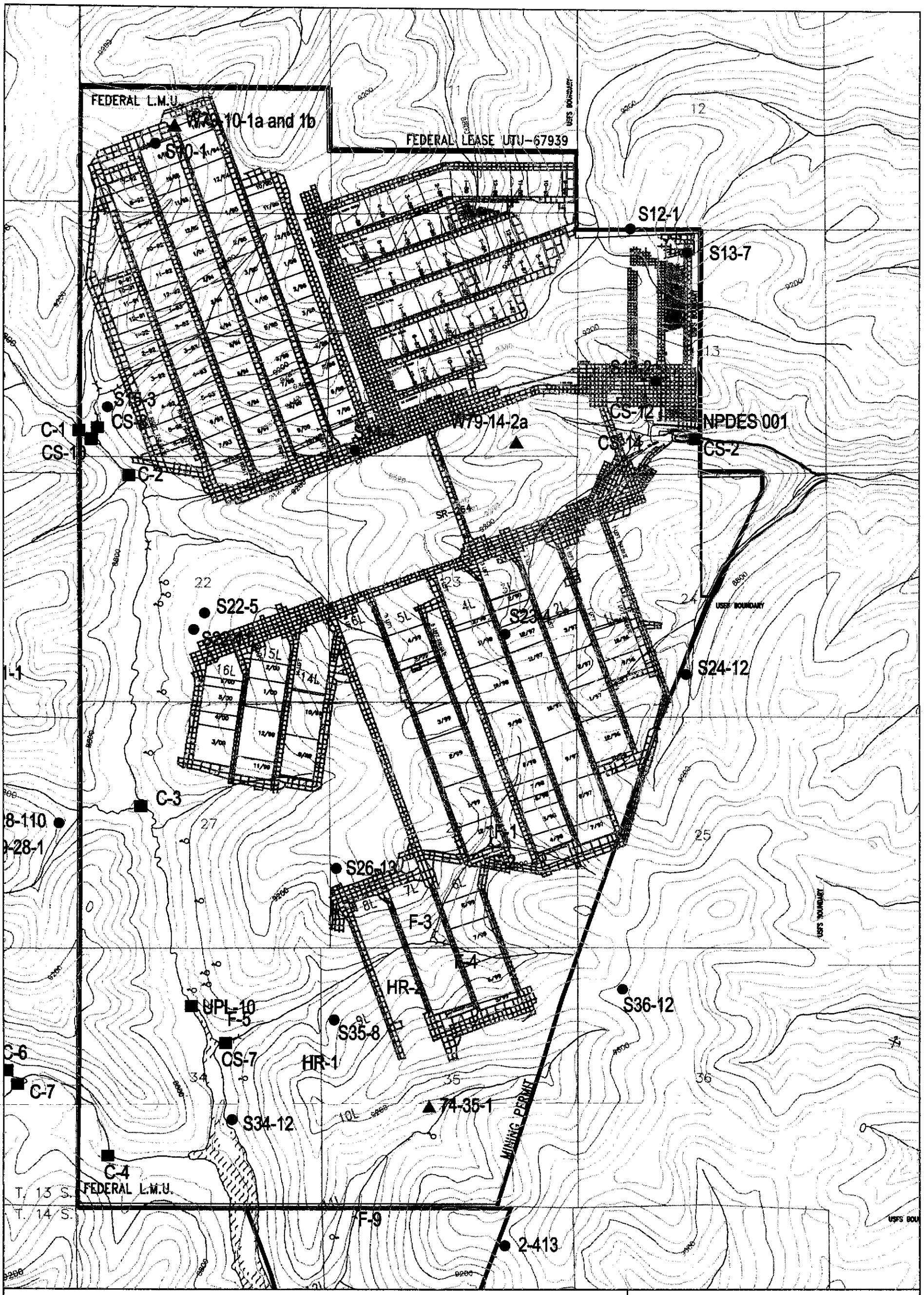

FIGURE D.2
MINE 2 AND MINE 3 WORKINGS AND
HYDROLOGIC MONITORING POINTS

FILE: DFIG.DWG	SCALE 1" = 2000'	NorWest
DATE: 10/20/2000		

Table D-1 Discharge Data for Springs Monitored in the Skyline Mine Area

Discharge in GPM

S10-1		S23-4		S13-2		S13-7		S14-4		S12-1		S24-12	
8/18/81	0.48	9/3/91	0	10/23/81	0.36	6/29/82	39.13	8/18/81	0.85	6/29/82	78.95	11/12/81	0.43
6/29/82	11.3	10/15/91	0	12/9/81	0.31	7/20/82	3.75	6/29/82	12	7/20/82	2.86	6/30/82	1.58
7/20/82	2.5	6/9/92	0	5/20/82	1.19	8/18/82	1.76	7/20/82	3.26	8/18/82	0.32	7/22/82	1.07
8/18/82	0.86	9/1/92	0	6/30/82	0.73	9/15/82	98.74	8/18/82	1.88	9/22/82	0	8/20/82	0.97
9/22/82	0.52	10/20/92	0	7/21/82	0.61	9/22/82	0	9/22/82	1.09	10/16/82	0.16	9/14/82	0.83
10/12/82	0.58	6/29/93	0	8/19/82	0.58	6/29/83	39.13	6/29/83	15	6/29/83	75	6/30/83	1.25
6/29/83	33.33	8/25/93	0	9/15/82	0.68	7/19/83	5.1	7/19/83	5.34	7/19/83	3.86	7/20/83	1.13
7/19/83	6.7	10/18/93	0	10/14/82	0.59	8/22/83	0.71	8/22/83	2.56	8/22/83	0.63	8/25/83	0.94
8/22/83	1.67	7/24/95	0.45	11/9/82	0.45	9/27/83	0	9/27/83	1.48	9/27/83	1.3	9/29/83	0.42
9/27/83	1.13	9/4/95	0	6/30/83	1.3	6/26/84	35.53	10/19/83	1.75	10/19/83	0.17	10/27/83	0.86
10/19/83	0.75	9/12/96	0	7/20/83	0.83	7/31/84	1.79	6/26/84	14.29	6/26/84	26.47	11/11/83	0.81
6/26/84	19.67	7/3/97	0.609	8/25/83	0.29	8/22/84	0.34	7/30/84	3.26	7/31/84	1.01	6/28/84	2.13
7/30/84	3.04	8/13/97	0.8976	9/28/83	0.31	9/26/84	0	8/22/84	2.29	8/22/84	0.34	7/30/84	1.43
8/22/84	1.54	7/6/98	4.7	10/26/83	0.3	6/18/85	12.21	9/26/84	1.49	9/26/84	<0.1	8/27/84	1.27
9/26/84	1.06	8/13/98	1.35	11/11/83	0.74	7/10/85	1.25	6/18/85	6.36	6/18/85	8.7	9/18/84	1.12
6/18/85	9.38	8/17/99	2.244	6/27/84	1.36	8/27/85	0	7/10/85	3.26	7/10/85	0.45	6/27/85	1.5
7/10/85	2.39			7/26/84	1.06	10/16/85	0	8/27/85	1.56	8/27/85	0	7/9/85	2.25
8/27/85	0.74			8/28/84	0.79	6/18/86	36.36	9/18/85	1.2	6/18/86	84.38	8/26/85	1.1
9/18/85	0.71			9/17/84	0.82	7/21/86	1.81	10/16/85	1.04	7/21/86	3.63	9/18/85	0.91
10/15/85	0.68			10/23/84	0.67	8/19/86	0.24	5/27/86	21.43	8/19/86	0.58	10/17/85	0.88
6/18/86	17.21			5/22/85	1.75	9/23/86	0	6/18/86	17.65	9/23/86	0.05	6/19/86	1.71
7/21/86	1.32			6/20/85	0.95	10/15/86	0	7/21/86	2.94	10/15/86	0.4	7/22/86	1.28
8/19/86	0.63			7/9/85	0.9	6/9/87	2.25	8/19/86	1.59	6/9/87	4.35	8/26/86	1.08
9/23/86	0.32			8/26/85	1.43	7/14/87	0	9/23/86	1.09	7/14/87	0	9/23/86	0.85
10/15/86	0.4			9/19/85	1.58	8/17/87	0	10/15/86	1.01	8/17/87	0	10/15/86	0.87
5/18/87	17.2			10/16/85	1.32	9/24/87	0	5/18/87	22.44	9/24/87	0	6/11/87	10.64
6/9/87	7.28			5/28/86	4.88	10/19/87	0	6/9/87	5.56	10/19/87	0	7/8/87	0.79
7/14/87	0.84			6/24/86	2.86	11/19/87	0	7/14/87	1.83	6/27/88	1.66	8/20/87	0.75
8/17/87	0.31			7/22/86	2.08	6/27/88	0.42	8/17/87	1.09	6/21/89	1.33	9/23/87	0.66
9/21/87	0.15			8/20/86	1.63	8/17/88	0	9/21/87	0.76	9/6/89	0	10/21/87	0.64
10/20/87	0.19			9/25/86	1.56	6/21/89	0.97	10/20/87	0.76	10/16/89	0	6/6/88	0.92
6/27/88	3.06			10/21/86	1.3	9/6/89	0	6/27/88	2.91	6/4/90	30.77	8/16/88	0.55
8/17/88	0.31			11/11/86	1.28	10/16/89	0	8/17/88	0.93	9/10/90	0	10/20/88	0.37
10/11/88	0.17			12/10/86	1.24	6/4/90	13.6	10/11/88	0.64	10/24/90	0	6/22/89	<0.1
9/5/89	<0.1			4/22/87	1.32	9/10/90	0	6/21/89	2.65	6/18/91	29.41	9/12/89	0
10/16/89	0.23			6/11/87	1.04	10/24/90	0	9/5/89	0.7	9/3/91	0	10/19/89	0
6/4/90	8.11			7/8/87	1.01	6/18/91	9.52	10/16/89	0.63	10/15/91	0	6/6/90	0
9/10/90	0.114			8/19/87	0.83	9/3/91	0	6/4/90	11.9	6/9/92	0	9/12/90	0
10/24/90	0.27			9/23/87	0.766	10/15/91	0	9/10/90	0.71	9/1/92	0	10/25/90	0
6/18/91	15.67			10/21/87	0.77	6/9/92	0.19	10/25/90	0.61	10/20/92	0	6/10/91	0.15
9/3/91	0.19			6/6/88	1.25	9/1/92	0	6/18/91	11.47	6/23/93	39.56	9/18/91	0
10/15/91	0.16			8/15/88	0.6	10/20/92	0	9/3/91	0.91	8/25/93	0	10/17/91	0
6/10/92	2.65			11/2/88	0.43	6/23/93	25.78	10/15/91	0.7	10/18/93	0	6/16/92	0
9/1/92	0.11			6/22/89	0.79	8/25/93	0	6/9/92	3.9	7/24/95	1.57	9/9/92	0
10/20/92	<0.1			9/13/89	0.42	10/18/93	0	9/1/92	0.39	9/4/95	0	10/22/92	0
6/23/93	8.82			10/31/89	0.36	7/17/95	3.35	10/20/92	0.47	6/24/96	8.53	6/23/93	0
8/25/93	0.54			6/6/90	1.03	9/4/95	0	6/23/93	0	9/11/96	0	8/30/93	0
10/18/93	0.33			9/13/90	0.34	10/17/95	0	8/25/93	0	6/23/97	13.464	10/28/93	0
7/17/95	3.7			10/25/90	0.27	6/27/96	5.8	10/18/93	0	8/13/97	0	6/16/94	0
9/4/95	0.22			6/11/91	2.08	7/3/97	4.76	7/17/95	0.12	7/6/98	5.9	9/8/94	0
6/24/96	3.59			10/17/91	0.4	8/13/97	0.4488	9/4/95	<0.1	8/17/99	0	10/10/94	0
9/11/96	0			6/15/92	0.22	7/6/98	2.56	10/17/95	0.88			7/11/95	0
6/23/97	4.488			9/8/92	<0.1	8/19/98	0.404	6/24/96	<44.88			9/6/95	0
8/13/97	0.4488			10/22/92	<0.1	8/17/99	0.40392	9/12/96	0			6/26/96	0
10/9/97	0.26928			6/22/93	2.56			6/23/97	0.097			9/1/96	0
6/22/98	4.9			8/26/93	1.01			8/13/97	0.08976				
8/19/98	0.18			10/27/93	0.55			10/9/97	0.31416			6/23/97	0
8/17/99	0.26928			6/20/95	4.48			6/22/98	0.13			8/13/97	0
				9/6/95	1			8/19/98	0.0898			10/15/97	0
				10/17/95	0.88			10/10/98	0.55				
				6/25/96	2.69			8/17/99	0.04039				
				9/11/96	0								
				9/24/96	0.8976								
				6/24/97	2.68							8/18/99	0
				8/13/97	0.8976								
				10/9/97	0.8976								
				6/16/98	0.86								
				8/11/98	0.4488								
				10/11/98	0.75								
				8/16/99	1.3464								

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Table D-1 Discharge Data for Springs Monitored in the Skyline Mine Area (continued)

Discharge in GPM

S15-3		S22-5		S22-11		S26-13		S34-12		S35-8		S36-12	
8/18/81	9.38	8/18/81	3.5	8/18/81	6.14	10/22/81	0.25	9/15/87	6.3	6/28/82	105	11/10/81	3.5
10/22/81	4	10/22/81	1	6/29/82	37.5	6/29/82	5.45	10/19/87	6.36	7/20/82	26.25	6/29/82	8.18
12/8/81	5.5	6/29/82	58	7/20/82	24	7/20/82	1.8	6/28/88	12	8/17/82	14.12	7/20/82	5
6/28/82	161.54	7/20/82	18.37	8/18/82	23.68	8/18/82	1.15	8/17/88	8.33	10/15/82	6	8/18/82	4.49
7/21/82	48.65	8/18/82	6	9/15/82	15	9/22/82	0.79	10/19/88	14.06	6/28/83	120	9/22/82	3.75
8/18/82	37.5	9/15/82	8.42	10/15/82	13.64	6/29/83	8.33	6/22/89	8.45	7/19/83	32.93	10/12/82	3.53
9/15/82	22.44	10/15/82	6	6/28/83	42.86	7/19/83	2	9/7/89	6.87	8/24/83	14.52	6/29/83	10.23
10/15/82	35.29	6/28/83	72	7/19/83	16.67	8/24/83	2.11	10/17/89	5.7	9/23/83	7.69	7/19/83	6.41
6/28/83	439.82	7/19/83	32.93	8/24/83	23.33	9/28/83	0.87	6/4/90	9.9	10/20/83	6.38	8/24/83	4.41
7/19/83	57.14	8/24/83	16.27	9/28/83	19.9	10/19/83	0.72	9/10/90	5.39	6/28/84	70.59	9/28/83	3.75
8/24/83	30	9/27/83	9.74	10/20/83	1920	6/26/84	6.21	10/24/90	4.93	7/31/84	22.44	10/19/83	3.9
9/27/83	23.68	10/20/83	9.46	6/27/84	41.38	7/30/84	1.95	6/12/91	42.19	8/22/84	10.56	6/26/84	7.96
10/20/83	27.27	6/26/84	56.25	7/31/84	22.44	8/22/84	1.28	9/3/91	3.8	9/26/84	6.82	7/30/84	4.76
5/24/84	1206.4	7/31/84	22.44	8/23/84	24.32	9/18/84	0.9	10/15/91	5.5	6/19/85	36	8/23/84	10.56
6/26/84	138.46	8/23/84	18.27	9/26/84	22.44	6/18/85	4.33	6/9/92	5.39	7/18/85	16.67	9/18/84	3.66
7/31/84	85.27	9/27/84	11.07	6/19/85	28.38	7/10/85	1.91	9/2/92	3.35	8/29/85	6.41	7/10/85	4.69
8/24/84	30.36	10/25/84	8.82	7/17/85	5.23	8/26/85	0.98	10/21/92	1.9	9/25/85	5.68	8/27/85	3.75
9/27/84	23.94	5/21/85	78.57	8/28/85	19.74	9/18/85	0.81	6/28/93	22.34	10/30/85	4.58	9/18/85	3.49
10/25/84	24.49	6/19/85	32.43	9/24/85	19.05	10/30/85	0.22	8/25/93	11.76	6/24/86	66.67	10/15/85	3.41
11/13/84	26.67	7/17/85	18.75	10/30/85	11.25	6/19/86	7.56	10/18/93	8.96	7/22/86	17.65	6/19/86	8.82
5/21/85	578.95	8/28/85	10.71	6/19/86	63.16	7/21/86	7.41	6/14/94	9.8736	8/20/86	8.9	7/21/86	4.76
6/19/85	105.88	9/24/85	20.45	7/21/86	25.61	8/18/86	0.95	8/31/94	5.8344	9/24/86	5.91	8/18/86	3.8
7/17/85	36.36	10/15/85	7.69	8/19/86	21.88	9/23/86	0.43	10/10/94	4.0392	10/16/86	3.95	9/23/86	3.45
8/28/85	20.33	6/19/86	42.86	9/24/86	16.81	10/15/86	0.31	9/5/95	25	5/19/87	11.7	10/15/86	3.33
9/24/85	19.44	7/21/86	20.69	10/16/86	14.71	6/10/87	2.73	10/18/95	10.4	6/10/87	8.93	6/10/87	5.88
10/15/85	25	8/18/86	10.82	5/19/87	6.25	7/14/87	0.96			7/27/87	7.26	7/14/87	3.8
5/27/86	1346.4	9/24/86	7.89	6/10/87	11	8/18/87	0.56	6/23/97	0	8/18/87	3.46	8/18/87	3.37
6/19/86	150	10/16/86	7.22	7/29/87	11.8	9/21/87	0.38			9/15/87	2.78	9/21/87	2.68
7/22/86	44.44	5/19/87	38.9	8/18/87	10.27	10/20/87	0.24			10/19/87	2.03	10/20/87	2.5
8/18/86	25	6/10/87	18.06	9/15/87	7.08	6/28/88	1.46			6/28/88	4.11	6/28/88	4.29
9/24/86	21.43	7/29/87	8.04	10/20/87	3.61	8/17/88	0.6			8/17/88	2.55	8/17/88	3.3
10/16/86	22.34	8/18/87	5.42	6/28/88	13.16	10/12/88	0.31			10/19/88	2.37	10/12/88	2.48
11/13/86	19.23	9/15/87	3.87	8/17/88	7.89	6/21/89	1.13			6/21/89	1.61	6/21/89	3.95
12/10/86	16.25	10/20/87	2.67	10/20/88	7.66	9/6/89	0.11			9/7/89	1.4	9/6/89	2.42
5/18/87	76.296	11/19/87	2.6928	6/22/89	8.52	10/16/89	0			10/17/89	1.62	10/16/89	1.95
6/10/87	66.67	6/28/88	21.2	9/6/89	3.75	6/4/90	3.4			6/5/90	1.9	6/25/90	5.27
7/28/87	22.34	8/17/88	4.81	10/17/89	0.93	9/10/90	0			9/11/90	2.54	9/10/90	2.52
8/17/87	16.07	10/20/88	3.37	6/5/90	5.5	10/24/90	0			10/10/90	1	10/26/90	2.05
9/22/87	9.62	6/22/89	9.28	9/11/90	4.92	6/19/91	4.41			6/24/91	9.55	6/19/91	7.26
10/19/87	13.64	9/6/89	4.34	10/10/90	1	9/3/91	0			9/5/91	4.92	9/3/91	3.41
11/20/87	13.464	10/17/89	3.57	6/19/91	9.23	10/15/91	0.38			10/16/91	3.75	10/15/91	2.61
6/28/88	42.86	6/5/90	20.5	9/5/91	11.54	6/9/92	1.06			6/9/92	2.46	6/19/92	3.26
8/18/88	11.61	9/11/90	5.25	10/16/91	7.59	9/1/92	0			9/2/92	1.22	9/1/92	1.91
10/12/88	11.39	10/10/90	2.38	6/10/92	0.88	10/20/92	0			10/21/92	1.01	10/20/92	1.35
6/21/89	38.71	6/19/91	42.86	9/1/92	1.09	6/29/93	3.37			6/29/93	32.61	8/25/93	3.7
9/6/89	11.54	9/5/91	8.91	10/20/92	0	8/25/93	1.08			8/24/93	13.5	10/18/93	2.27
10/17/89	8.82	10/16/91	5.03	6/28/93	26.09	10/18/93	0.44			10/19/93	4.57	6/13/94	0.49368
6/4/90	185.26	6/10/92	8.26	8/25/93	17.14	6/13/94	2.15424			6/19/95	25.13	9/1/94	0.58344
9/11/90	10.17	9/1/92	4.69	10/18/93	10.17	9/1/94	0.8976			7/6/95	29.96	10/5/94	8.0784
10/25/90	8.45	10/20/92	3.26	6/13/94	4.488	10/13/94	0.62832			9/5/95	10.7	7/17/95	6.67
6/12/91	510.12	6/28/93	35.29	9/1/94	6.2832	7/19/95	2.73			10/18/95	3.99	9/4/95	3.7
9/3/91	16.67	8/25/93	12.35	10/13/94	2.244	9/4/95	1.53			9/11/96	6.732	10/17/95	1.8
10/16/91	13.95	10/18/93	3.51	7/19/95	27.27	10/17/95	0.94			6/19/97	35.904		
6/10/92	40.38	7/24/95	29.03	9/4/95	19.15	9/12/96	0.8976			8/13/97	8.976	9/11/96	0.8976
9/2/92	11.3	9/4/95	12.9	10/18/95	8.5					10/9/97	4.488		
10/21/92	11.54	10/18/95	7.91	6/20/96	25.58					6/15/98	75	7/3/97	5.77
6/23/93	162.38	6/20/96	35.9	9/12/96	10.7712	7/3/97	5.2			8/13/98	8.98	8/13/97	3.5904
8/26/93	30.47	9/11/96	4.488			8/13/97	2.244			10/8/98	6	10/9/97	2.6928
10/19/93	22.06	6/19/97	35.904	6/23/97	22.44	10/9/97	0.8976			8/19/99	8.976	7/6/98	6.1
5/19/95	637.296	8/12/97	13.464	8/12/97	17.952	7/6/98	3.75					8/13/98	3.14
6/19/95	637.296	10/9/97	8.976	10/9/97	17.952	8/13/98	1.8					10/10/98	3
9/4/95	42.86	6/15/98	42.8	6/21/98	23.1	10/10/98	0.43						
10/18/95	28.13	8/11/98	37.7	8/11/98	74.95							8/19/99	3.1416
6/24/96	122.07	10/8/98	2.5	10/8/98	11.25	8/17/99	1.7952						
9/11/96	4.488	8/18/99	0.02										
10/28/96	24.2352			8/18/99	18.8								
6/19/97	40.392												
8/12/97	3.5904												
10/9/97	58.344												
6/15/98	350.064												
8/11/98	53.86												
10/7/98	18												
8/19/99	31.416												

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Table D-2 Comparison of Skyline Mine Discharge Water Quality to State of Utah Beneficial Use Standards (UAC R317-2)

		Beneficial Use Standards				CS-12				CS-14				UPDES Outfall			
Parameter	Unit	1C Domestic	2A, 2B Recreation	3A 4-Day Aquatic Wildlife	4 Agriculture	n	Max	Min	Average	n	Max	Min	Average	n	Max	Min	Average
226 Radium	pc/l	5				0	---	---		0	---	---		1	0	0	
Alpha gros	pc/l	15			15	0	---	---		0	---	---		1	0	0	
Ammonia N	mg/l			About 2		42	1.8	0	0.34	30	1.5	0	0.33	1	0.17	0.17	0.17
Arsenic-T*	mg/l	0.05		0.19	0.1	0	---	---		0	---	---		1	0	0	
B.O.D. 5	mg/l		5	5	5	1	7	7		0	---	---		1	9.3	9.3	9.30
Barium-D	mg/l	1				7	0.061	0	0.03	9	0.089	0	0.03	0	---	---	
Beta gross	pc/l	50		50	50	0	---	---		0	---	---		1	0	0	
Boron-T	mg/l				0.75	13	0.8	0.109	0.38	10	0.7	0.16	0.42	1	0.04	0.04	0.04
Cadmium-T*	mg/l	0.01		0.0011	0.01	0	---	---		0	---	---		1	0	0	
Chromium-T*	ug/l	0.05		0.011	0.1	0	---	---		0	---	---		1	0	0	
Copper-D	mg/l			0.012	0.2	7	0.01	0	0.00	9	0.01	0	0.00	0	---	---	
Cyanide	mg/l			0.0052		13	0.01	0	0.00077	10	0	0	0.00	1	0.014	0.014	0.0140
Fluoride	mg/l	2.4				17	2.07	0.1	0.65	10	1.52	0	0.45	1	0.33	0.33	0.33
Iron-D	mg/l			1 (Max)		7	0.23	0	0.07	8	0.23	0	0.03	0	---	---	
Lead-D	mg/l	0.05		0.0032	0.1	7	0.008	0	0.00114	9	0.008	0	0.00133	0	---	---	
Mercury-T*	ug/l	0.002		0.012		0	---	---		0	---	---		1	0.2	0.2	0.20
Nickel-T*	ug/l			0.16		0	---	---		0	---	---		1	0	0	0.00
Nitrate N	mg/l			4		29	2.7	0	0.80	20	12.32	0	2.47	1	0.84	0.84	0.84
NO2+NO3 N	mg/l	10				5	0.8	0.4	0.56	11	2.4	0	1.20	0	---	---	
Phenol	ug/l			0.01		18	1330	0	87.22	18	230	0	33.06	0	---	---	
Phos.-T	mg/l		0.05	0.05		38	0.21	0	0.04	19	0.99	0	0.13	1	0.62	0.62	0.62
TDS @ 180C	mg/l				1200	140	2084	288	797.08	67	2570	405	1104.12	28	718	120	311.21
Missing																	
Selenium		X		X	X												
Silver		X		X													
Zinc				X													
Residual Chlorine				X													
H2S				X													
TSS			X	X													
Strontium-90		X															
Tritium		X															

*Total used in lieu of dissolved because dissolved data not availble

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TECHNICAL REPORT SURFACE-WATER AND GROUNDWATER RESOURCES IN THE FLAT CANYON AREA

ADDENDUM 1

Submitted to:
MANTI-LA SAL NATIONAL FOREST

AND

BUREAU OF LAND MANAGEMENT, UTAH STATE OFFICE

January 21, 2001

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IMPACTS TO RECEIVING WATER QUALITY

Sections 5.1.3 and 5.1.4 of the technical report describe the potential impacts to water quality of Eccles Creek and Electric Lake as a result of discharge of mine water to these watercourses. Table D-2 in the technical report presents a comparison of the State of Utah Beneficial Use Standard to historic water quality of discharge from the Skyline Mine. Based on this comparison, nine water quality parameters have been identified that have, at some time, exceeded the most stringent Beneficial Use Standards in the mine discharge water. The water quality history of these nine parameters has been further reviewed and is summarized in Table AD1.1 below. Also reported in the table below is a determination of the qualitatively estimated impact that discharge of mine water poses to the quality of the receiving water.

Table AD1.1
Skyline Mine Discharge Water Quality History for Parameters that Have Exceeded Beneficial Use Standards

Parameter	Comments	Qualitatively Estimated Impact
BOD	Only sampled once in CS-12 and UPDES outfall—both exceeded standard.	Of concern
Boron	Standard exceeded only once in 13 samples at CS-12; Not exceeded in any of 10 samples at CS-14 or the one sample at UPDES outfall.	Not of concern
Cyanide	Only detected once in 13 samples at CS-12; not detected in 10 samples at CS-14; only sampled once at UPDES outfall—standard exceeded.	Not of concern
Lead-D	Detected only once in seven samples at both CS-12 and CS-14. Both detections occurred on the same date and at the same concentration, which suggests lab or sampling error.	Not of concern
Mercury-D	Dissolved mercury never sampled at discharge points. Total Mercury sampled only once at UPDES outfall and standard exceeded; never sampled at CS-12 or CS-14.	Of possible concern
Nitrate	Standard only exceeded once in 20 samples at CS-14; 29 samples at CS-12 and one sample at UPDES outfall in compliance with standard.	Not of concern
Phenol	Detected four times in 20 samples at CS-12; detected six times in 18 samples at CS-14. All detections exceeded standard.	Of concern
Phosphorous-T	Standard exceeded in 12 of 38 samples at CS-12 and in 10 of 19 samples in CS-14; sample exceeded in the one sampling event at UPDES outfall	Of concern
TDS	Standard exceeded in CS-12 and CS-14 beginning in early 1990s. Exceedences attributed to use of gypsum rock dust (see 4.2). Practice has been discontinued and discharge water is generally in compliance	Not of concern

Based on the analysis above, four parameters—BOD, dissolved mercury, phenol, and total phosphorous—are of concern in the analysis of possible water quality impacts to Eccles Creek and

downstream watercourses or Electric Lake. To assess the degree to wh the quality of receiving waters could be impacted, water quality of receiving waters has been reviewed. Water quality data for Scofield Reservoir and Electric Lake have been collected by the Department of Environmental Quality, Division of Water Quality (DWQ). These data were obtained from the EPA's STORET database. Water quality data f Eccles Creek was obtained from UDOGM's mining hydrology databas Summary data for the parameters of concern are presented in Table AD1.2. Raw data are being submitted in electronic format as part of th project file.

ECCLES CREEK/ SCOFIELD RESERVOIR

Water quality is measured on Eccles Creek by Skyline Mine at CS-2. This monitoring station is located at the USFS boundary and above the mine discharge point. The DWQ has collected information from 18 sites on Scofield Reservoir. Two sites on the southern end of t reservoir, where Mud Creek enters the reservoir, were utilized in this analysis.

BOD

BOD has been measured at CS-2 on one occasion and the result did not exceed the Beneficial Use Standard. BOD has been measured in Scofie Reservoir on 7 occasions and the Beneficial Use Standard was exceede on one occasion.

The limited data from the mine discharge water do not allow a good characterization of BOD in mine discharge water. However, it is expec that BOD would be satiated in a well-aerated stream such as Eccles Cre

Dissolved Mercury

Dissolved mercury has not been measured at CS-2. However, total mercury has been measured on one occasion at CS-2 and the result was non-detect.

If the Beneficial Use Standard for mercury is exceeded in mine dischar water, there is a potential that the receiving waters could become impaired. However, it is likely that if more measurements of mercury i mine discharge water were made, the results would indicate that mercu is not a parameter of concern.

Phenol

Phenol has been measured 29 times at CS-2 and was detected on six occasions. The maximum measured concentration is 350 mg/l. Phenol has not been measured in Scofield Reservoir by DWQ.

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Table AD1-2 Trace Constituent Water Quality

Station	Description	BOD			Dissolved Mercury			Phenol			Total Phosphorous			Data Source
		n	avg mg/l	max mg/l	n	avg ug/l	max ug/l	n	avg mg/l	max mg/l	n	avg mg/l	max mg/l	
CS-2	Eccles Creek at USFS boundary	1	3.6	3.6	1	ND*	ND*	22	29	350	42	0.324	9.30	DOGM
593099	SCOFIELD RES S BAY 03	7	2.3	6	0	---	---	0	---	---	114	0.035	0.16	STORET
593102	SCOFIELD RES S END OF RES 06	0	---	---	0	---	---	0	---	---	2	0.06	0.11	STORET
UPL-10	Upper Huntington Creek	0	---	---	1	ND*	ND*	2	0	0	26	0.101	0.80	DOGM
493119	ELECTRIC L AB DAM 01	0	---	---	4	ND	ND	0	---	---	47	0.012	0.09	STORET
493120	ELECTRIC L MIDWAY UP LAKE 02	0	---	---	0	---	---	0	---	---	22	0.146	3.00	STORET

*Total used because dissolved data not availble

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Phenol is generally considered an industrial waste and is not expected to occur naturally in surface water or groundwater. The source of phenol in Eccles Creek or Skyline Mine discharge water has not been investigated.

Phenol has been detected in mine discharge water during less than 25% of the sampling events and appears to be an occasional rather than a constant nuisance. Nevertheless, when phenol does occur in mine water discharge, it can easily cause the receiving water to be impaired. For instance, assuming a mine discharge rate of 3,000 gpm, a minimum discharge rate in the receiving stream of 3,000,000 gpm of phenol-free water would be required to dilute the lowest measured phenol concentration in Skyline Mine discharge water—10 mg/l—to the Beneficial Use Standard.

Total Phosphorous

Total phosphorous at CS-2 (Eccles Creek at the USFS boundary and above the mine discharge point) has been measured 42 times. Total phosphorous was not detected on twelve of these events. The maximum recorded total phosphorous concentration was 9.3 mg/l. This concentration is anomalous because the next highest concentration is 0.83 mg/l. If the 9.3 mg/l concentration is excluded, the average total phosphorus concentration at CS-2 is 0.105 mg/l, which exceeds the Beneficial Use Standard by 11 fold.

The average total phosphorous concentrations of mine discharge waters are 0.04 mg/l at CS-12 and 0.13 mg/l at CS-14. The maximum concentrations at these sites are 0.21 mg/l and 0.99 mg/l. The average and maximum concentrations of mine discharge waters are consistent with the average and maximum concentrations of water in Eccles Creek. Thus, while the total phosphorous Beneficial Use Standard is occasionally exceeded in mine discharge water, the potential for water quality degradation of Eccles Creek water is not great because of the elevated background concentrations in Eccles Creek.

Total phosphorous has historically been a concern for Scofield Reservoir. The reservoir is listed as impaired relative to the Beneficial Use Standard for total phosphorous per Section 303d of the Clean Water Act. A total maximum daily load (TMDL) analysis of the reservoir has been completed by DWQ. According to the DWQ, sediment erosion in the Scofield Reservoir watershed is the major source of pollution into Scofield Reservoir. Intense livestock grazing, grazing within the riparian zone, road

construction, summer home construction, and mining activities have been identified as accelerating the erosion process.

The effects of elevated phosphorous concentrations in mine water discharge have been assessed in terms of loading rather than by direct comparison to water quality in the lake, which varies with depth, location, and time. The Scofield Reservoir TMDL reports the current total phosphorous load to the reservoir as 6,723 kg/year and set a target load of 4,842 kg/year. If it is assumed that Skyline Mine continuously discharges 3,000 gpm of water and this water has an average total phosphorous concentration of 0.13 mg/l (which is the average concentration at CS-14), the additional total phosphorous load from mine water discharge is 776 kg/year. This additional load is notable relative to the target load set by the TMDL. However, the addition of 3,000 gpm of continuous discharge would increase inflow to the reservoir by 4,840 ac-ft/year. The model used to determine the target load for Scofield Reservoir assumed a contribution from the Mud Creek drainage of 8,441 ac-ft/year. Thus mine water represents a 57% increase in the annual water contribution from Mud Creek and lessens the severity of the increased total phosphorous load.

ELECTRIC LAKE

Water quality is measured on Upper Huntington Creek by Skyline Mine at UPL-10. This monitoring station is located at the high water line of Electric Lake. The DWQ has collected information from 2 sites on Electric Lake.

BOD

BOD has not been measured at UPL-10 or in Electric Lake.

The limited data from the mine discharge water do not allow a good characterization of BOD in mine discharge water. If the Beneficial Use Standard is consistently exceeded in mine water discharge there could be an impact to water quality if mine water were discharge directly to Electric Lake.

Dissolved Mercury

Dissolved mercury has not been measured at UPL-10. However, total mercury has been measured on one occasion at UPL-10 and the result was non-detect. Dissolved mercury has been measured four times in Electric Lake by DWQ and the results were non-detect.

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If the Beneficial Use standard for mercury is exceeded in mine discharge water there is a potential that the receiving waters could become impaired. However, it is likely that if more measurements of mercury in mine discharge water were made, the results would indicate that mercury is not a parameter of concern.

Phenol

Phenol has been measured two times at UPL-10 and not detected on either occasion. Phenol has not been measured in Electric Lake by DWQ. Phenol is generally considered an industrial waste and is not expected to occur naturally in surface water or groundwater. The source of phenol in Skyline Mine discharge water has not been investigated.

Phenol has been detected in mine discharge water during less than 25% of the sampling events and appears to be an occasional rather than a constant nuisance. Nevertheless, when phenol does occur in mine water discharge, it can easily cause the receiving water to be impaired. For instance, assuming a mine discharge rate of 3,000 gpm, a minimum discharge rate in the receiving stream of 3,000,000 gpm of phenol-free water would be required to dilute the lowest measured phenol concentration in Skyline Mine discharge water—10 mg/l—to the Beneficial Use Standard.

Total Phosphorous

Concentrations of total phosphorous at UPL-10 (Upper Huntington Creek at Electric Lake) have ranged from non detect to 0.80 mg/l with an average concentration of 0.101 mg/l. Total phosphorus has been measured during 26 sampling events, 14 of which were non-detect for total phosphorous. Similar to the history at Eccles Creek, the average and maximum total phosphorous concentrations on Upper Huntington Creek are consistent with the average and maximum concentrations observed in water discharges from the Skyline Mine. Thus, while the total phosphorous Beneficial Use Standard is occasionally exceeded in mine discharge water, the potential for water quality degradation of Electric Lake is not great because of elevated background concentrations.

Total phosphorous concentration at the DWQ sampling location 'Electric Lake Midway Up Lake 02' averages 0.146 mg/l, a 29-fold increase over the Beneficial Use Standard. Annual loading calculations described above indicate that the total phosphorous load to Electric Lake could increase by 776 kg/year.

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BURNOUT CREEK BASEFLOW

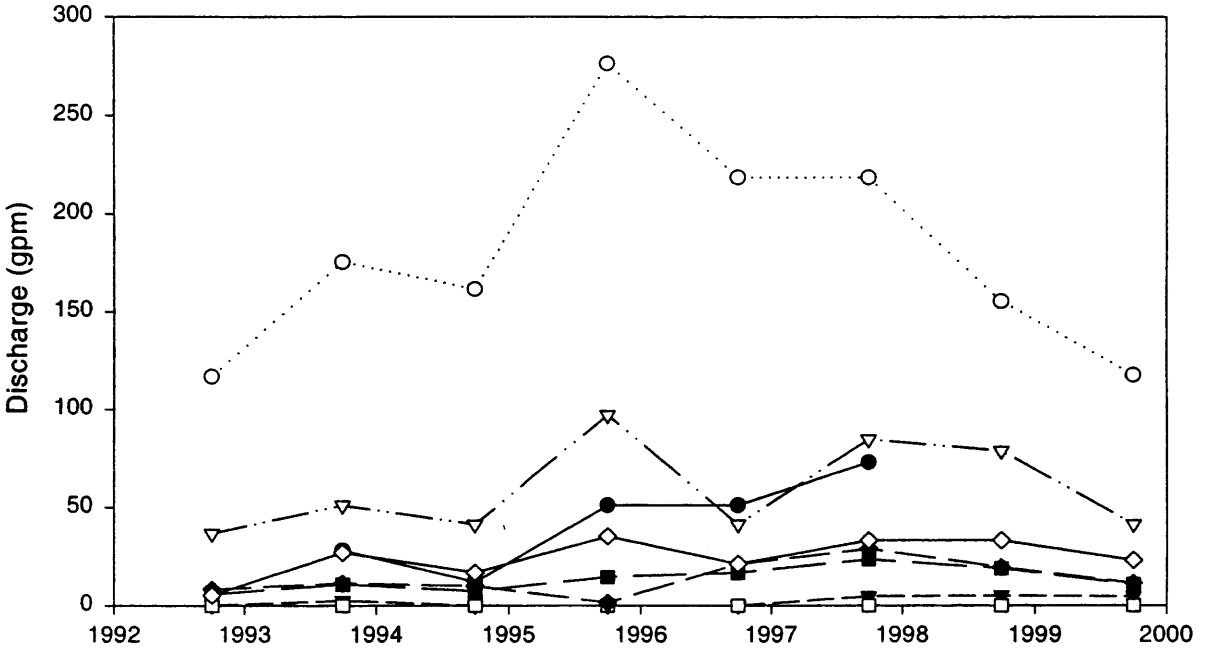
The baseflow and peak discharge characteristics of Burnout Creek during the period it underwent longwall mining were discussed in Section 4.1.3 of the Technical Report. To facilitate a more detailed analysis of the baseflow characteristics of Burnout Creek during this period, the annual October baseflow discharge at each of the monitorin stations was plotted for the years 1992-1999 (Figure AD1.1). To determine the baseflow discharge, the first monitoring event during the month of October was utilized. The month of October was chosen because 1) it is the end of the water year and discharges during this mo were usually the lowest of the year, and 2) it was usually the last montl the year that discharge measurements were routinely measured.

Inspection of Figure AD1.1 indicates that, although some anticipated fluctuations in yearly baseflow have occurred, over the long-term, baseflow discharge rates in Burnout Creek have remained more or less constant. At each monitoring station, the baseflow discharge measured during 1999 is slightly greater than that measured at the beginning of th monitoring program in 1992. The intervening years are marked by periodic increases and declines in baseflow discharge rate. This sugges that, relative to the discharge rates at the beginning of the routine monitoring, mining beneath the Burnout Canyon area has not resulted i any lasting detrimental impacts to baseflow discharge rates at a scale th could be detected by this analysis.

It should be noted that the 1992 baseflow measurement occurred during period of moderate drought (Technical Report, Figure 2.1). However, t 1999 measurement also occurred as the region was entering a similar period of moderate drought. Thus, because the climatic conditions duri 1992 and 1999 are similar, comparison of the 1992 and 1999 baseflow discharge rates seems reasonable.

It is true that during the period from late 1986 to late 1991 the region w in a protracted, severe drought while the climatic conditions in the five years prior to 1999 were relatively wet. However, as discussed in the Technical Report, the near-surface rocks of the Blackhawk Formation c not accommodate much groundwater storage from year to year. This is evident in the Burnout Creek hydrographs, which show very sharp annu peaks with rapidly declining flows during the summer and fall months. Thus, because the most or all of the recharge to the basin exits the basir each year, the effect on future year's discharge rates resulting from the climatic conditions of previous years is minimal.

Figure AD1.1
Baseflow Hydrographs for Burnout and James Creeks



- F-9 James Canyon Creek
- F-5 (Lower Main Burnout Creek)
- HR-2 (Middle Half Round)
- F-3 (Middle Main Burnout Creek)
- F-4 (Middle South Burnout Creek)
- HR-1 (Upper Half Round)
- F-1 (Upper North Burnout Creek)
- F-2 (Upper South Burnout Creek)

Baseflow discharge is the first monitoring event in October.

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SEDIMENT TRANSPORT IN ECCLES CREEK AND MUD CREEK

Section 5.1.3 of the technical report describe the potential impacts of discharging mine discharge water to Eccles Creek. This section provides further information regarding erosion potential as a result of increased flows in Eccles Creek and Mud Creek resulting from mine water discharge.

Relationships have been described (Buffington, 1995; Emmett, 1999) that relate the initiation of the bedload sediment transport in armored stream channels. In general, at streamflows greater than about 60 – 70% of the bankfull discharge, streampower becomes adequate to move armoring sizes of bed material. In the absence of field observations to determine bankfull flow rates, it is generally accepted that bankfull discharge can be estimated by determining the 1.5-year flood frequency. Table AD1.3 below reports the estimated 1.5-year flood frequency and the threshold level for bedload sediment transport.

Table AD1.3
Flood Frequency and Threshold Sediment Transport Flow Rates

	1.5-Year Flood Frequency Flow Rate (cfs)	Threshold Bedload Sediment Transport Flow Rate (cfs)
Eccles Creek	1.5	1.05
Mud Creek	5.9	4.13

The proposed maximum mine water discharge would be 6.68 cfs, which represents an increase of 5.57 cfs over current levels. The 5.57 cfs increase is greater than the threshold rate for bedload sediment transport. This suggests that the proposed increase in the mine water discharge rate has the potential to cause transport of the armoring sizes of bedload materials in both Eccles Creek and Mud Creek.

Because the analysis presented above relies on generalized estimations, field investigations to determine channel substrate composition and bankfull flow rates would certainly refine these calculations.

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REFERENCES

Buffington, J.M., 1995, Effects of hydraulic roughness and sediment supply on surface textures of gravel-bedded rivers. Timber, Fish & Wildlife, Document TFW-SH10-95-002.

Emmett, W.W., 1999, Quantification of channel-maintenance flows for gravel-bed rivers, in Olsen D.S. and Potyondy, J.P., eds., Wildland Hydrology. American Water Resources Association, Herndon, VA, TPS-99-3, 536 p.

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Table D-3 Discharge Data for James and Burnout Creeks

Discharge in GPM

James 6"		Lower Main		Middle Main		Middle South		Upper North		Upper South		Middle half round		Upper half round	
7/13/93	184	8/6/91	345.6	7/11/91	309.2	7/11/91	55.4	7/11/91	51.9	7/11/91	155.6	7/2/92	2.7	7/2/92	0
7/16/93	145.3	8/19/91	276.4	8/6/91	156.6	8/6/91	22.4	8/6/91	30.1	8/6/91	70.5	7/10/92	2.8	7/10/92	0
7/29/93	208.8	8/29/91	212.8	8/19/91	116.8	8/19/91	14.6	8/19/91	22.2	8/19/91	50.6	7/15/92	2.7	7/15/92	0
8/13/93	84.5	9/17/91	53.7	8/29/91	93.8	8/29/91	10.7	8/29/91	16.9	8/29/91	38.7	7/23/92	2.3	7/23/92	0
8/18/93	61.6	6/19/92	241	9/17/91	78.5	9/17/91	11.7	9/17/91	17	9/17/91	41	7/28/92	2.3	7/28/92	0
8/31/93	46.1	6/26/92	258.5	6/19/92	123.7	6/19/92	19	6/19/92	17.7	6/19/92	53.1	8/7/92	1.8	8/7/92	0
9/15/93	24.3	7/2/92	235.3	6/26/92	130.8	6/26/92	19	6/26/92	19.5	6/26/92	54.4	8/12/92	1.4	8/12/92	0
10/12/93	28.3	7/10/92	212.8	7/2/92	116.8	7/2/92	15.7	7/2/92	17.7	7/2/92	45.7	8/26/92	1	8/18/92	0
6/28/94	78.5	7/15/92	207.3	7/10/92	97	7/10/92	8.9	7/10/92	13.6	7/10/92	33.2	9/2/92	0.9	8/26/92	0
10/26/94	12.3	7/23/92	165.2	7/15/92	84.5	7/15/92	7.6	7/15/92	14.7	7/15/92	34.3	9/11/92	0.7	9/2/92	0
5/31/95	769.1	7/28/92	165.2	7/23/92	68.7	7/23/92	6.3	7/23/92	14.7	7/23/92	29.2	9/17/92	0.1	9/11/92	0
7/5/95	1573.3	8/7/92	165.2	7/28/92	58.9	7/28/92	6	7/28/92	12.1	7/28/92	25	9/22/92	0.1	9/17/92	0
7/20/95	391	8/12/92	143.5	8/7/92	61	8/7/92	5	8/7/92	11.3	8/7/92	23.5	9/28/92	0.3	9/22/92	0
8/14/95	138	8/18/92	130.2	8/12/92	57.8	8/12/92	4.6	8/12/92	7.9	8/12/92	21.3	10/15/92	0.1	9/28/92	0
9/5/95	90.7	8/26/92	122.9	8/18/92	3.6	8/18/92	2	8/18/92	7.3	8/18/92	16	10/21/92	0.2	10/8/92	0
10/11/95	51.1	9/2/92	131.2	8/26/92	39.1	8/26/92	4.6	8/26/92	9.2	8/26/92	18.1	7/8/93	18.4	10/15/92	0
6/29/96	649.8	9/11/92	119.2	9/2/92	41.4	9/2/92	5.2	9/2/92	9.6	9/2/92	16.2	7/14/93	13	10/21/92	0
7/17/96	261.8	9/17/92	113	9/11/92	34.6	9/11/92	2	9/11/92	6.1	9/11/92	12.8	7/20/93	8.9	7/8/93	1.3
8/8/96	103.4	9/22/92	117.4	9/17/92	41.4	9/17/92	4.3	9/17/92	7.3	9/17/92	12.1	7/29/93	7.1	7/14/93	0
9/23/96	61.6	9/28/92	117.4	9/22/92	36.8	9/22/92	2.5	9/22/92	6.6	9/22/92	11.6	8/4/93	6.9	7/20/93	0
10/15/96	51.1	10/8/92	117.4	9/28/92	36.8	9/28/92	3.1	9/28/92	7.3	9/28/92	11.3	8/9/93	6.9	7/29/93	0
6/16/97	1074.8	10/15/92	117.4	10/8/92	36.8	10/8/92	5.7	10/8/92	8.3	10/15/92	5.1	8/18/93	5.4	8/4/93	0
7/16/97	217.4	10/21/92	117.4	10/15/92	34.6	10/15/92	5	10/15/92	7.9	10/21/92	4.9	8/24/93	4.5	8/9/93	0
8/23/97	72.7	10/28/92	145.4	10/21/92	34.6	10/21/92	5.7	10/21/92	7.9	6/30/93	180	8/31/93	4.2	8/18/93	0
8/26/97	72.7	6/30/93	942.1	6/30/93	599.2	6/30/93	95.6	6/30/93	67.7	7/8/93	159.3	9/8/93	3.2	8/24/93	0
11/6/97	72.7	7/8/93	696.1	7/8/93	369.9	7/8/93	58.7	7/8/93	42.2	7/14/93	141	9/15/93	3.5	8/31/93	0
7/9/98	468.1	7/14/93	567.4	7/14/93	289.9	7/14/93	45.8	7/14/93	31.1	7/20/93	110.1	9/23/93	3	9/8/93	0
8/17/98	156.6	7/20/93	477.1	7/20/93	234.8	7/20/93	28.7	7/20/93	31.1	7/29/93	79.1	9/29/93	2.8	9/15/93	0
8/22/98	145.3	7/29/93	326.2	7/29/93	160.4	7/29/93	16.8	7/29/93	23.1	8/4/93	65	10/7/93	2.5	9/23/93	0
6/16/99	1382.5	8/4/93	301	8/4/93	138	8/4/93	16.8	8/4/93	23.1	8/9/93	67.7	10/12/93	3.6	9/29/93	0
6/25/99	748.7	8/9/93	301	8/9/93	145.3	8/9/93	14.6	8/9/93	25	8/18/93	49.4	10/19/93	2.6	10/7/93	0
8/5/99	217.4	8/18/93	241	8/18/93	97	8/18/93	14.6	8/18/93	16	8/24/93	39.9	6/14/94	2.8	10/12/93	0
		8/24/93	229.6	8/24/93	90.7	8/24/93	14.6	8/24/93	14.4	8/31/93	42.2	6/29/94	1.9	10/19/93	0
		8/31/93	229.6	8/31/93	78.5	8/31/93	14.6	8/31/93	15.2	9/8/93	33.2	7/7/94	1.2	6/14/94	0.1
		9/8/93	175.4	9/8/93	56.2	9/8/93	8.9	9/8/93	12.8	9/15/93	33.2	7/12/94	1.1	6/29/94	0
		9/15/93	196.5	9/15/93	58.9	9/15/93	8.9	9/15/93	11.3	9/23/93	33.2	7/20/94	0.8	7/7/94	0
		9/23/93	175.4	9/23/93	51.1	9/23/93	8.9	9/23/93	11.3	9/29/93	31.1	7/26/94	0.6	7/12/94	0

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James 6"

Lower Main		Middle Main		Middle South		Upper North		Upper South		Middle half round		Upper half round	
9/29/93	155.2	9/29/93	46.1	9/29/93	8.9	9/29/93	11.3	10/7/93	27	8/3/94	0.5	7/20/94	0
10/7/93	175.4	10/7/93	51.1	10/7/93	10.7	10/7/93	11.3	10/12/93	33.2	8/8/94	0.4	7/26/94	0
10/12/93	207.3	10/12/93	72.7	10/12/93	14.6	10/12/93	16	10/19/93	3.9	8/18/94	0	8/3/94	0
10/19/93	352.2	10/19/93	41.4	10/19/93	2.3	10/19/93	0.8	6/14/94	130.4	8/25/94	0	8/8/94	0
6/14/94	448.2	6/14/94	280.4	6/14/94	55.4	6/14/94	34.3	6/29/94	62.3	9/1/94	0.1	8/18/94	0
6/23/94	942.1	6/23/94	599.2	6/23/94	95.6	6/23/94	67.7	7/7/94	51.9	9/7/94	0	8/25/94	0
6/29/94	313.5	6/29/94	138	6/29/94	23.7	6/29/94	20.4	7/12/94	43.4	9/12/94	0	9/1/94	0
7/7/94	252.6	7/7/94	110	7/7/94	20.1	7/7/94	17.7	7/20/94	35.4	9/19/94	0	9/7/94	0
7/12/94	246.8	7/12/94	97	7/12/94	16.8	7/12/94	14.4	7/26/94	32.1	9/26/94	0	9/12/94	0
7/20/94	218.4	7/20/94	78.5	7/20/94	12.6	7/20/94	12.8	8/3/94	27	10/5/94	0	9/19/94	0
7/26/94	207.3	7/26/94	72.7	7/26/94	12.6	7/26/94	12.8	8/8/94	21.3	10/13/94	0	9/26/94	0
8/3/94	185.9	8/3/94	64.3	8/3/94	10.7	8/3/94	9.2	8/18/94	17.7	10/20/94	0	10/5/94	0
8/8/94	165.2	8/8/94	53.6	8/8/94	6.5	8/8/94	9.9	8/25/94	15.2	7/6/95	46.9	10/13/94	0
8/25/94	135.9	8/18/94	46.1	8/18/94	6.5	8/18/94	9.2	9/1/94	14.4	7/17/95	18.2	10/20/94	0
9/1/94	145.4	8/25/94	39.1	8/25/94	5.7	8/25/94	8.6	9/7/94	13.6	7/24/95	10.3	8/15/95	0
9/7/94	135.9	9/1/94	43.7	9/1/94	4.3	9/1/94	9.2	9/12/94	14.4	8/2/95	6.7	9/1/95	0
9/12/94	131.2	9/7/94	36.8	9/7/94	4.3	9/7/94	8.6	9/19/94	12.1	8/14/95	0.1	9/5/95	0
9/19/94	131.2	9/12/94	43.7	9/12/94	5.7	9/12/94	9.2	9/26/94	12.1	8/15/95	0.1	9/22/95	0
9/26/94	131.2	9/19/94	36.8	9/19/94	5.7	9/19/94	8.6	10/5/94	16.9	9/1/95	0	9/27/95	0
10/5/94	160.2	9/26/94	32.4	9/26/94	5.7	9/26/94	7.3	10/13/94	9.9	9/5/95	0	10/5/95	0
10/13/94	157.2	10/5/94	41.4	10/5/94	7.3	10/5/94	9.9	10/20/94	35.4	9/13/95	0	10/11/95	0
10/20/94	198.6	10/13/94	36.8	10/13/94	7.3	10/13/94	8.6	7/5/95	180	9/22/95	0	10/18/95	0
10/26/94	170.3	10/20/94	48.6	10/20/94	10.7	10/20/94	7.9	7/17/95	151.9	9/27/95	0	10/25/95	0
7/5/95	2131.5	7/5/95	1184.8	7/5/95	303.1	7/5/95	103.6	7/24/95	126.9	10/5/95	0	6/23/97	0
7/17/95	1172.7	7/17/95	538.2	7/17/95	99.7	7/17/95	65	8/2/95	116.7	10/11/95	0	6/30/97	0
7/24/95	646.8	7/18/95	491	7/18/95	91.7	7/24/95	26	8/14/95	49.4	10/18/95	0	7/7/97	0
8/2/95	477.1	7/24/95	280.4	7/24/95	65.6	8/2/95	39.9	8/21/95	59.6	10/25/95	0	7/13/97	0
8/14/95	352.2	7/27/95	280.4	7/27/95	62.1	8/14/95	35.4	9/1/95	51.9	6/18/96	48.2	7/21/97	0
9/1/95	288.6	8/2/95	208.8	8/2/95	36.9	8/21/95	39.9	9/5/95	42.2	7/11/96	0	7/31/97	0
9/5/95	252.6	8/14/95	138	8/14/95	31.4	9/1/95	17.7	9/22/95	37.6	7/15/96	0	8/3/97	0
9/18/95	241	8/15/95	138	8/15/95	31.4	9/5/95	12.8	9/27/95	42.2	7/16/96	0	8/5/97	0
9/22/95	264.5	8/21/95	145.3	8/21/95	23.7	9/22/95	6.1	10/5/95	35.4	7/17/96	0	8/11/97	0
9/27/95	301	9/1/95	116.8	9/1/95	23.7	9/27/95	6.6	10/11/95	29	7/18/96	0	8/13/97	0
10/5/95	276.4	9/5/95	110	9/5/95	19	10/11/95	9.9	10/18/95	23.1	7/25/96	0	8/21/97	0
10/11/95	241	9/13/95	84.5	9/13/95	12.6	10/18/95	12.8	10/25/95	23.1	8/1/96	0	8/24/97	0
10/18/95	218.4	9/19/95	84.5	9/19/95	12.6	10/25/95	9.9	6/27/96	180	8/8/96	0	8/28/97	0
10/25/95	252.6	9/22/95	78.5	9/22/95	16.8	6/19/96	116.7	7/11/96	103.6	8/13/96	0	10/3/97	0
6/18/96	1821.1	9/27/95	84.5	9/27/95	19	6/27/96	103.6	7/17/96	103.6	8/20/96	0	10/22/97	0
6/27/96	1093.9	10/5/95	97	10/5/95	14.6	7/11/96	57	7/18/96	88	8/29/96	0	11/5/97	0
7/11/96	663.1	10/11/95	69.9	10/11/95	35.5	7/17/96	51.9	7/25/96	70.5	9/5/96	0	6/18/98	30
7/15/96	630.6	10/18/95	53.6	10/18/95	15.7	7/18/96	39.9	8/1/96	59.6	9/11/96	0	6/24/98	24

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Lower Main		Middle Main		Middle South		Upper North		Upper South		Middle half round		Upper half round	
7/16/96	552	10/25/95	72.7	10/25/95	16.8	7/25/96	31.1	8/8/96	44.5	9/18/96	0	7/2/98	0
7/17/96	663.1	6/19/96	824.4	6/18/96	191.7	8/1/96	29	8/13/96	39.9	10/2/96	0	7/10/98	0
7/25/96	448.2	6/27/96	574.5	6/27/96	129.4	8/8/96	29	8/20/96	39.9	10/10/96	0	7/17/98	0
8/1/96	365.4	7/11/96	271.1	7/11/96	42.8	8/13/96	27	8/29/96	27	10/15/96	0	7/23/98	0
8/6/96	365.4	7/15/96	234.8	7/15/96	48.9	8/20/96	25	9/5/96	23.1	6/16/97	150	7/31/98	0
8/8/96	365.4	7/16/96	217.4	7/16/96	36.9	8/29/96	21.3	9/11/96	35.4	6/23/97	150	8/7/98	0
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8/20/96	264.5	7/18/96	217.4	7/18/96	36.9	9/11/96	25	10/2/96	21.3	7/7/97	15	9/17/98	0
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9/18/96	264.5	7/29/96	123.7	7/29/96	23.7	10/15/96	16	6/23/97	180	8/3/97	10	10/19/98	0
10/2/96	218.4	8/1/96	116.8	8/1/96	19	6/16/97	144.6	6/30/97	180	8/5/97	12	11/2/98	0
10/10/96	196.5	8/6/96	72.7	8/6/96	12.6	6/23/97	110.1	7/7/97	174.5	8/11/97	10	6/25/99	0
10/15/96	196.5	8/8/96	72.7	8/8/96	19	6/30/97	82	7/13/97	120.1	8/13/97	12	7/8/99	0
10/22/96	218.4	8/13/96	78.5	8/13/96	19	7/7/97	59.6	7/21/97	88	8/21/97	12	7/23/99	0
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6/23/97	1377.8	8/29/96	56.2	8/29/96	14.6	7/21/97	35.4	8/3/97	66.3	8/28/97	10	9/15/99	0
6/30/97	1074.5	9/5/96	46.1	9/5/96	8.9	7/31/97	35.4	8/5/97	73.3	10/3/97	4.7	9/29/99	0
7/7/97	798.3	9/11/96	72.7	9/11/96	39.8	8/3/97	25	8/11/97	46.9	10/10/97	4.1	10/15/99	0
7/13/97	630.6	9/18/96	61.6	9/18/96	16.8	8/5/97	25	8/13/97	59.6	10/17/97	2.5	10/29/99	0
7/21/97	552	10/2/96	41.4	10/2/96	16.8	8/11/97	25	8/21/97	46.9	10/22/97	2.4	11/9/99	0
7/31/97	477.1	10/10/96	41.4	10/10/96	16.8	8/13/97	25	8/24/97	35.4	11/5/97	4.3	6/6/00	15
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8/28/97	218.4	7/21/97	176	7/21/97	36.9	10/22/97	27	6/24/98	180	7/31/98	10.6		
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7/23/98	552	10/17/97	72.7	10/17/97	16.8	8/22/98	42.4	10/2/98	33.2	7/8/99	20		

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Lower Main		Middle Main		Middle South		Upper North		Upper South		Middle half round		Upper half round
7/31/98	477.1	10/22/97	61.6	10/22/97	12.6	9/17/98	19.5	10/9/98	29	7/23/99	12	
8/7/98	372.1	11/5/97	72.7	11/5/97	12.6	9/23/98	27	10/19/98	27	8/6/99	10	
8/14/98	339.1	6/18/98	1399.4	6/18/98	378.2	10/2/98	21.3	11/2/98	27	9/1/99	6.6	
8/22/98	270.4	6/24/98	1074.8	6/24/98	256.4	10/9/98	19.5	6/11/99	180	9/9/99	5.9	
9/17/98	165.2	7/2/98	748.7	7/2/98	129.4	10/19/98	17.7	6/25/99	180	9/15/99	5.5	
9/23/98	165.2	7/10/98	468.1	7/10/98	69.1	11/2/98	21.3	7/8/99	180	9/29/99	5.8	
10/2/98	155.2	7/17/98	359.5	7/17/98	52.1	6/11/99	180	7/23/99	103.6	10/29/99	4.6	
10/9/98	155.2	7/23/98	285.2	7/23/98	36.9	6/25/99	100	8/6/99	66.3	11/9/99	4.5	
10/19/98	165.2	7/31/98	217.4	7/31/98	36.9	7/8/99	50	9/1/99	49.4			
11/2/98	175.4	8/7/98	138	8/7/98	36.9	7/23/99	30.1	9/9/99	33.2			
6/25/99	1377.8	8/14/98	138	8/14/98	23.7	8/6/99	20.4	9/15/99	35.4			
7/8/99	712.8	8/22/98	145.3	8/22/98	26.1	9/1/99	16	9/29/99	27			
8/6/99	276.4	9/17/98	110	9/17/98	21.3	9/9/99	11.3	10/15/99	23.1			
9/1/99	301	9/23/98	90.7	9/23/98	21.3	9/15/99	9.9	6/6/00	180			
9/9/99	145.4	10/2/98	78.5	10/2/98	19	9/29/99	12.8	6/20/00	100.4			
9/15/99	145.4	10/9/98	72.7	10/9/98	19	10/15/99	11.3					
9/16/99	145.4	10/19/98	78.5	10/19/98	16.8	10/29/99	9.9					
9/29/99	135.9	11/2/98	84.5	11/2/98	19	11/9/99	11.3					
10/15/99	117.4	6/25/99	625	6/25/99	225	6/6/00	49.4					
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6/6/00	630.6	8/6/99	125	8/6/99	52.1							
6/20/00	420	9/1/99	90.7	9/1/99	19							
		9/9/99	56.2	9/9/99	12.6							
		9/15/99	56.2	9/15/99	14.6							
		9/29/99	51.1	9/29/99	12.6							
		10/15/99	41.4	10/15/99	10.7							
		10/29/99	41.4	10/29/99	10.7							
		11/9/99	36.8	11/9/99	7.3							
		6/6/00	401.7	6/6/00	65.6							
		6/20/00	217.4	6/20/00	31.4							

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MEMORANDUM

NORWEST MINE SERVICES, INC.
136 East South Temple, 13th Floor
Salt Lake City, UT 84111

Tel: (801) 539-0044
USA: (800) 366-8521
Fax: (801) 539-0055

DATE: 15 November 2000 **JOB NUMBER:** 00-2439

FROM: Kelly Payne

TO: Project File

SUBJECT: Comparison of S10-1 spring discharge data to climate

Attached is a discharge hydrograph for spring S10-1, which was undermined at the Skyline Mine. (Details regarding the mining history can be found in the technical report for Surface Water and Groundwater Resources.) Also shown are graphs of monthly average precipitation at the Skyline Mine weather station and daily snow water equivalent for the Mammoth-Cottonwood Snotel station. Raw data can be found on the MS Excel file "s10-1comp.xls" on the attached floppy disk.

This graph was created in order to further determine if there is a correlation between the muted springtime peak discharges measured at S10-1 and climate. That there is no correlation between climate and the muted springtime peak discharges was stated in the first and subsequent drafts of the technical report. This observation was originally based on comparison of the discharge data to the PHDI for Utah Division 5, which is presented in the technical report.

Both the precipitation and snowpack data indicate several wetter years during the time of muted peak springtime discharges. This is consistent with statements previously made that there is no identifiable climatic cause for the muted springtime discharges at S10-1.

Given the mining history and the lack of correlation to spring discharge to climate, it is possible that the cause of the muted peak flows is attributable to mining. However, as stated in the technical report and described in the written response to second round comments, there is other evidence that cause the contractor's specialists to believe that this is not a mining-related diminution of flow.

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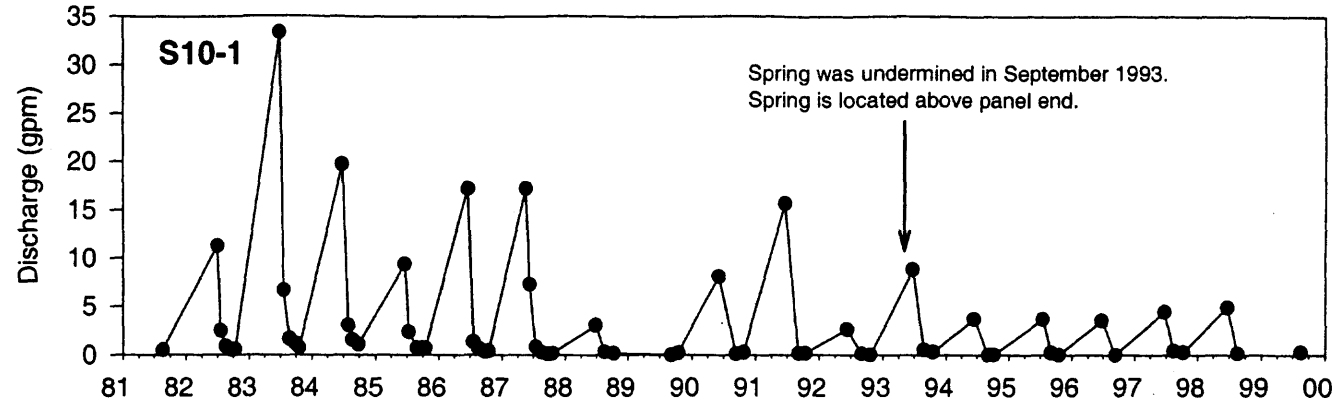

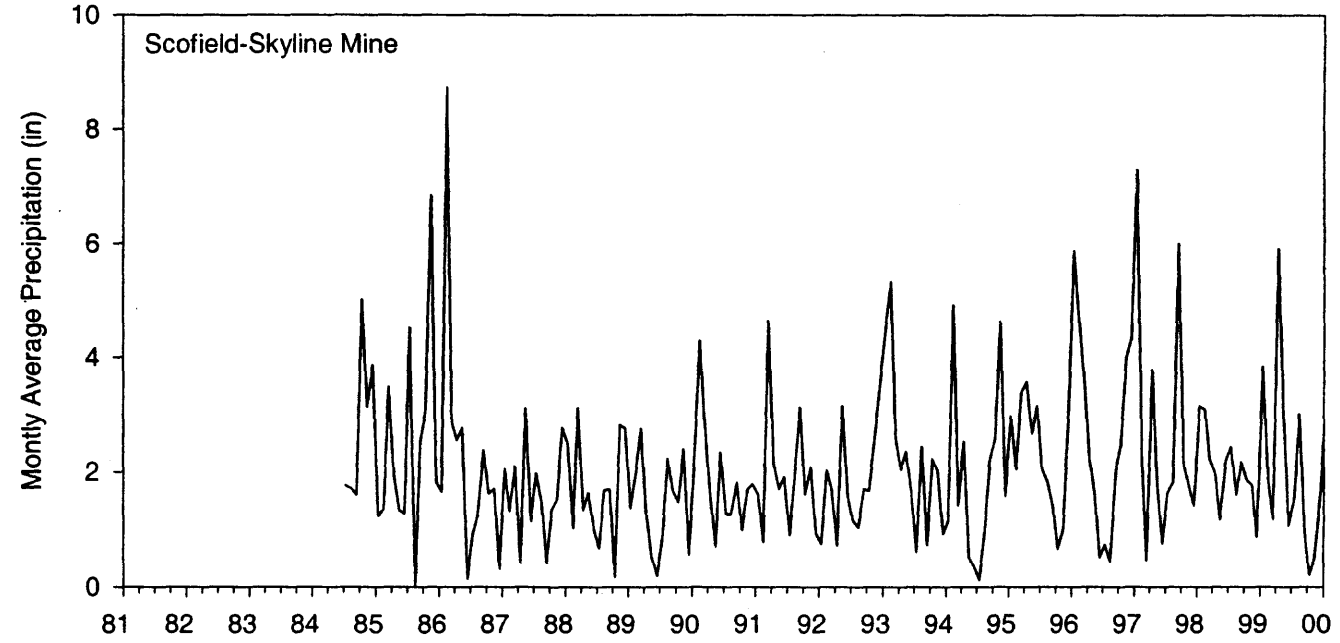

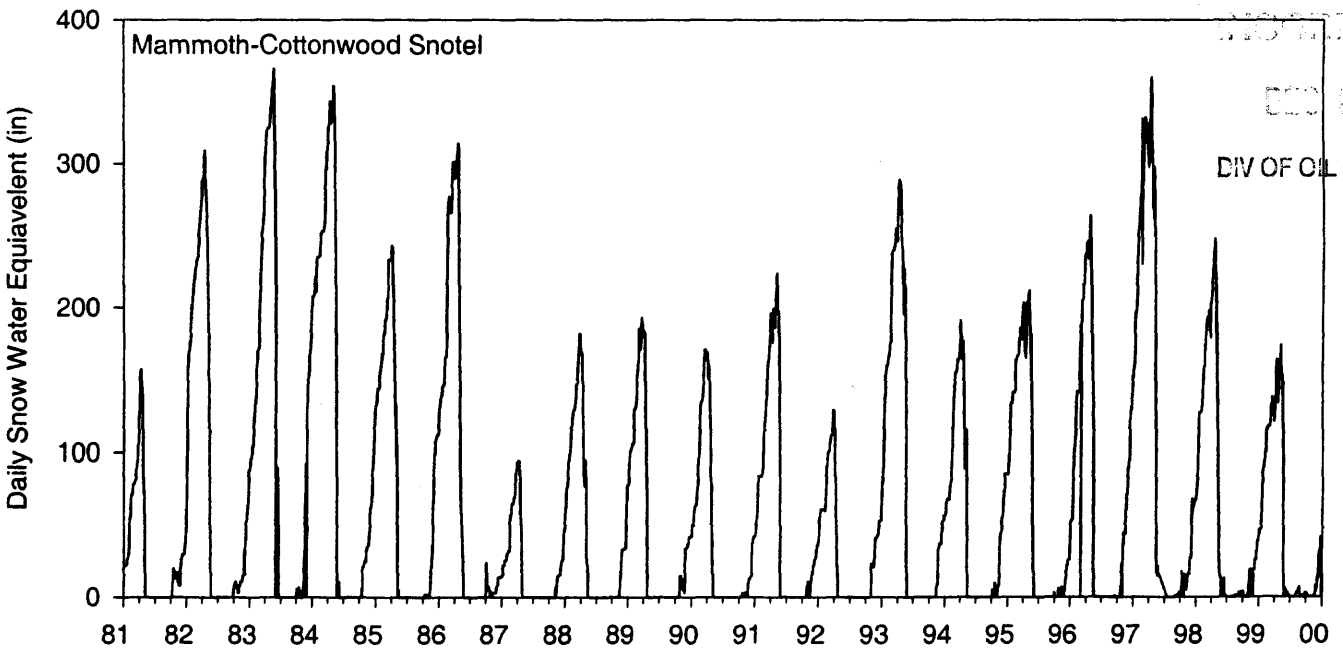

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PHC ADDENDUM

APPENDIX C
HCI PROGRESS REPORT NO. 2

PROGRESS REPORT NO. 2

UPDATED CONCEPTUAL HYDROGEOLOGY, EVALUATION OF CURRENT AND FUTURE DEWATERING, AND PROPOSED TESTING PROGRAM FOR SKYLINE MINE

Prepared for

Canyon Fuel Company, LLC
Helper, Utah

by

Hydrologic Consultants, Inc. of Colorado

HCI-1787

February 2002

HCI HYDROLOGIC COLORADO CONSULTANTS, INC.

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EXECUTIVE SUMMARY
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1. In August 2001, a ground-water inflow of approximately 4,300 gpm was encountered in two entries for the planned 10-Left panel at Skyline Mine. The inflow was associated with a minor splay of the Diagonal Fault.

2. Two large diameter wells were drilled from surface in James Canyon immediately above the inflows in September-October 2001 in an attempt to intercept as much of the ground water as possible before it flowed into the 10-Left entries. The first well, JC-1, produces 2,200 gpm and is pump-limited (i.e., the formation and well could yield more). The second well, JC-2, is either well- or formation-limited, and produces only about 300 gpm.

3. The rate of inflow at 10-Left has not been adequately monitored through time. The rate was approximately 4,300 gpm shortly after the inflow began. Based on different methods of measurement, the rate appears to have decreased to about 3,400 gpm by early October, and to 3,200 gpm since then (all discounting the effect of James Canyon pumping).

4. The effect of pumping from JC-1 and JC-2 on the rate of ground-water inflow at 10-Left has been estimated three different ways, each yielding different values. A comparison of Doppler meter readings on the discharge line to stage volume changes, done prior to and described in Progress Report No.1, produced an estimate of 650 gpm. Subsequent examination of power-usage records suggests that the inflow rate has been reduced by only about 200 gpm. Finally, an estimate based on water level declines and a basic well hydraulics relationship suggests the effect is about 800 gpm.

5. When the lower part of the Level 2 mine is allowed to flood (after mining in the 8-Left and 9-Left panels is complete), the resulting decrease in hydraulic gradient is expected to decrease the rate of inflow at 10-Left by about 1,000 to 1,500 gpm.

6. The hydrostratigraphy described in Progress Report No.1 has been refined with more accurate isopachs of the Storrs and Panther Sandstones underlying the coal to be mined. More significantly, however, is the potential existence of a series of stacked sandstones up to 700 ft thick based on a recently obtained geophysical log of a nearby gas exploration drillhole. The presence of these deep sandstones could potentially explain the relatively large, sustained ground-water inflows to the Skyline mine along faults.

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EXECUTIVE SUMMARY
(Page 2 of 2)

7. As previously reported, the major inflows correlate with structural trend. Where north- to northeast-trending structures dominate, relatively large inflows have been encountered. Currently, large inflows have not occurred in areas where east-west structures dominate. Based on this factor alone, there is a greater risk of significant ground-water inflows in the Flat Canyon tract where northeast-trending faults have been mapped than in the Winter Quarters tract where CFC has mapped only east-west faults.

8. Final laboratory results of water chemistry analyses do not change previously reported chemical interpretations. On the basis of major ions, carbon-based age, and tritium content, the underground inflows and discharge from the James Canyon wells do not have any significant component of water from Electric Lake or from any other surface source.

9. Additional water level data from monitoring wells in the Flat Canyon tract suggest an even higher degree of interconnection among faults than previously recognized. In addition, a preliminary comparison suggests that the faults in the Flat Canyon tract are hydraulically similar to the Diagonal Fault and dewatering requirements could be similar.

10. HCI believes that an estimate of the amount of water that might have to be managed in the Flat Canyon tract and planning the timing of implementation and location(s) of a dewatering system will require a true feasibility-level study involving additional field testing, numerical ground-water flow modeling, and a detailed economic and environmental assessment of the various dewatering and water management options.

11. A numerical ground-water flow model of the Skyline Mine and vicinity is currently being constructed. The model will evaluate flow within the deeper confined aquifers and will not incorporate shallow ground-water effects. The model will be used to predict the amounts of water that will have to be removed, the timing of such dewatering, and optimal locations of pumping centers in the Flat Canyon tract.

12. Future work should include:

    a) Installation of additional water-level instrumentation in existing monitoring wells and shut-in boreholes in the Skyline Mine area.

    b) An underground drilling and testing program, to be initiated in April 2002, to obtain data on the hydraulic properties of the various sandstones beneath the 11-Left area (including some of the deep sandstones), the hydraulic conductivity of the 14-Left fault, and the potential leakance between the sandstones.

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1.0 INTRODUCTION

Ground-water inflow of approximately 1,200 gpm was encountered in a previously unmapped splay fault associated with the Diagonal Fault (Plate I) at Skyline Mine on August 6, 2001 during development of an entry for the 10-Left panel. This was the fourth relatively large inflow that had occurred in the mine during the past 2.5 years.

On August 16, an additional inflow of approximately 3,100 gpm was encountered from an extension of the same structure in an adjacent entry, bringing the total inflow at 10-Left to approximately 4,300 gpm. Canyon Fuel Company (CFC) decided to try to intercept as much of this water as possible using an "emergency" dewatering well completed from the surface. A site in James Canyon was selected (Plate I), and CFC contracted Lang Exploratory Drilling of Salt Lake City to drill and complete a nominal 14-in diameter well. While drilling of the wellbore was in progress, CFC asked Hydrologic Consultants Inc. of Colorado (HCI) to assist in the design and testing of this well. HCI advised completing the well (JC-1) into the Storrs Sandstone alone (i.e., not extending it into the underlying Panther Sandstone).

Test pumping of JC-1, which then continued into production pumping at a rate of 2,200 gpm, began on September 16. CFC commissioned another larger diameter well, designated JC-2, which was installed from September 18 to October 4. Well JC-2 was found to be capable of producing only 300 to 500 gpm. With both JC-1 and JC-2 pumping, the inflow to 10-Left has apparently decreased only a relatively small amount.

A meeting was held at the CFC office in Midvale on October 31 among CFC, Arch Coal, Ark Land, NorWest Mine Services, Inc. (NorWest), and HCI to discuss the results of the dewatering to date (HCI, 2001a) and the ramifications relative to mining of 10-Left and the Flat Canyon tract. As part of that meeting, HCI and CFC agreed on a work plan (HCI, 2001b) to conduct a more comprehensive hydrogeologic study to:

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1) Assess whether the inflow to the 10-Left entries can be stopped in a cost-effective manner.

2) Define the hydrogeologic conditions in the Flat Canyon tract, evaluate the potential need for dewatering in that area, and design, if deemed necessary, a dewatering system to be installed as timely and cost-effectively as possible.

3) Evaluate, on a preliminary level, whether the Winter Quarters area would constitute a better mining option in terms of hydrologic risk.

Findings, conclusions, and recommendations based on the hydrogeologic investigation through November 2001 were submitted to CFC in Progress Report No. 1 (HCI, 2001c). This second Progress Report summarizes the work completed since November and presents HCI's updated findings, conclusions, and recommendations. Much of the material from Progress Report No. 1 is included in this report to enable it to be a stand-alone document.

In summary, HCI has compiled, reviewed, and interpreted all of the hydrogeologic data and information that have been made available to us to date. These include the data and information described in Progress Report No. 1 (e.g., coal exploration drillhole logs, water chemistry data, water level data) as well as new water level data from other monitoring wells, stratigraphic data from nearby deep gas exploration wells, power usage records for the underground sump pumps, and additional water chemistry data. This second Progress Report includes a re-evaluation of the effectiveness of the two dewatering wells, JC-1 and JC-2, based on the most recent data. It also includes a significantly revised plan to install and test underground hydrostratigraphic testholes into sandstones beneath the LOA coal seam. Except for the identification of these underlying sandstones, the conceptual hydrogeologic model of the mine area described in Progress Report No.1 has not changed significantly.

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2.0 SUMMARY OF HYDROGEOLOGIC INVESTIGATION TO DATE

The following is a point summary of the tasks completed to date as part of HCI's hydrogeologic investigation of the Skyline Mine area.

1) Compilation of general and anecdotal information on the location, timing, and rates of various inflows encountered during the history of mining at Skyline.

2) Installation of water level monitoring equipment in surface monitoring wells and in the horizontal drillhole in the 9-Left headgate (Plate I) and continuous collection of water level data since mid-September 2001.

3) Collection of water samples from various underground inflows, from the discharge from JC-1 and JC-2, and from Electric Lake in conjunction with CFC to help identify the source of the ground-water inflow and the water pumped by JC-1 and JC-2.

4) Review and analysis of the results of pumping from JC-1 and JC-2.

5) Compilation, review, and interpretation of all relevant geologic, water chemistry, and water level data from the files at Skyline Mine.

6) Meeting with Mark Bunnell of Ark Land and Alan Mayo of Mayo and Associates on December 7 to discuss a) the water chemistry data, structures, and hydrostratigraphy of the Skyline Mine area, and b) how that information can be incorporated into a numerical ground-water flow model.

7) Preparation and submittal of Progress Report No. 1 (HCI, 2001c).

8) Initial work on the numerical ground-water flow model including construction of the model grid and layering, defining hydraulic boundary conditions and significant hydrogeologic features, and preliminary assignment of hydraulic properties to the various hydrogeologic units.

9) Installation, in conjunction with CFC, of additional water-level monitoring instruments in monitoring wells west of Electric Lake and review of the initial data from them.

10) Compilation and review of power-usage data for the underground sump pumps and re-evaluation of the inflow to 10-Left.

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11) Meeting with Idea Drilling Company at Skyline Mine on January 24, 2002 to discuss the procedures and requirements for underground drilling and testing.

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3.0 UPDATED CONCEPTUAL HYDROGEOLOGIC MODEL

Using all of the available, relevant geologic, hydrologic, and water chemistry data, HCI has developed a conceptual hydrogeologic model to describe the occurrence and movement of ground water in the Skyline Mine area. This conceptual model, to be further refined with some additional drilling and hydraulic testing (to be described in Section 5.1), is currently being incorporated into a predictive numerical ground-water flow model. Together, the two models will be used to evaluate the necessity of dewatering the Flat Canyon tract and to design a dewatering system if active dewatering is deemed necessary.

3.1 HYDROSTRATIGRAPHY

The Skyline Mine is developed in the O'Connor and Flat Canyon coals of the Cretaceous Blackhawk and Starpoint Formations. The overburden consists primarily of siltstones, sandstones, coals, and shales of the Blackhawk Formation. Underlying units, primarily members of the Starpoint Formation, include interbedded siltstones and sandstones, and are interpreted to be a stacked transgressive-regressive shoreline assemblage.

The two proximal sandstone units beneath the coal seams, and hence the two most well known, are the Storrs and Panther Sandstones. The upper part of the Storrs Sandstone, as encountered at JC-1, consists of partly- to non-cemented sand that was probably deposited in an upper shoreface environment. The lower part of the Storrs Sandstone in this area is thinly bedded and calcareous, and could represent an overlapped lower shoreface or transition facies. The Panther Sandstone, which appears to be lithologically similar to the lower Storrs in the cuttings from JC-1, seems to be less permeable than the Storrs based on geophysical log data. The Panther Sandstone most likely represents an older transitional zone in the James Canyon area. As will be described in more detail below, numerous additional shoreface sandstone units locally underlie the Panther Sandstone.

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HCI examined geologic logs of 45 exploration boreholes. In order to determine if there is any correlation between the sandstones, structures (to be described below), and ground-water inflows, a series of isopachs was constructed of the various sandstones and interburden beneath the Level 3 and Level 2 mine areas. Figures 1 and 2 show the areal distribution and thickness of the Storrs and Panther Sandstones, respectively. A comparison of the location of the major ground-water inflows to the isopachs in Figures 1 and 2 shows no obvious correlation between inflow and the thickness of either sandstone.

An examination of the interburden beneath the mine area, specifically the thickness of the low permeability units between the mined coal and the first significant sandstone (either Storrs or Panther) beneath the coal, shows no relationship between the occurrence of ground-water inflow and relatively thin interburden. In fact, the opposite appears to be true. In the Level 3 area, the LOA seam was mined just 0 to 10 ft above the Storrs Sandstone without any significant ground-water inflow. Conversely, in the current Level 2 area, ground-water inflows have occurred where interburden between the LOB and the Storrs Sandstone is 70 to 100 ft thick.

It is important to note that the storage capacity of the Storrs, Panther, and Trail Canyon Sandstones beneath the Skyline Mine is insufficient to account for the sustained ground-water inflows experienced in the mine (HCI, 2001a). Although exploration drilling by CFC has not gone significantly below the Starpoint Formation, Doelling (1972) indicates that on a regional scale, a thick, stacked sequence of shore facies sands can occur locally beneath the Starpoint Formation. In order to assess the potential occurrence of such sandstones beneath the Skyline Mine, CFC obtained geologic and geophysical logs of nearby gas exploration drillholes. The log of one nearby drillhole (Figure 3) shows a stacked sequence of sandstones totaling at least 700 ft in aggregate thickness beneath the Panther Sandstone (Plate III) in the vicinity of the northwest corner of the mine (near "The Kitchen" as shown on Plate I). CFC interprets the sandstones represented in the log to be of shoreface affinity (M. Bunnell, 2002, personal

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commun.). This is a most significant finding. If present beneath the Skyline Mine, these sandstones could explain the sustainability of the five existing major inflows into the mine -- the missing source -- as well as pose risk to future mining. A field program to address this possibility will be described in Section 5.1

3.2 MAJOR FAULTS

Major north-south trending, regional-scale faults cut through the Skyline Mine area. The two most significant are the Pleasant Valley Fault Zone along Mud Creek to the east of the mine, and the Gooseberry Fault Zone, a segment of the Joes Valley Fault, in Gooseberry Creek to the west. The two faults juxtapose lower-permeability rocks of the Blackhawk Formation (on the east) and the North Horn Formation (on the west) against the Starpoint sandstones in the block beneath the mine area (Witkind and Weiss, 1991).

A number of lesser faults and fracture zones occur between the Pleasant Valley and Gooseberry Creek Faults, many of which have been encountered in the mine workings (Plates I and IV). In Mine 3 Level 2, the Connellville, 14-Left, and 16-Left Faults trend northeast-southwest, at an angle to the Pleasant Valley and Gooseberry Creek Faults. The Diagonal Fault trends north-south, parallel to the regional faults, and apparently intersects both the Connelville and 14-Left Faults. The Connelville Fault, with about 200 ft of vertical displacement, defines the southeast boundary of the mine. The Diagonal Fault displays up to 40 ft of vertical displacement, whereas the 14-Left and 16-Left Faults only locally show more than 10 ft of vertical displacement.

In the Mine 3 Level 3 area, no major north- or northeast-trending faults have been mapped. CFC's structural interpretation shows mostly east-west trending faults of minor displacement north of the LOB/LOA merge line (Plate I). The most prominent east-west fault, with 30 ft of vertical displacement, defines the merge line. The east-west faults are locally

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accompanied by east-west trending igneous dikes. CFC's geological maps suggest that the north- and northeast-trending faults cut the dikes.

All of the significant ground-water inflows in the Skyline Mine to date have been associated with north- and northeast-trending faults in the Level 2 area. The east-west trending faults in the Level 3 area apparently have not produced large nor persistent inflows.

HCI is not aware of any regional-scale analysis of fault/fracture orientation and displacement. However, such a structural analysis might help determine why different orientations of structures are associated with different hydrologic conditions and help predict which structures might be more water-bearing than others. It is noteworthy that the inflow rates do not appear to have any relationship to fault displacement.

Ground-water inflows to other coal mines in the Wasatch Plateau and Book Cliffs have been characterized as highly compartmentalized (Mayo and Morris, 2000). Although there is definitely strong structural control of ground-water flow in the Skyline Mine area, measured changes in water levels over relatively large areas (to be described in more detail below) suggest the ground-water system might not be as compartmentalized as at other mines in the Wasatch Plateau or at the West Elk Mine in Colorado (Mayo and Koontz, 2000).

3.3 GROUND-WATER LEVELS

Shallow ground-water level data are currently available from four monitoring wells (W79-26-1, 79-10-1b, 79-14-2a, and 79-35-1b). The monitoring records are discontinuous in time, but indicate the shallow ground-water levels (most likely representative of the water table) fluctuate over a relatively large range. Locally, the water table in the area of the mine appears to have declined in the mid- to late-1990s, but to have since stabilized. HCI has not assessed whether the local decline was due to mining or to changes in recharge.

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Records of deep ground-water levels are available from eight monitoring wells (79-35-1a, 98-2-1m, 99-4-1, 99-21-1, 99-28-1, 20-4-1, 20-4-2, and 20-28-1) and from one of the underground horizontal boreholes (in 9-Left, see Plate I). Older, but sparse, data from well 79-35-1a suggest that a general decline in the deep water levels occurred from the late-1980s to the mid-1990s. Local mine inflows have recently accelerated this general decline.

Most of the deep monitoring wells are screened in and just below the LOB seam (wells 99-21-1, 99-28-1, and 20-4-1 are screened in the Panther Sandstone just below the Flat Canyon coal; well 20-4-2 is screened in the Storrs Sandstone just below the LOA coal). Hydrographs for these wells (Figure 4) indicate a relatively large range of water levels. It is important to note that the water levels decrease with proximity to the four major mine inflows, regardless of the stratigraphic position of the screen in the monitoring well. The hydrographs also clearly show that, prior to the beginning of inflow at 10-Left in August 2001, the ground-water levels beneath the Flat Canyon area were already dropping at a rate of about 0.03 to 0.08 ft/day. This decline was most likely in response to the inflows at 14-Left, 16-Left, and the Fault Crossing. Since August 2001, the rate of water level declines in the Flat Canyon monitoring wells have, in most cases, significantly increased. The wells in the Flat Canyon tract are clearly responding not only to the 10-Left inflow, but also to the pumping from the James Canyon wells. The hydrograph of 99-4-1 (Figure 5) shows a distinct response to a shut down of JC-1 in January 2002.

Figure 6 shows the water levels as of October 2001 (the most recent comprehensive measuring event) in all available deep monitoring wells in the Level 2 and Flat Canyon areas. Figure 7 shows the interpreted drawdown in all wells due solely to the 10-Left inflow and pumping of the JC wells between August and October 2001. Because the water level contours shown in Figures 6 and 7 are based on relatively sparse data, they are very subjective and interpretive, especially in the broad area between the Diagonal and 14-Left Faults. These interpreted water levels and drawdowns suggest:

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- Drawdown from the major inflows to the mine has propagated primarily along the larger, mapped fault zones. However, there is a broad area in the northeast corner of the Flat Canyon tract, centered on the three earliest inflows, where water levels have drawn down an estimated 200 to 300 ft since the original water "hits" in 1999.

- The inflow at 10-Left and pumping from JC-1 alone has resulted in more than 100 ft of additional drawdown locally since August 8 and between 10 and 35 ft of additional drawdown across the Flat Canyon tract.

- There are no apparent vertical gradients between the Storrs sandstone, Panther Sandstone, and LOB seam.

- All of the mapped faults in the Level 2 and Flat Canyon areas are hydraulically connected and have propagated drawdown into areas where faults have not yet been mapped (e.g., into the areas of 99-21-1 and 20-28-1).

3.4 WATER CHEMISTRY

Because it was concluded by HCI at the very beginning of the investigation that the ground-water storage in the Storrs and Panther Sandstones was not capable of sustaining the inflows at 10-Left, a significant effort was made to collect and analyze water samples in an attempt to identify the potential source(s) of the inflow. Water samples were collected, either by CFC or HCI, in the mine, from wells JC-1 and JC-2, and from Electric Lake (Plate I). The laboratory analyses included major cations (calcium, magnesium, sodium, and potassium) and anions (chloride, sulfate and alkalinity), trace components (iron, fluoride and barium), stable isotopes (^{2}H or deuterium, ^{18}O, and ^{13}C), and radiogenic isotopes (^{3}H or tritium and ^{14}C), and the data are summarized in Table 1.

A trilinear (or Piper) diagram was prepared to help define and compare the major ionic compositions of the various surface and underground waters (Figure 8). The surface-water samples from Electric Lake (green symbols) have an ionic composition quite distinct from the ground-water samples collected from the underground (red symbols). This is most readily

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indicated by the lake waters having less magnesium and alkalinity than the waters from the underground. The total dissolved solids (TDS) concentrations of the samples are represented in the central diamond by the relative diameters of the circles. It is apparent that the TDS levels in the underground waters are greater than the TDS levels in the lake waters. Such differences in TDS, alkalinity, and magnesium (although, somewhat surprisingly, not calcium) are consistent with dissolution of carbonate materials (the cement in the sandstones) as recharge from precipitation and/or surface-water bodies moves through the subsurface.

The stable isotope ratios (or δ values) for ^{2}H and ^{18}O from selected samples are plotted on Figure 9 along with the so-called global meteoric water line. The three samples from Electric Lake are isotopically heavier than the four samples from the underground, indicating the two groups of water have different origins. The isotopic composition of the four samples from the underground suggest that the origin (rain or snowmelt) of these waters had a lower temperature than that of the lake water. This suggests that the underground waters originated at a higher elevation or from a colder time than the waters of Electric Lake. In either case, the waters are different.

Tritium (^{3}H) concentrations were analyzed in six of the samples. As indicated in Table 1, the two samples from Electric Lake both had measurable concentrations of tritium whereas the ground-water samples had concentrations that were near, or below, the detection limit. These data strongly indicate that the underground inflow at 10-Left and the discharge from JC-1 do not have a significant hydraulic connection with Electric Lake.

Analyses of ^{14}C concentrations also strongly indicate that the waters from the mine and Electric Lake are very different. The Electric Lake samples had percent modern carbon (pmc) values of 72.4 and 82.2 percent whereas waters collected from the underground or JC-1 had values ranging from 30 to less than 16 pmc.

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In summary, the water chemistry data clearly indicate that the ground water flowing into the mine (specifically at 10-Left) and the water being pumped from dewatering wells JC-1 and JC-2 are significantly different from Electric Lake water. This precludes the existence of a direct "conduit" between Electric Lake and the 10-Left inflow and JC wells.

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4.0 EVALUATION OF CURRENT AND FUTURE DEWATERING

Dewatering well JC-1 produces approximately 2,200 gpm, but is currently "pump limited." HCI estimates its maximum yield to be in the range of about 5,000 to 6,000 gpm. Well JC-2, only about 80 ft away (but 200 ft at the bottom) from JC-1, and also completed into the Storrs sandstone, produces only 300 to 500 gpm, much less than anticipated. Reasons for the very high and very low yields of the two wells and a discussion of unusual responses to pumping are provided in HCI (2001c). Pumping from the two wells has had a limited effect on the ground-water inflow at 10-Left, as described in Section 4.2, below.

The question of being able to stop, or at least significantly reduce, the 10-Left inflow with pumping has been partly answered by the disappointing results of the James Canyon wells. CFC's current plan is to flood the lower part of the Level 2 mine once mining has been completed in the 8-Left and 9-Left panels. The inflow at 10-Left is currently driven by the hydraulic gradient between the elevation of the potentiometric surface in the "aquifer" and the elevation of the discharge points in the 10-Left entries. As already described in HCI (2001c), if water were allowed to pond to the floor level at the north end of the Diagonal Mains (at an elevation of about 8,135 ft), the driving head differential would be reduced by about 95 ft. Based simply on "black boxing" the Darcy flow relationship, as described in HCI (2001c), such a reduction in the head differential would decrease the inflow at 10-Left by approximately 1,000 gpm. Conversely, using proportions illustrated in Figure 10 (to be discussed in more detail below), a "specific yield" estimate of the reduction in inflow would be closer to 1,500 gpm.

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4.1 INFLOW TO 10-LEFT

The rate of ground-water inflow at 10-Left has not been monitored with an adequate degree of accuracy and precision over time. The inflow was approximately 4,300 gpm on

August 16 based on an assumed stage-volume relationship and the change of the "beachline" in the partially flooded entries. A stage-volume estimate of inflow, probably the most accurate of the methods used to date, has been made only one other time, on October 9, 2001. At that time the rate appeared to have fallen to 3,050 gpm, but well JC-1 was pumping during the measurement (see below).

An alternative estimate of the effect of pumping on the 10-Left inflow can be made with the power usage by the two vertical pumps SP43 and SP44. These pumps lift all the water from the 10-Left inflow, and recently, water emanating from the Connelville Fault and 9-Left gob (an estimated 200 gpm). Records of the power usage by the two pumps, though not continuous, are available beginning on September 4, 2001. According to the pump-specific and site-specific relationship developed by CFC (G. Kenzy, CFC, 2002, personal commun.), power usage can be converted to pumping rate by the relationship 1 amp = 6.83 gpm.

Power usage records (Figure 11) show that prior to about October 1, 2001, the power usage fluctuated greatly and for reasons HCI does not currently understand. The power usage dropped after completion and grouting of JC-1, but appears to have steadily increased from about 435 amps to about 500 amps in the first 2 weeks of pumping from JC-1 (which is also the period when JC-2 was being drilled). When JC-2 was completed about September 30, power usage by SP43 and SP44 began to decline from about 500 amps to about 475 amps over the subsequent 2 weeks. With continued pumping from JC-1 and intermittent pumping from JC-2, the power usage continued more or less steadily for 2 months at an average of about 475 amps. On November 17, the pumps in the James Canyon wells were turned off; and power usage increased back to an average of about 500 amps within 7 days. When the pumps in the James Canyon wells were re-started on December 17, the power usage again declined to about 475 amps. The beachline at 10-Left fluctuated during all of these periods of drilling and pumping, but storage gains and losses indicated by changes in the beachline were found to be insignificant when compared with the long-term pumpage rates.

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Table 2 summarizes the estimated inflow to 10-Left based on the various methods of measurement and subtracting out the contribution to the sumps from other sources (i.e., the 9-Left gob and Mine 1). Assuming the estimates of inflow from the various methods can be compared, it appears that the inflow to 10-Left decreased from about 4,300 gpm in August 2001 to about 3,400 gpm in early October. It should be noted that the inflow rate had been estimated as high as 7,000 gpm in early September based on un-recorded power usage. That high inflow, if real, might have been a temporary condition due to the opening of a new "conduit" during the drilling of JC-1. By mid-October, the inflow to 10-Left had decreased to a relatively steady rate of about 3,000 gpm with the James Canyon wells pumping and about 3,200 gpm with the wells off. An alternative, and slightly higher, estimate of this inflow difference is described below.

In late December 2001 and early January 2002, the power used by SP43 and SP44 increased again (Figure 11) to a peak of about 545 amps as water was drained from Mine 1 through a drainhole in 8-Left B. The increase in amperage suggests that the two sump pumps were pumping an additional 500 gpm due to the Mine 1 drainage. Since January 4, 2002, the power usage has decreased back to about 490 amps, suggesting an essentially continuous drainage from Mine 1 of about 100 to 150 gpm.

4.2 EFFECT OF PUMPING OF JC-1 AND JC-2 ON INFLOW TO 10-LEFT

As described above, the power usage records suggest that pumping of the James Canyon wells is currently reducing the inflow to 10-Left by only about 200 gpm (Table 2), only about 6 percent of the inflow. However, as will be described below, such a small impact is questionable based on water level changes. Using both metered (with Doppler meters on the discharge lines) pumping rates and a stage-volume relationship for the strand line, HCI had earlier estimated (HCI, 2001c) that pumping from the James Canyon wells reduced inflow to 10-Left by about 650 gpm. Not surprisingly, a direct comparison of flow rates measured by

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the Doppler meter readings and calculated from power use (on October 16, 2001; see Table 2) suggests that one or the other method is not very accurate. The Doppler meter measured about 500 gpm more flow than estimated from power usage. An estimate of the effect of pumping from JC-1 based on a third method, to be described below, suggests that the Doppler meter may be the more accurate of the other two methods.

The third method of assessing the effect of pumping of JC-1 is based on basic ground-water hydraulics and changes in local ground-water levels. Figure 10 shows the potentiometric surface within or near the Diagonal Fault zone as measured at three points (monitoring well 98-2-1m, 9-Left horizontal drillhole, and monitoring well 79-35-1A) when JC-1 was shut down in late December 2001 and again at the same three points plus the 11-L horizontal drillhole when JC-1 pumping resumed in January 2002. The water level data indicate that the water level in well 98-2-1m, about 4,200 ft north of JC-1, declined an additional 14 ft when pumping resumed. In the 9-Left drillhole, about 2,300 ft south of JC-1, the water level declined by an additional 26 ft over the same period. Assuming a linear hydraulic gradient based on the latter two water levels (a reasonable assumption in such a conduit-like fault zone), the decrease in water level at the 10-Left inflow point, just 150 ft from JC-1, would have been about 50 ft. It is noteworthy that this amount of drawdown is comparable to the drawdown measured in JC-1 itself which has been very consistently about 50 to 60 ft since the first week of pumping.

Using these declines in water levels, an estimate of the effect of the James Canyon wells on inflow to 10-Left can be made assuming a linear "specific capacity" (i.e., a well hydraulics concept defined as the discharge per unit of drawdown) for the 10-Left inflow area. If we assume a pre-inflow water level (based on the projected water level in 1998, see Figure 10) of about 8,520 ft and a water level of 8,320 ft in response to an inflow of 3,200 gpm in December 2001, the specific capacity would be about 16 gpm/ft. As described above, the minimum additional drawdown at the inflow points due to the pumping of JC-1 is about 50 ft.

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Thus, the decrease in inflow at 10-Left associated with another 50 ft of drawdown propagated by JC-1 is estimated to be about 800 gpm.

In summary, an accurate and reliable measure of the effect of pumping from the James Canyon wells on the inflow at 10-Left has yet to be made. Estimates of the decrease in inflow based on three different methods range from about 200 to about 800 gpm. HCI is of the opinion that the higher end of the range provides the most reasonable estimate. If that is the case, the ratio of pumping (2,200 gpm) to reduction in passive inflow to 10-Left is about 2.8:1, within the 1.5 to 3 ratio often cited by dewatering practitioners.

The answer to the question of the effect of pumping the James Canyon wells on the 10-Left inflow has significant economic ramifications. CFC must decide whether to keep the wells pumping based upon the estimated reduction in inflow to 10-Left caused by pumping 2,200 gpm from the wells. The factors obviously include power costs and the trade-off of discharging 2,200 gpm into Electric Lake vs. reducing discharge to Eccles Creek by 200 to 800 gpm. The James Canyon wells are affecting water levels regionally (Section 3.3), but keeping the wells pumping solely for the purpose of regional dewatering is not justified.

4.3 FLAT CANYON TRACT

The hydrostratigraphy, structures, and water levels described in Sections 3.1, 3.2, and 3.3, respectively, present a preliminary understanding of the ground-water conditions that might be encountered during proposed mining of the Flat Canyon tract. The apparent current drawdown in the Flat Canyon area suggests that the various water-bearing units in the Starpoint Formation are reasonably well hydraulically connected, probably via the more prominent faults, throughout this area. The favorable aspect of interconnection, rather than compartmentalization, is that dewatering might be done at a limited number of dewatering "centers" rather than with wells into each of many compartments. Conversely, relatively large

quantities of water might have to be managed at the relatively large hydraulic heads that will exist in that down-dip area (Plate III).

There are still insufficient data from which to quantify the amount of water that might have to be managed and the timing of implementation and location(s) of a dewatering system that would produce acceptable mining conditions. To do that, more data will be needed on the hydraulic properties of the various sandstones (Section 5.1); and subsequent numerical ground-water flow modeling of the area needs to be conducted (Section 5.4). Nevertheless, a very preliminary comparison of drawdown relationships in the Flat Canyon tract versus the Diagonal Fault area can be made.

Monitoring well 99-4-1 at the south end of the Flat Canyon tract (Plate I) is probably screened within or near the fracture zone of the 16-Left Fault in Boulger Canyon. It should be noted that the geophysical "mapping" in this area, the basis of the fault location, is not considered to be very accurate (M. Bunnell, 2002, personal commun.). In any case, the hydrograph of 99-4-1 (Figure 5) shows rapid, distinct responses to both the temporary shut down of JC-1 and a recent inflow encountered on the 14-Left Fault in the East Submains (Plate I). The timing and magnitude of the water level responses suggest a relatively high hydraulic conductivity and possibly a relatively low storage coefficient of the "aquifer" between the piezometer and the pumping and inflow points.

Monitoring well 99-4-1 is located about two miles southwest of the East Submains inflow. Similarly, monitoring Well 98-2-1m is located on or near the Diagonal Fault, two miles south of the Fault Crossing inflow. Figure 5 shows that the East Submains inflow (visually estimated to be 300 gpm) resulted in an increase of 0.05 ft/day in the drawdown rate at 99-4-1. This corresponds to a "specific drawdown" of about 1.7×10^{-4} ft/day/gpm. In comparison, Figure 10 shows that the water level in monitoring well 98-2-1m declined 40 ft between June 2000 and June 2001 in response to the Fault Crossing inflow of about 1,000 gpm. This corresponds to a specific

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drawdown of about 1.1 x 10^{-4} ft/day/gpm, a very similar number in such a comparison. The implication, though based on a simple semi-quantitative comparison, is that the hydrology of the two faults is similar, and by extension, dewatering challenges in the Flat Canyon tract might not be significantly different than those experienced by CFC in the current Level 2 mine.

As shown on Figure 5, the water level in monitoring well 99-4-1 is currently at about 8,550 ft, about 1,000 ft above the level of the LOB seam, and is currently declining at a rate of about 0.16 ft/day. At the current rate of ground-water extraction (i.e., from all current inflows and pumping affecting the water level in monitoring well 99-4-1), it can be estimated by simple linear extrapolation of the drawdown that it would take about 17 years for the water level to decline to the level of the coal in this area. In order to depress the water level 1,000 ft in just five years, the time by which mining will advance to the vicinity of well 99-4-1 under the current mine plan, a drawdown rate of about 0.55 ft/day would have to be induced. This is considerably higher than the rate at which water levels are declining in the Diagonal Fault area (0.43 ft/day) in response to current inflows and pumping (a total of about 6,000 gpm).

Planning the most appropriate dewatering system for the Flat Canyon area should consider:

- managing inflow passively vs. actively dewatering in advance of mining,
- development of a better method for predicting the occurrence and hydraulic nature of water-bearing faults,
- targeting faults vs. dewatering the "source" sandstones,
- the timing of implementing any active dewatering, and
- using wells drilled from surface versus from the underground wells.

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HCI believes this will require a true feasibility-level study involving the proposed field investigation described in Section 5.1, numerical ground-water flow modeling (described in Section 5.4), and a detailed economic and environmental assessment of the various options.

4.4 WINTER QUARTERS TRACT

Whether mining should proceed west into the Flat Canyon tract or north into the Winter Quarters tract on the basis of hydrologic risk can only be addressed in a preliminary manner at this time. The current conceptual understanding of the hydrogeology of the entire Skyline Mine area suggests that defining the structural setting, rather than sandstone thickness and proximity, will be key to predicting ground-water inflow risks in a given area. As previously described, the sandstones are the source of and sustain the inflows to the mine via the faults: but the sandstones do not, by themselves, pose the risk.

As a preliminary observation, the major structures in the Flat Canyon tract are extensions of or parallel to the N-S trending structures in the wet Level 2 area. Conversely, structures currently mapped in the Winter Quarters tract are similar to those in the drier Level 3 mine.

By this simple analogy, the Flat Canyon tract has greater risk associated with structurally controlled ground-water inflows. Although there are even fewer existing hydrogeologic data for the Winters Quarter tract than for Flat Canyon tract, the hydrologic risk is intuitively lower in the Winter Quarters area.

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5.0 PROPOSED ADDITIONAL HYDROGEOLOGIC INVESTIGATION

5.1 HYDRAULIC TESTING

HCI previously developed (HCI, 2001c) a relatively simple and inexpensive program to conduct flow and shut-in tests of the Storrs and Panther Sandstones in at least three locations. Those tests were to be fairly shallow, to depths of about 260 ft, just penetrating the first sandstone (Trail Canyon) beneath the Panther Sandstone. However, the recently obtained geologic information from nearby deep gas exploration drillholes indicates that there could be a very significant sequence of sandstones beginning at a depth of only about 75 ft below the Trail Canyon Sandstone. As discussed in Section 3.1, HCI believes these deep sandstones could be the "reservoir" providing water to and sustaining the five existing major inflows in the mine. There is no reason to doubt they could provide a similar role at any permeable faults intersected by future mining.

Consequently, HCI now highly recommends deeper drilling and hydraulic testing to determine if the deeper sandstones exist beneath future mining areas. If so, CFC needs to know what the hydraulic properties of these sandstones are relative to a) their potential ability to provide and sustain flow to faults encountered by future mining and b) the feasibility of dewatering at least some of the sandstones prior to mining.

The depth of new proposed testing would be to about 700 ft. and piezometers would be installed in specific, isolated horizons. This will require using either a multi-level packer system (such as a Westbay *MPP*™ or Solinst's *Waterloo Multi-Level System*™) or multiple coreholes (HCI's recommendation) for individual piezometers. Due to the increased costs of deeper drilling and piezometer installation, HCI recommends conducting only a single series of tests at one location at this time.

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The three specific goals of the new proposed hydraulic testing are:

1) To determine the horizontal hydraulic conductivity and piezometric levels in the individual sandstones.

2) To assess the potential ability of the deeper sandstones to provide inflow to the mine. This is a function of the hydraulic conductivities of the faults and how they vary with depth.

3) To assess the leakance between the sandstones through the interburden units. We recognize the effects of the faults might totally mask this response under the hydraulic stress we will be able to put on the local ground-water system during the proposed test, but we will still attempt to collect the data required for such an assessment.

5.1.1 General Logistics

HCI visited potential underground sites for the proposed drilling and testing with Mark Bunnell of Ark Land and Dick Backstrom of Idea Drilling on January 24, 2002. The locations considered available (relative to ongoing mining) at that time were 1) in the #2 tailgate of 11-Left (about Crosscut 33) and 2) in the West Mains near the Fault Crossing inflow. Both sites are relatively near the Diagonal Fault and active inflow points. Subsequent to that site visit, HCI and CFC identified a third site in the East Submains near the 14-Left Fault. Any of the three sites would potentially yield valuable information on the sandstones. However, the 11-Left and Fault Crossing locations would most likely provide information about leakance on the Diagonal Fault, whereas only the East Submains location will yield information in future mining areas, specifically in the 14-Left Fault area. Consequently, HCI recommends that the drilling and testing be done at the latter; and it is our present understanding that CFC concurs.

At this selected test location, CFC will need to excavate a suitable drillstation out of the way of mine traffic; and the drillstation needs to be large enough to accommodate at least four closely spaced wells. There will also be considerable moving back and forth between the

coreholes (to be described below), so the corehole layout and the overall size of the drill station must take that into account.

The drilling and testing will be done using either CFC's diamond core rig, already on site, or a similar rig provided by the drilling contractor. The CFC rig is capable of drilling PQ core to shallow depths and NQ core to depths of at least 700 ft. The following description of drilling and testing assumes that multiple coreholes will be used rather than multi-level piezometer systems to isolate specific strata for testing and monitoring. HCI believes that multiple coreholes would ultimately be less expensive and easier to install under the anticipated artesian flowing conditions.

For each corehole/piezometer, a nominal 4-in diameter (PQ) hole will be drilled to a depth of 20 ft, into which nominal 4-in diameter threaded surface casing will be installed and sealed with cement. A wellhead with a stuffing box (Figure 12) will then be attached to the surface casing in order to control water discharges during subsequent drilling and testing. The wellhead (with the stuffing box removed) will remain in place after testing, to provide for long-term monitoring.

Flow and shut-in tests will be conducted and four permanent packer assemblies (to be supplied by the drilling contractor) will be installed and grouted in place to isolate the various sandstones for both testing and long-term monitoring. Although CFC's experience suggests that free flowing NQ coreholes in unfractured sandstones will not produce significant amounts of water (< 100 gpm), it would be advisable to have a water disposal plan for the testing period.

Core samples of the various sandstone units will be selected during drilling and submitted to a suitable laboratory for testing to determine core-scale hydraulic conductivity and effective porosity. It is currently planned to submit 6 to 12 core samples for testing. HCI also

recommends collecting samples of the deeper ground water (up to four samples) for chemical analysis.

5.1.2 Drilling and Testing Program

The proposed details of the drilling and testing plan are based on the assumed stratigraphy, extrapolated from two miles away, as shown in Figure 3 and reproduced on Plate III and in Figure 13. HCI recognizes that the actual stratigraphy encountered by drilling at East Submains (or another location) could be significantly different, and maximum flexibility needs to be maintained during the drilling and testing program.

An initial NQ corehole will be drilled vertically downward through the wellhead and surface casing to a depth of approximately 700 ft (to the sandstone labeled "H" in Figure 13). As each significant (>20 ft thick) shoreface sandstone is penetrated, the core rods will be retracted to a point above the top of the sandstone. The corehole will then be shut-in with the wellhead assembly and valves until the shut-in pressure essentially stabilizes. Then the valve will be opened and the corehole will be allowed to flow for approximately 30 minutes. The discharge will be measured using a 5-gal bucket or 55-gal drum, depending on what is required. The corehole will then be shut-in again for about 30 minutes, and recovery water pressures will be recorded. This procedure will be repeated in each major sandstone until total depth, so drilling of the first corehole will be a relatively slow process. The corerods will then be removed from the initial deep corehole, and the corehole will be shut-in.

The drill rig will then move over, install another surface casing and wellhead assembly in a PQ corehole, and then core (again vertically) down to Sandstone "D". In this corehole, a permanent, grouted-in-place packer assembly as shown in Figure 14 will be installed as a point piezometer. This packer assembly and installation procedure is specially suited for artesian flowing conditions

A third vertical corehole will similarly be drilled and completed with a piezometer to the Panther Sandstone. The fourth and final corehole, an inclined corehole, will be drilled to intercept the 14-Left Fault at a low angle (Figure 13). The drilling will be the same as for the other coreholes, but a piezometer will not be initially installed in this corehole.

After the four coreholes have been drilled and the two piezometers have been installed and their grout seals have set, the drill rig will go back to the initial deep corehole. Depending on the findings from the preliminary flow and shut-in tests during the drilling of the corehole, the rods will be tripped in to above one or more of the sandstones. A relatively long-term (perhaps as long as 24 hrs) flow test will be conducted in which water is discharged from the deep corehole and water levels are measured in the two newly installed piezometers and the angle corehole into the fault. Depending on the hydrostratigraphic conditions encountered, there could be several such tests with the corerods set at different depths. Upon completion of this phase of the testing, a piezometer similar to the others (Figure 14) will be installed in the deepest sandstone in the deep corehole.

The final test will be a potentially large discharge and long-term test (again, approximately 24 hrs) of the corehole into the fault in which the discharge from the corehole and the water levels in the other three piezometers (including the newest one in the deep corehole) will be monitored. The fault corehole will then be shut-in, and recovery water levels will be measured for another approximately 24 hrs.

Upon completion of this test, a piezometer similar to the others will be installed in the fault corehole. All four of the piezometers will then be available for long-term monitoring of water levels in response to mining and mine inflow. It should be noted that HCI will furnish on a rental basis and utilize a series of transducers connected to a single datalogger for the testing program. Whether CFC wants to purchase and utilize this system for long-term monitoring or whether water levels will be monitored some other way (a single

transducer/datalogger in each piezometer, simply installing gages on the wellheads, etc.) can be decided when the testing is complete.

5.2 CONTINUED MONITORING

Transducers for recording water levels are currently installed in surface wells 79-35-1 (in Burnout Canyon), 98-2-1 (south of James Canyon), 99-4-1 and 20-4-1 (both in Boulger Canyon), and 20-28-1 (in Swens Canyon) and in the underground horizontal drillhole in 9-Left (Plate I). Gages have been installed, and are intermittently read, in shut-in boreholes in the #1 Tailgate of 11-Left.

It is recommended that water levels in other surface monitoring wells be measured monthly in order to quantify the effects of various stresses on the ground water system beneath the Flat Canyon tract.

5.3 DRILLING FROM SURFACE

The initial Work Plan (HCI, 2001b) recognized that additional hydraulic testing of the faults in the Flat Canyon tract is necessary and suggested that underground tests would be needed to evaluate the permeability and degree of connection between the various faults. Such testing can only be conducted cost effectively when mining progresses to within a few hundred feet of the faults.

However, the compilation of water levels in the surface monitoring wells (Figure 6) suggest a relatively good hydraulic connection among the faults, and the 14-Left Fault especially appears to be a significant conduit (Figure 5). Consequently, HCI recommended (HCI, 2001c) that hydraulic testing be conducted in the Flat Canyon faults from the surface. CFC is currently permitting the planned exploration borehole 02-33-1 (Plate I and Figure 6) as

a nominal 16-inch diameter borehole to 2,300 ft depth, and investigating the possibility of test pumping the well for several days this summer. In the longer term, a permit for a larger diameter well may be required. It should be noted that the central location of 02-33-1 relative to the Flat Canyon mine plan and its position astride the 14-Left Fault make it an ideal location for potential future mine dewatering.

5.4 NUMERICAL GROUND-WATER FLOW MODELING

The conceptual hydrogeologic model described in Section 3.0 is currently being incorporated into a fully three-dimensional numerical ground-water flow model of the Skyline Mine area. The numerical model will be used to predict the dewatering requirements for mining of the Flat Canyon tract in terms of how much water will have to be removed, the timing (i.e., how far in advance of mining will the dewatering have to be implemented), and the approximate locations of dewatering centers (which could be comprised of one or more wells).

The overall framework of the numerical model was discussed at length with Mark Bunnell and Alan Mayo at the meeting on December 7, 2001. As shown on Plate IV, the boundaries of the model to the east and west are defined by the large regional faults that juxtapose the target sandstones against thick sequences of low-permeability sediments. To the north and south, the model limits are a function of the continuity of the sandstones and will be defined by variable flux boundaries, a special feature within the *MINEDW* code utilized by HCI. The hydrostratigraphy that HCI is simulating in the model is shown in cross-section on Plate V.

The model currently utilizes 12 layers to simulate the overburden unit, LOB coal, four interbedded units, and three sandstone units (Storrs, Panther, Starpoint). A single layer with an approximate thickness of 500 ft is used to represent the deeper sequence of interbedded

sandstones. The model explicitly simulates the 16-Left, 14-Left, Diagonal, Conneville and O'Connor Faults, with the Pleasant Valley and Gosseberry Faults acting as model boundaries.

Surface-water features (such as Electric Lake and numerous perennial creeks and streams) are not simulated in the model. Primarily on the basis of the water chemistry data, the surface-water system does not appear to be hydraulically connected to the deeper ground-water system contributing to the mine inflows (Section 3.0). Consequently, the model treats the ground-water system in the Skyline Mine area as being separated into a shallow and a deep system in which the deep system is, for all practical purposes, independent of the shallow system, as described by Mayo and Morris (2000). This conceptualization implies that the majority of the ground water will be derived from storage within the confined sandstones and interburden. This concept is incorporated into the model by assigning a low vertical hydraulic conductivity to the overburden unit such that it essentially de-couples the shallow and deep ground-water systems.

HCI is currently conducting a steady-state calibration of the model. The purpose of this calibration is to obtain pre-mining water levels that will later be used as the starting point for transient simulations. After the steady-state calibration is complete, HCI will start conducting transient simulations and a transient calibration of the model, prior to starting predictive simulations.

As before, this ground-water flow model (or any other model) will not and cannot predict the location or the magnitude of inflows to the mine. These will always be hydrogeologic uncertainties. However, the model will be a very useful planning tool for designing a dewatering and water management program including:

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- Determining the optimal general locations for dewatering wells,
- Predicting the amounts of water that will most likely have to be pumped,
- Assessing the time required to lower water levels at the working entries and panels to achieve acceptable, manageable inflow rates, and
- Predicting the potential hydrologic impacts on water resources (e.g., the magnitude and extent of drawdown propagated by the dewatering), if CFC desires such information.

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EXPLANATION

SANDSTONE THICKNESS

- 0 – 30 ft
- 30 – 45 ft
- 45 – 60 ft
- > 60 ft.
- MAJOR INFLOW

STORRS SANDSTONE THICKNESS BASED ON FACIES INTERPRETATION BY CFC

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Isopach of Storrs Sandstone

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DRAWN:	SAC	PLOT FILE:	STORRS-02
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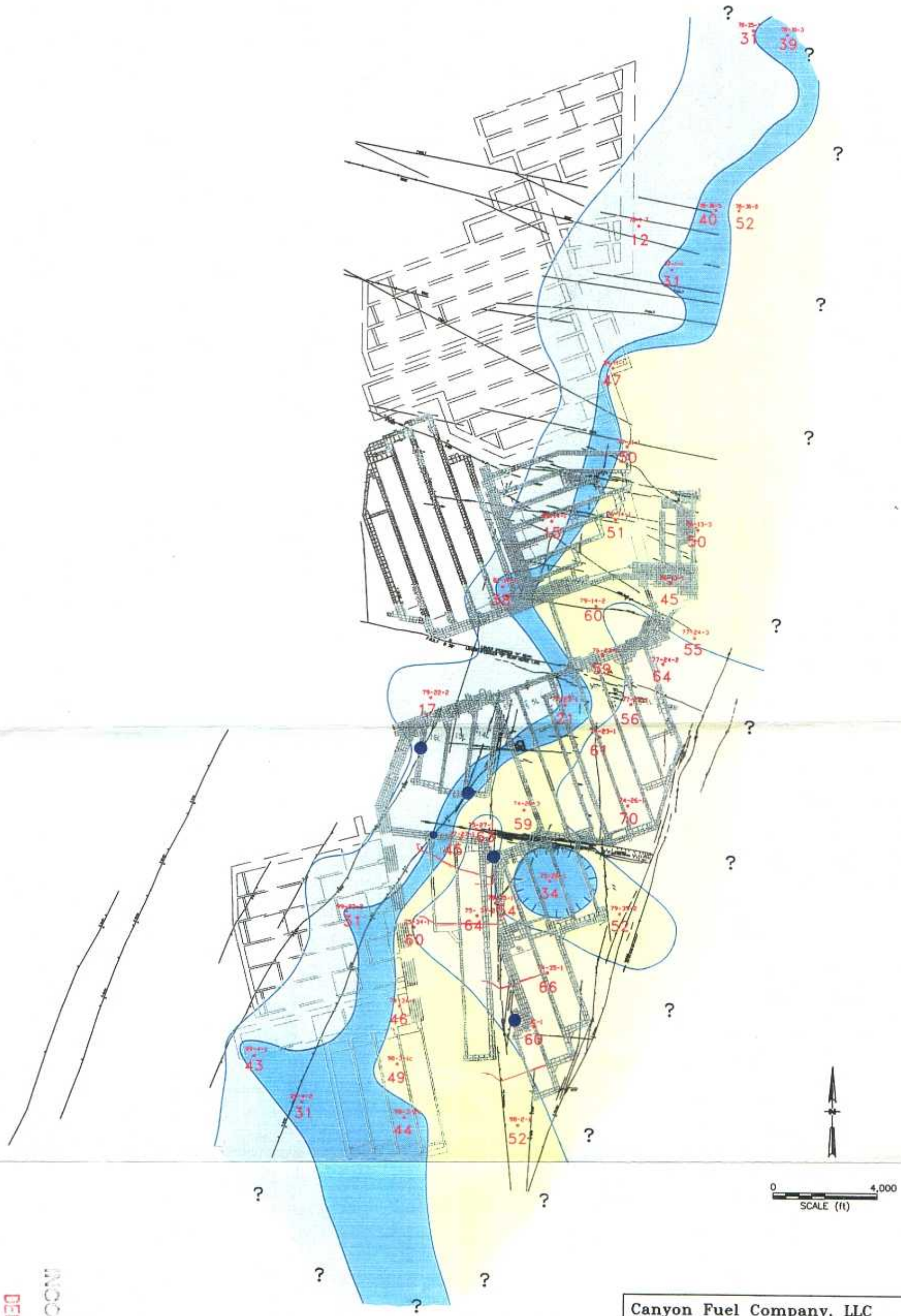
FIGURE 1



STORRS SANDSTONE THICKNESS BASED ON FACIES INTERPRETATION BY CFC

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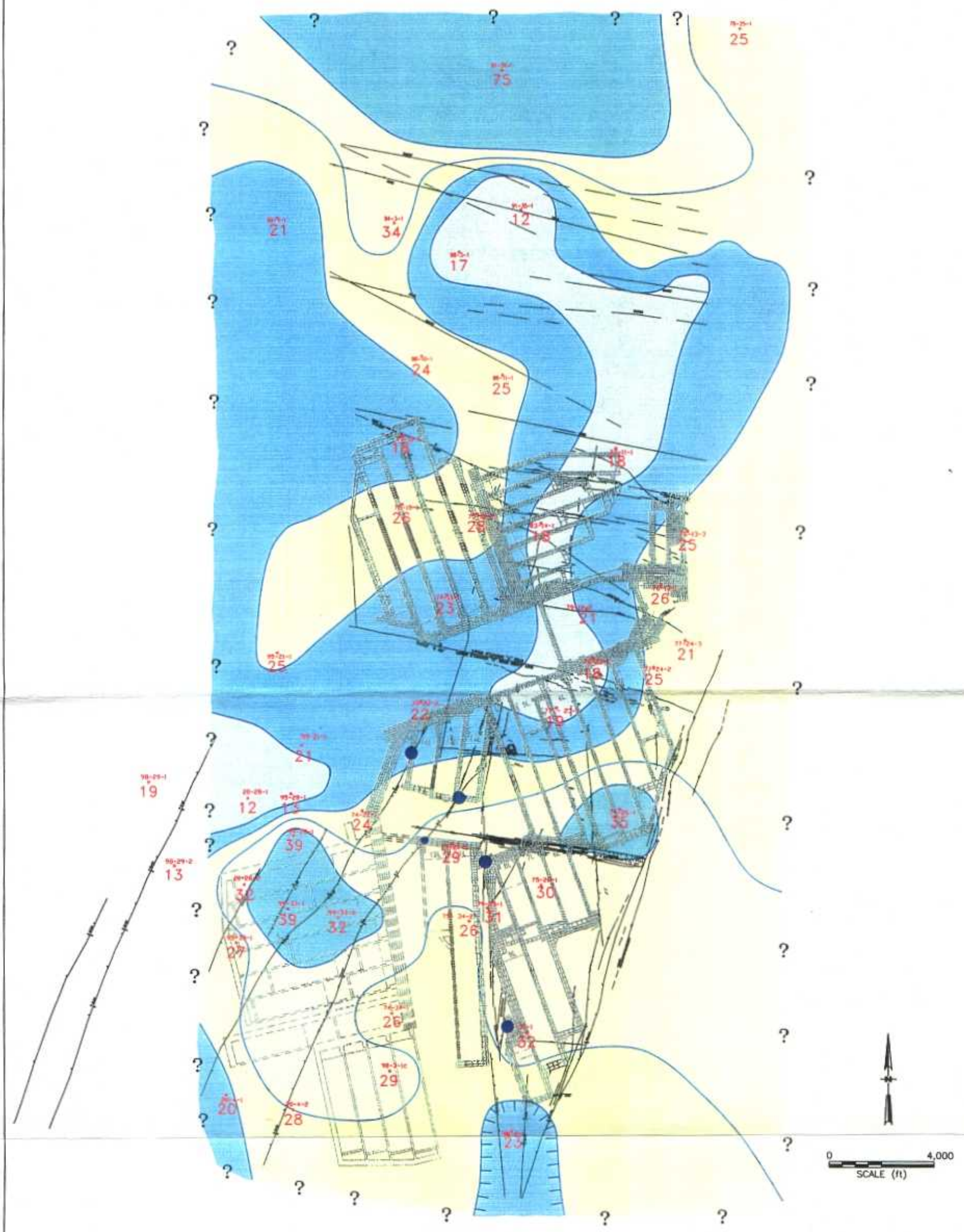
FIGURE 1



EXPLANATION

SANDSTONE THICKNESS

< 20 ft

20 – 24 ft

24 – 28 ft

28 – 32 ft

> 32 ft

MAJOR INFLOW

PANTHER SANDSTONE THICKNESS BASED ON FACIES INTERPRETATION BY CFC

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Isopach of Panther Sandstone

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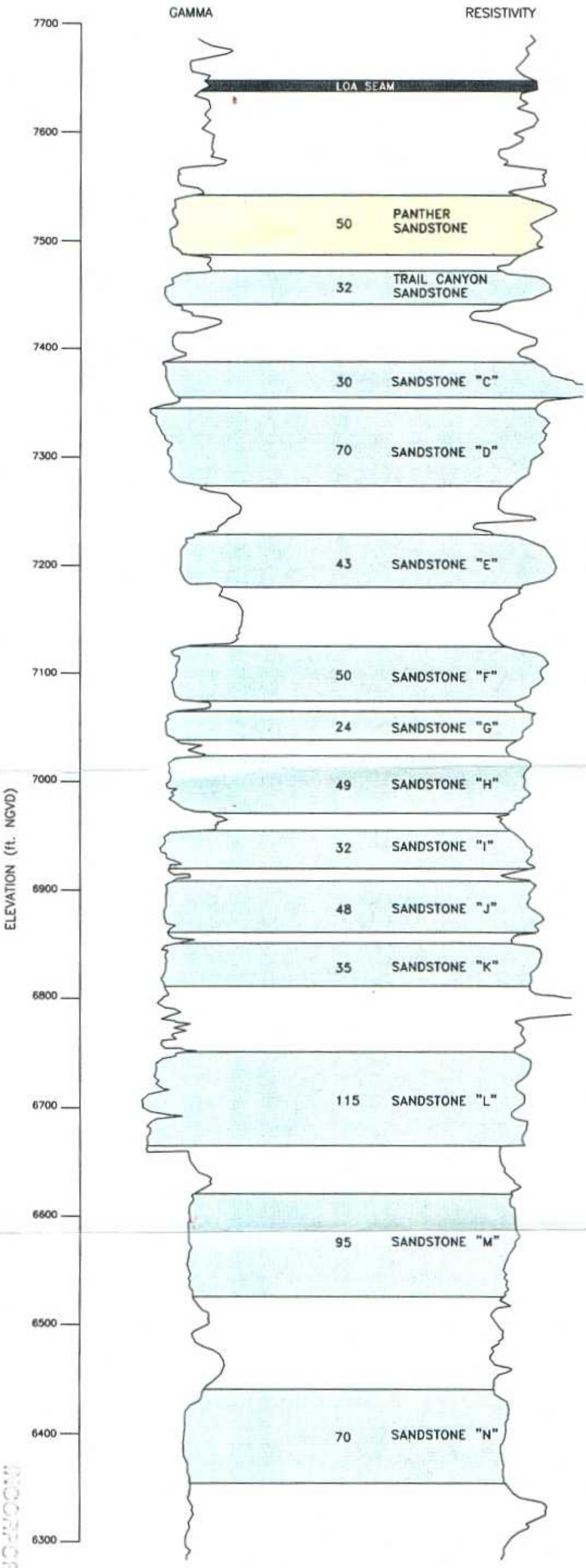
FIGURE 2



95 INTERPRETED SHOREFACE SANDSTONE (THICKNESS IN ft.)

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Geophysical and Interpreted Geologic Log of Carter Oil Well No. 1 in Upper Huntington Canyon

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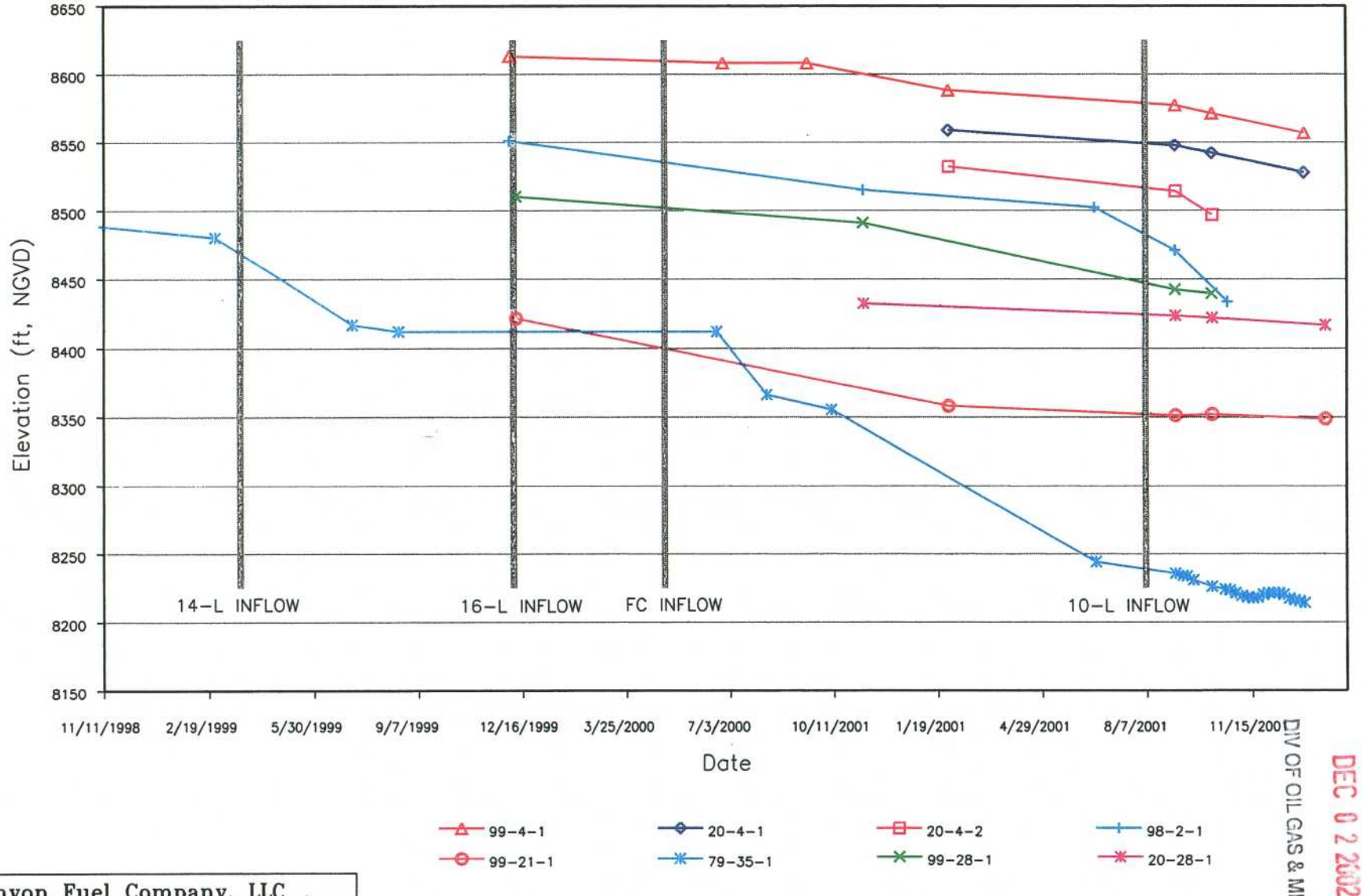
FIGURE 3



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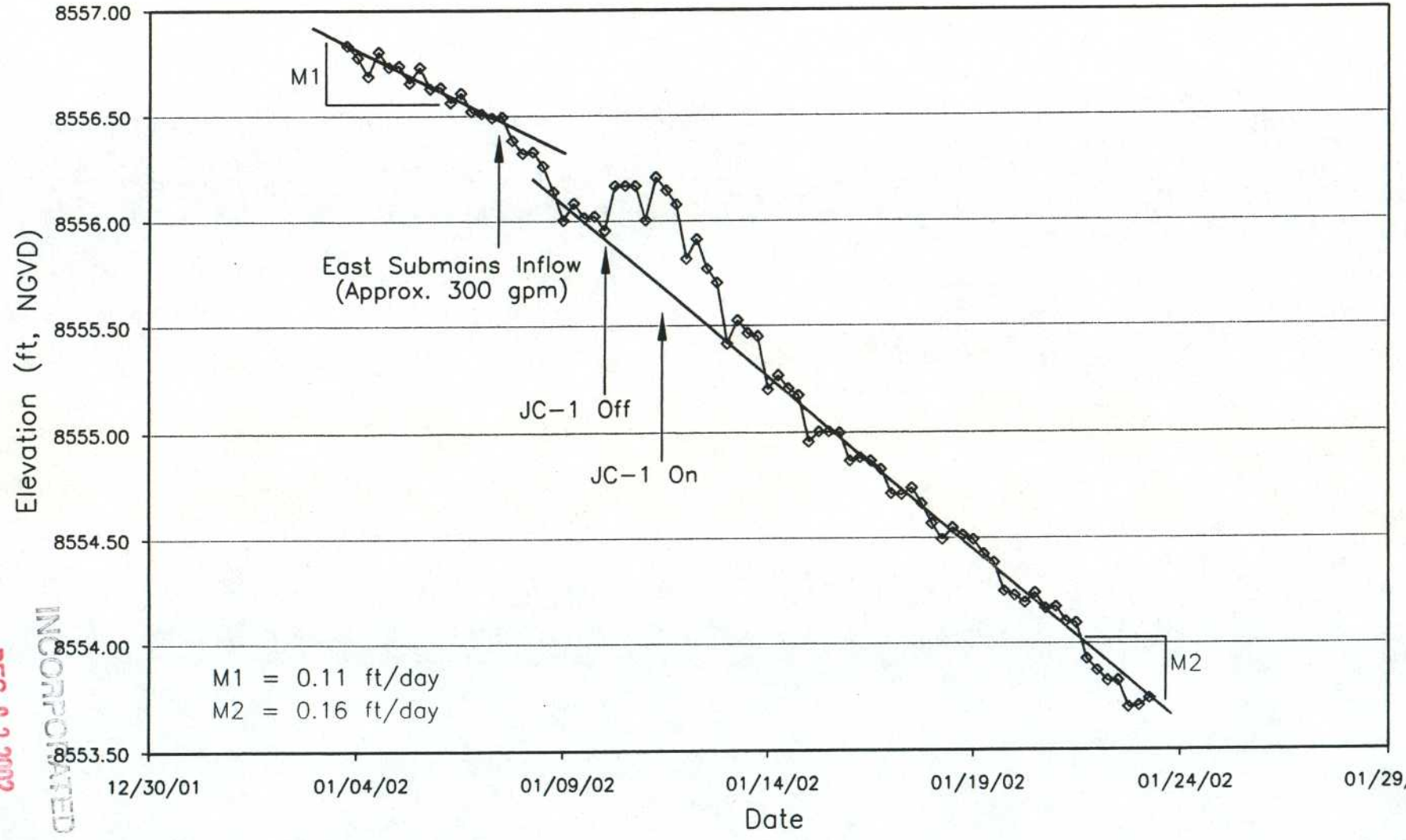
Water Levels in Flat Canyon Monitoring Wells

FIGURE 4



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BY:	RLH	DWG FILE:	WL-99-4-1
DRAWN:	SAC	PLOT FILE:	WL-99-4-1
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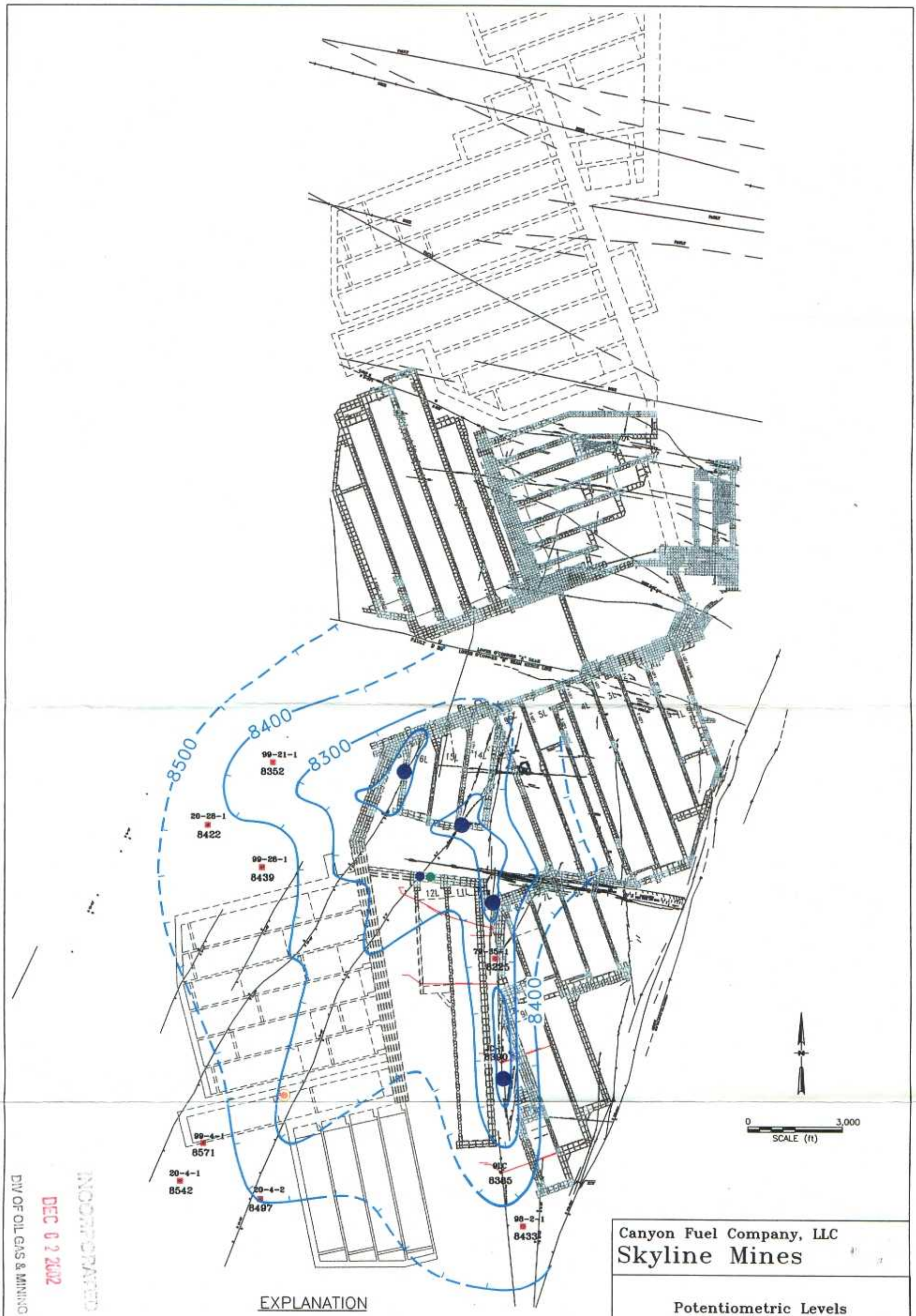
Water Levels in Monitoring Well 99-4-1

FIGURE 5



EXPLANATION

WATER LEVEL CONTOUR (ft, NGVD)
(DASHED WHERE INFERRED)

MAJOR INFLOW

MONITORING WELL

PROPOSED SITE OF UNDERGROUND DRILLING AND TESTING

PROPOSED SITE OF SURFACE DRILLING AND TESTING

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Potentiometric Levels as of October 2001

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DRAWN:	SAC	PLOT FILE:	POT-LEVLS
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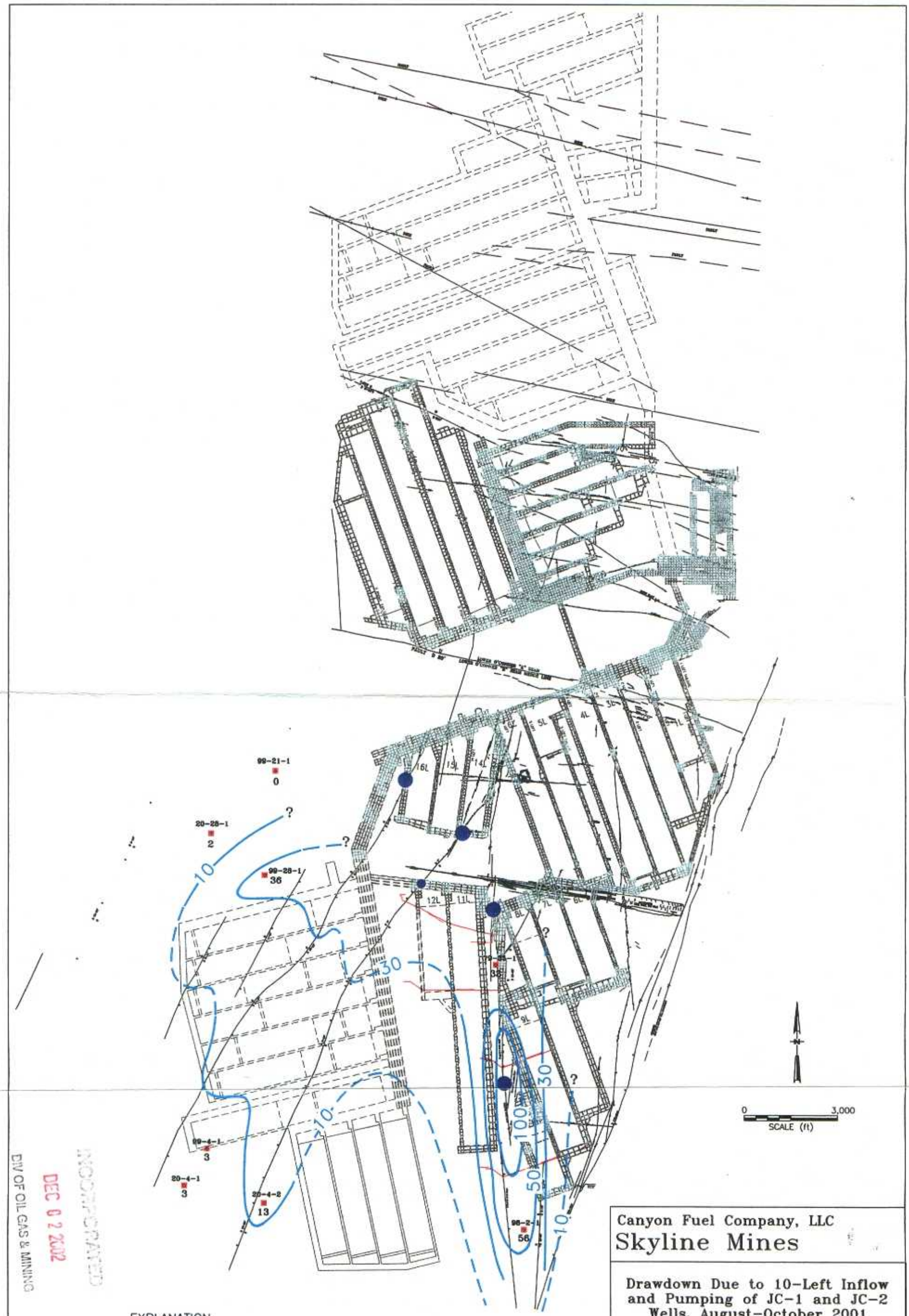
FIGURE 6



EXPLANATION

DRAWDOWN CONTOUR (ft)
(DASHED WHERE INFERRED)

MAJOR INFLOW

NOTE:
DRAWDOWN DUE TO 10-LEFT INFLOW CALCULATED BY SUBTRACTING DRAWDOWN FROM OTHER SOURCES (PROJECTED FROM HYDROGRAPHS) FROM TOTAL DRAWDOWN, JANUARY TO OCTOBER 2001.

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Drawdown Due to 10-Left Inflow and Pumping of JC-1 and JC-2 Wells, August-October 2001

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BY:	RLH	DWG FILE:	DD-2001
DRAWN:	SAC	PLOT FILE:	DD-2001
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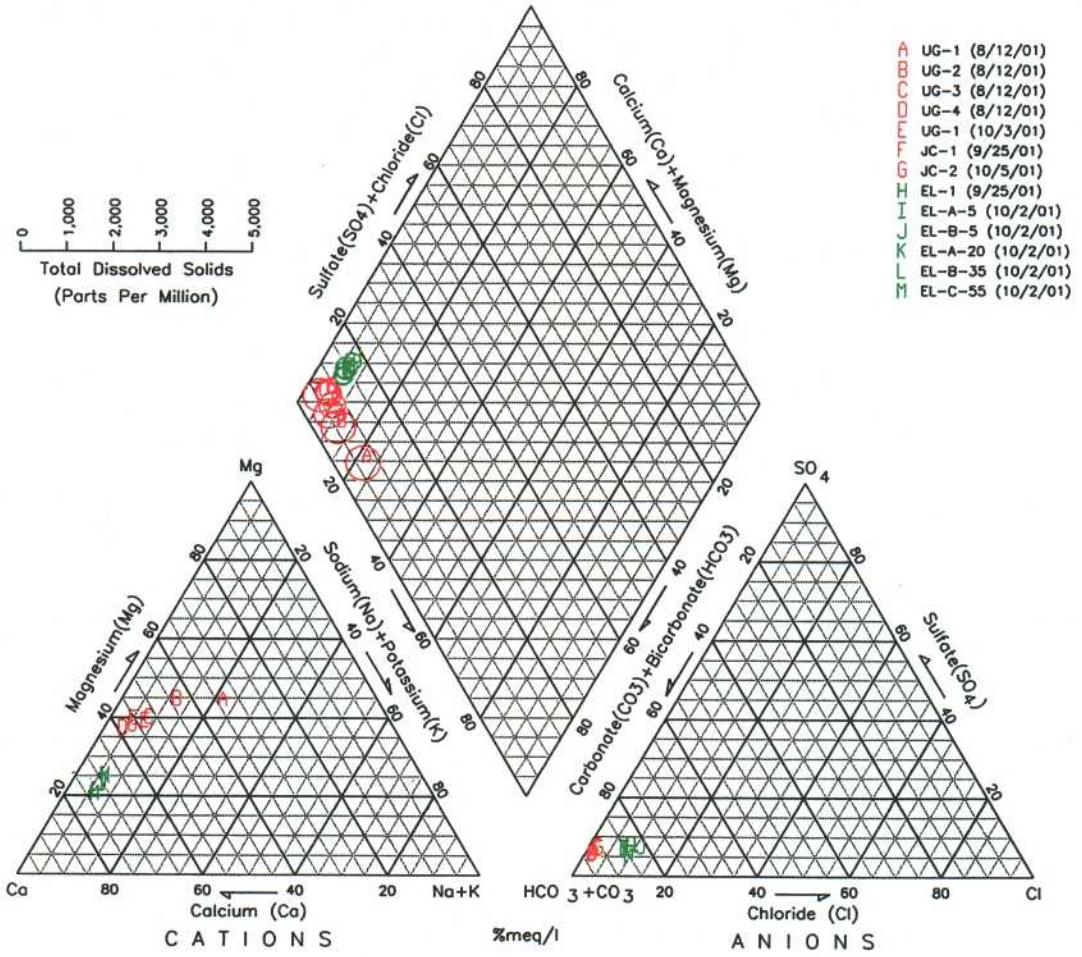
FIGURE 7



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DRAWN:	SAC	PLOT FILE:	PIPER02
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Trilinear Plot of Water Chemistry: Mine Inflows, Dewatering Wells, and Electric Lake

FIGURE 8

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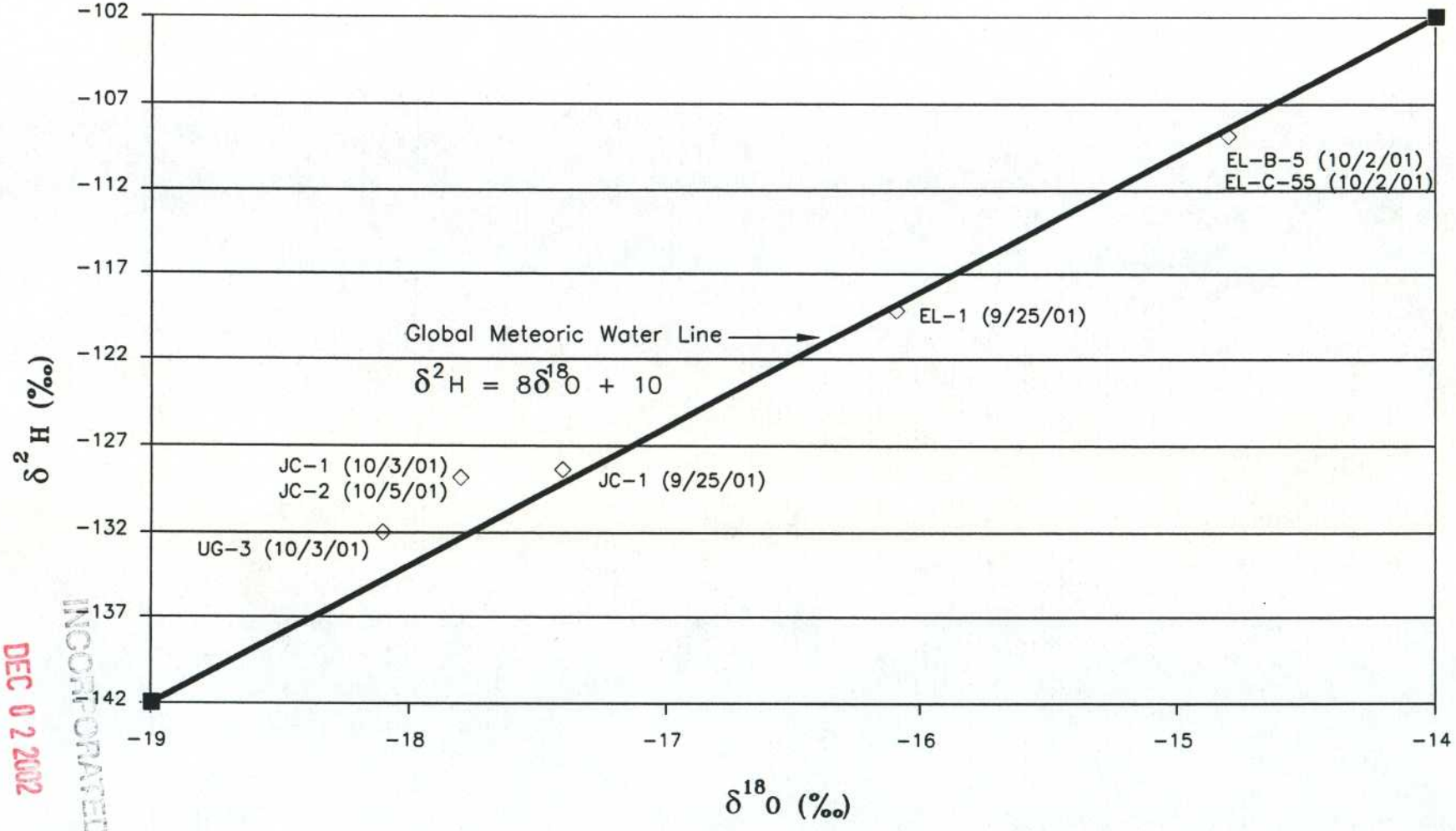

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JOB NO.	HCI-1787	DATE:	12/14/01
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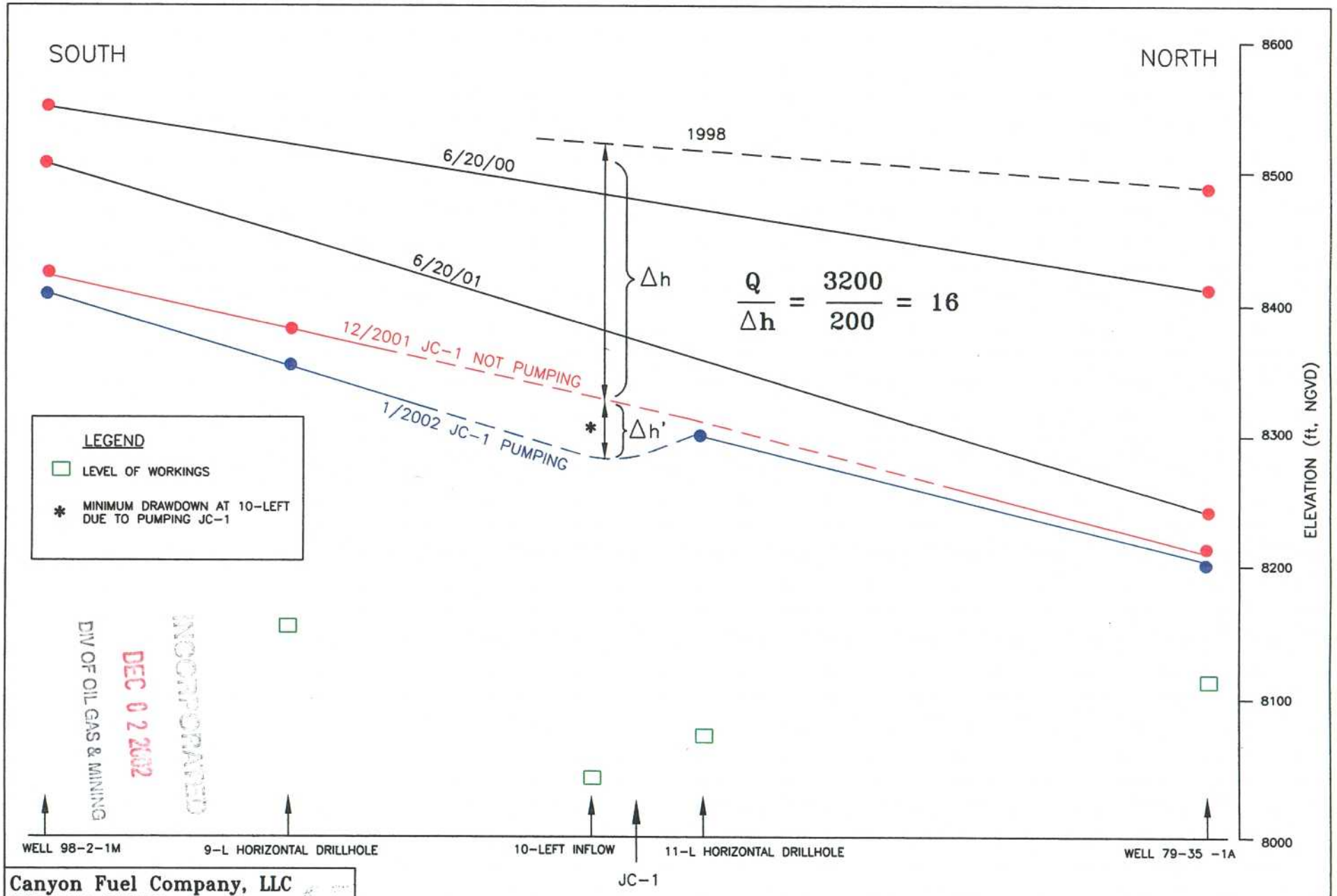
DRAWN:	SAC	PLOT FILE:	MINE-INFLOWS02
CHECKED:		PLOT DATE:	2/21/02

δ^2H and δ^{18}O for Mine Inflows, Dewatering Wells, and Electric Lake

FIGURE 9



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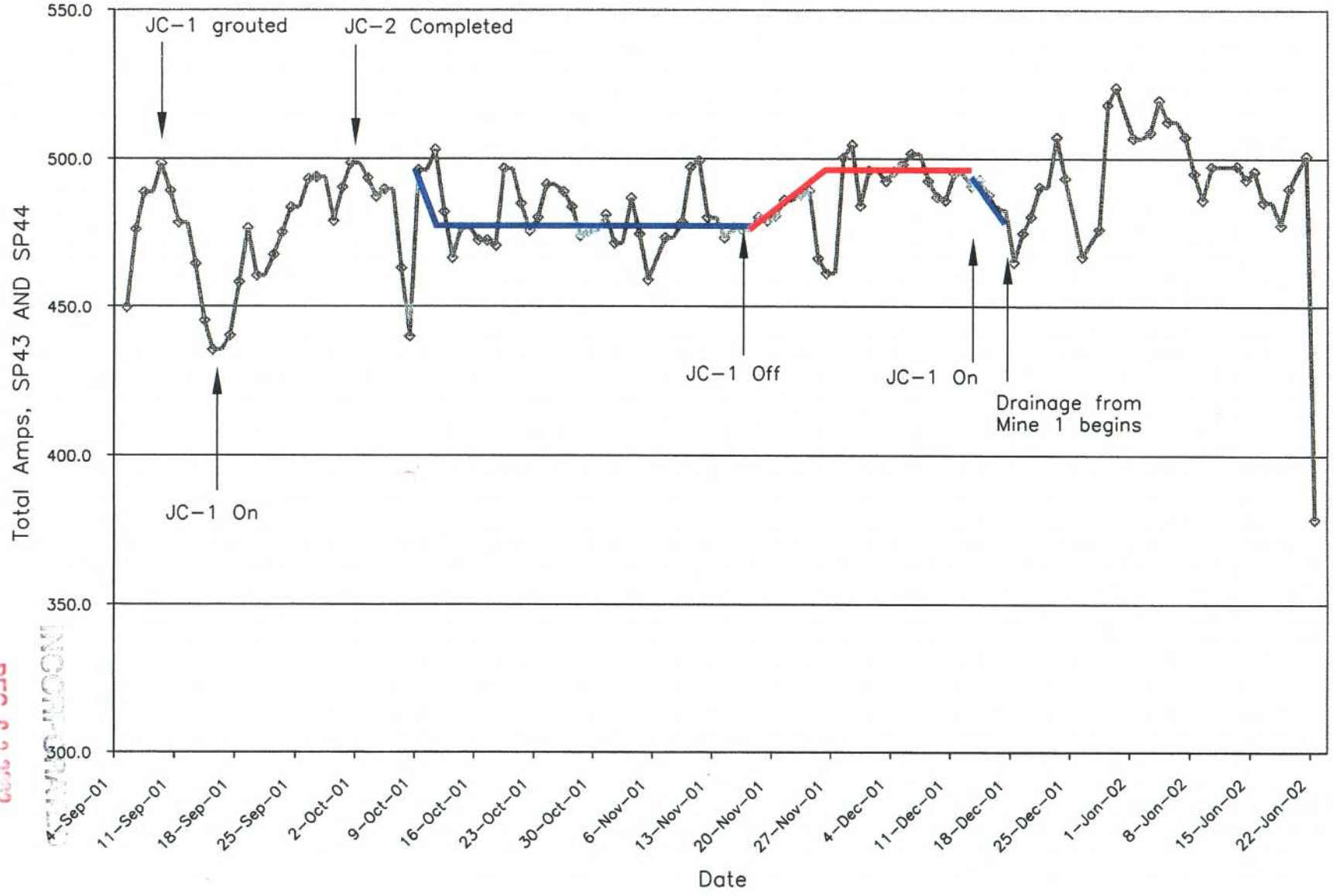
DRAWN:	SAC	PLOT FILE:	SCHEMATIC
CHECKED:		PLOT DATE:	2/22/02

Water Levels Measured in and near the Diagonal Fault, 1998-2002

FIGURE 10



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JOB NO.	HCI-1787	DATE:	2/15/02
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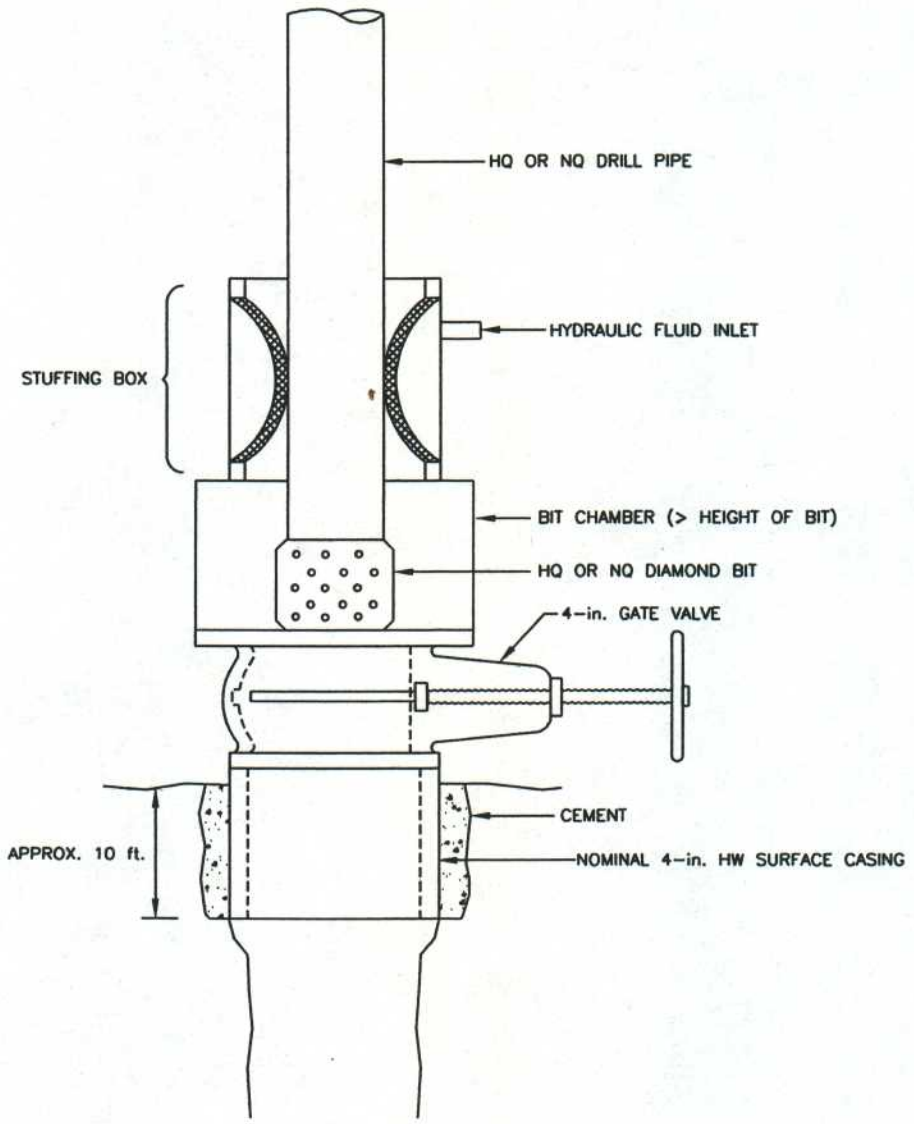
DRAWN:	SAC	PLOT FILE:	AMPS
CHECKED:		PLOT DATE:	2/21/02

Average Total Power Usage by Sump Pumps at 10-Left

FIGURE 11



Core Drilling through Wellhead and Stuffing Box

Canyon Fuel Company, LLC	
Skyline Mines	
JOB NO. HCI-1787	DATE: 12/11/01
BY: RLH	DWG FILE: UG-TESTWELL02
DRAWN: SAC	PLOT FILE: UG-TESTWELL02
CHECKED:	PLOT DATE: 2/21/02

NOT TO SCALE

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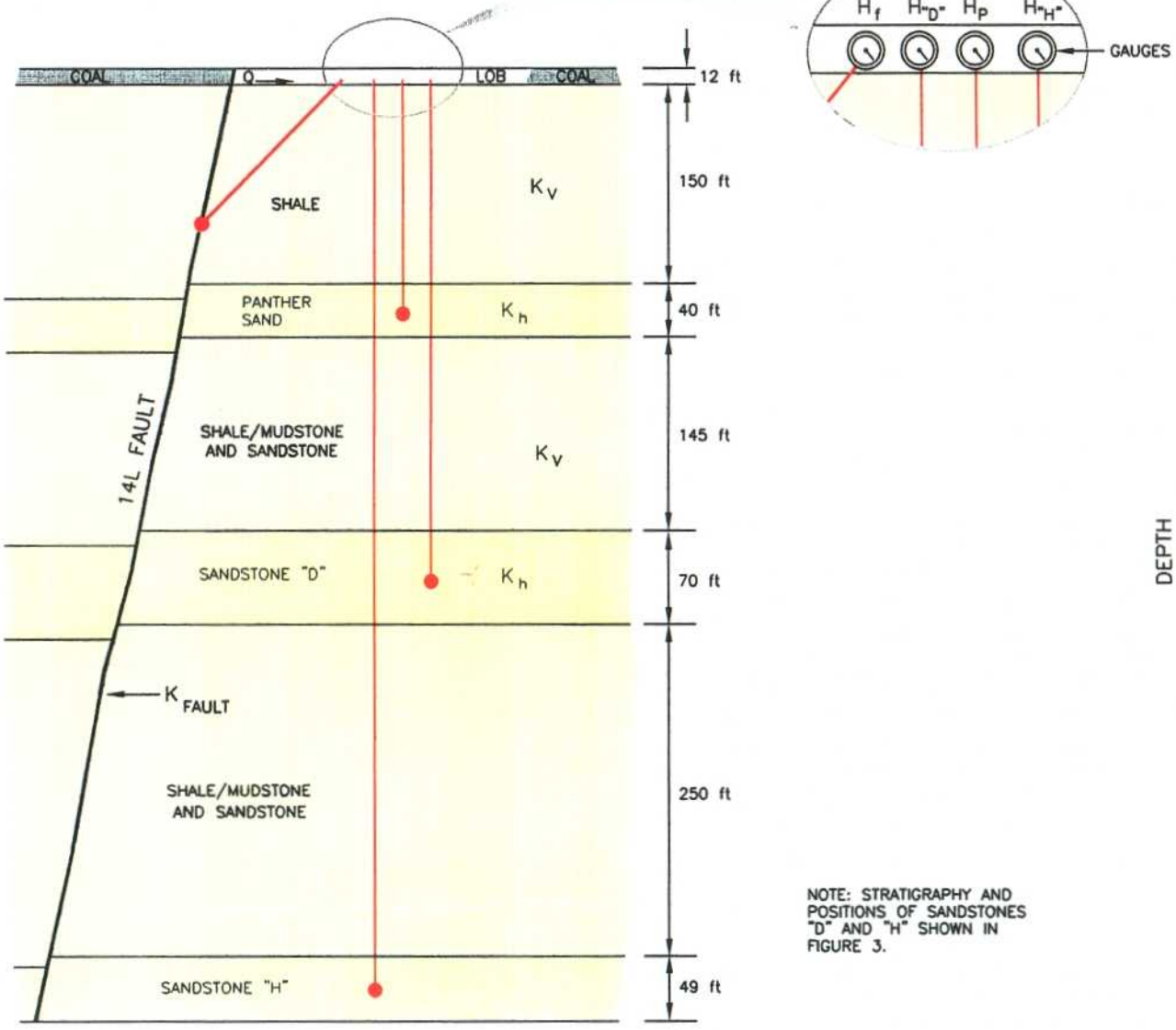
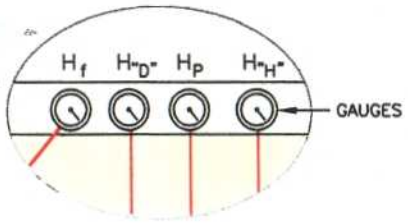
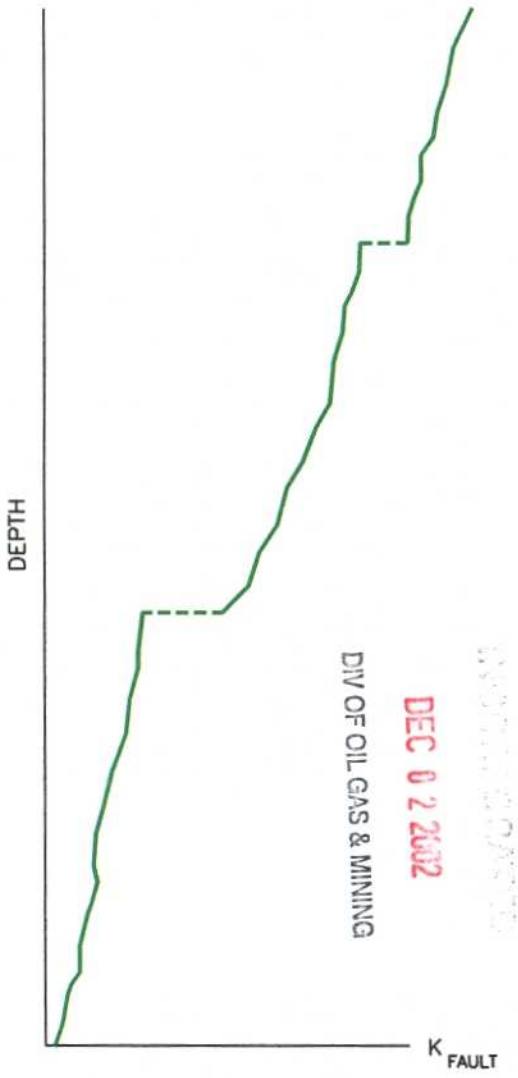
Wellhead for Underground Test Wells

FIGURE 12





NOTE: STRATIGRAPHY AND POSITIONS OF SANDSTONES "D" AND "H" SHOWN IN FIGURE 3.



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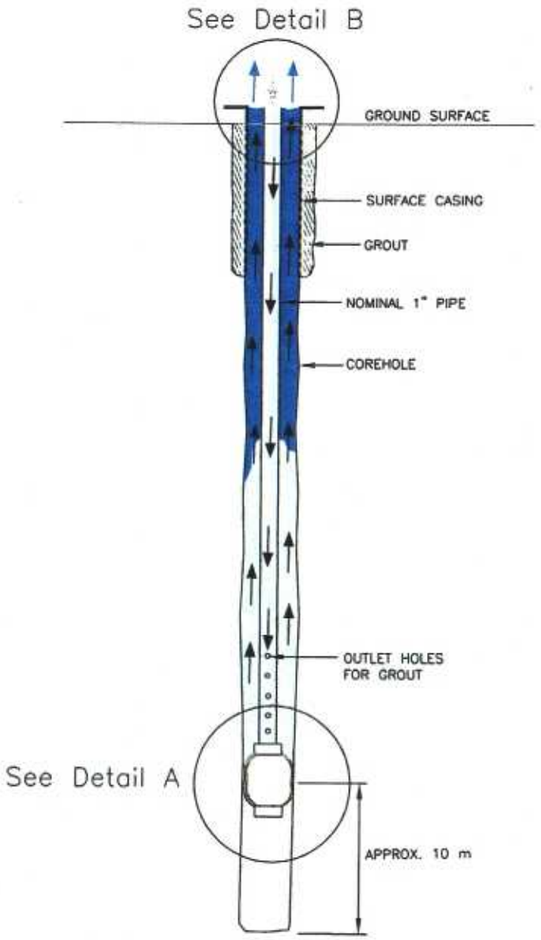
Canyon Fuel Company, LLC
SKYLINE MINES

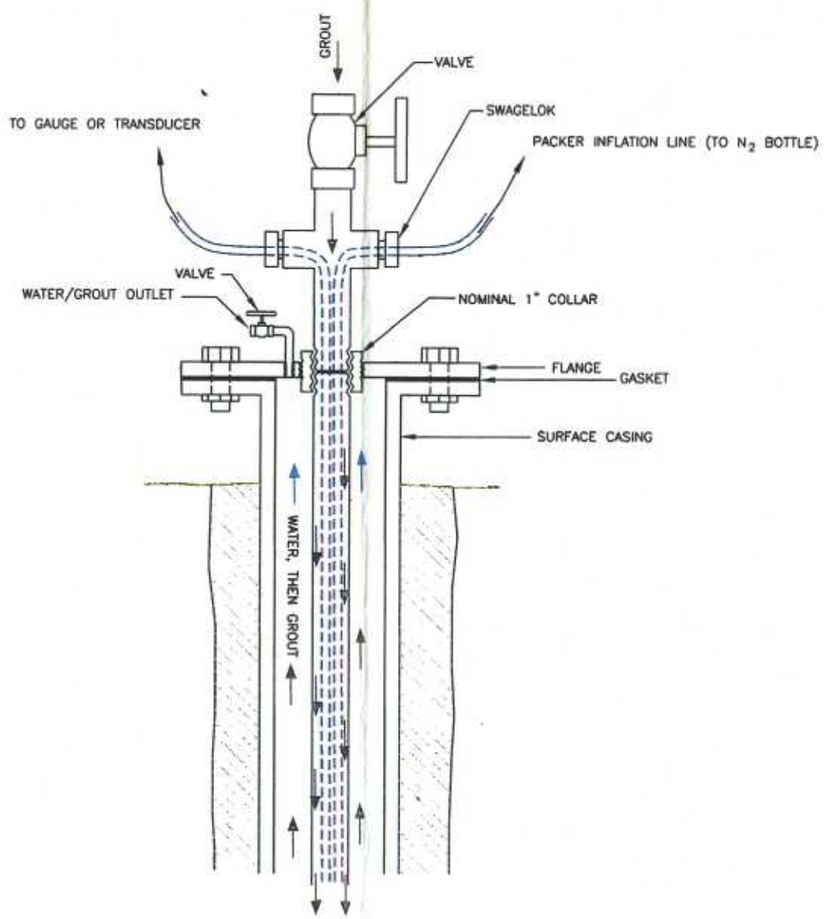
HCI HYDROLOGIC CONSULTANTS, INC.
HC TASCA company

JOB NO.	HCI-1787	DATE:	2/13/02
BY:	LCA\RLH	DWG FILE:	CROS-SEC
DRAWN:	SAC	PLOT FILE:	CROS-SEC
CHECKED:		PLOT DATE:	2/22/02

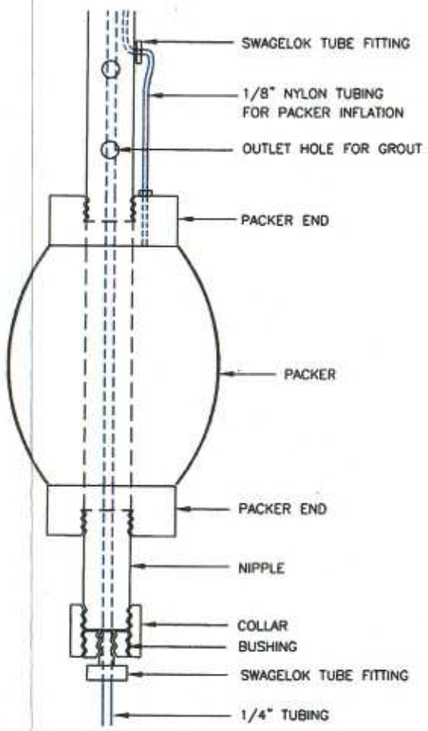
Planned Underground Drilling at East Submains

FIGURE 13





Detail B



Detail A

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Canyon Fuel Company, LLC
Skyline Mines

Point Piezometer Construction in Artesian Flowing Corehole

JOB NO.	HCI-1787	DATE:	2/13/02
BY:	LCA/RLH	DWG FILE:	PT-PIEZO
DRAWN:	SAC	PLOT FILE:	PT-PIEZO
CHECKED:		PLOT DATE:	2/21/02

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FIGURE 14

TABLE 1
Water Chemistry Data

Sample[2]		Mine Inflows[2]						Dewatering Wells in James Canyon[2]								Electric Lake[2]							
		UG-1	UG-2	UG-3		UG-4		JC-1						JC-2	Average James Canyon	Shallow					Deep		
Parameter[1]		Connel-ville Fault	10 Left Entry #3 Borehole	Fault Crossing 3 West Submain		9 Left Headgate Horizontal Borehole	Average Mine Inflows									EL-1	EL-A-5	EL-B-5	EL-A-20	Average Shallow Lake	EL-B-35	EL-C-55	Average Deep Lake
Date		8/12/01	8/12/01	8/12/01	10/3/01	8/12/01		9/19/01	9/21/01	9/23/01	9/25/01	9/28/01	10/3/01	10/5/01		9/25/01	10/2/01	10/2/01	10/2/01		10/2/01	10/2/01	
Cations	Ca	34.1[3]	42.6[3]	44.5[3]	46.1	56.7[3]	44.8	NA	NA	NA	44.6	NA	NA	48.3	46.5	42.0	39.4	40.0	41.4	40.7	44.5	43.9	44.2
	Mg	25.1[3]	24.6[3]	19.3[3]	19.1	20.1[3]	21.6	17.7	18.5	18.6	18.0	16.8	17.1	18.3	17.9	8.6	7.2	7.2	8.3	7.8	7.2	6.7	7.0
	K	8.2[3]	8.9[3]	4.1[3]	3.4	2.1[3]	5.3	NA	NA	NA	2.6	NA	NA	3.0	2.8	1.0	0.87 J	0.88 J	1.6	1.3	0.82 J	0.78 J	0.8
	Na	19.8[3]	7.9[3]	5.6[3]	5.8	3.2[3]	8.5	NA	NA	NA	3.2	NA	NA	3.8	3.5	3.7	3.7	3.8	3.6	3.7	3.9	3.9	3.9
	Ba	0.2	0.4	0.3	NA	0.2	0.3	0.2	0.2	0.3	0.2	0.2	0.2	NA	0.2	NA	NA	NA	NA	NA	NA	NA	NA
Anions	Cl	2.7	2.8	2.4	2.5	2.9	2.7	2.6	2.3	2.7	2.2	2.6	4.0	2.8	2.7	10.1	7.3	10.1	7.3	8.7	7.9	8.2	8.1
	SO_4	11.3	8.9	7.2	8.3	8.8	8.9	9.0	9.2	8.8	8.8	8.7	8.6	8.6	8.8	8.9	6.6	7.0	6.8	7.3	6.2	< 4.0	5.1
	HCO_3^- as $CaCO_3$	225[4]	222[4]	196[4]	196.0	220[4]	249.8	186.0	184.0	182.0	182.0	188.0	188.0	186.0	185.1	133.6	106.0	108.0	116.0	115.9	128.0	126.0	127.0
	CO_3^{2-}	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	<0.1	16.0	10.0	10.0	9.0	< 2	< 2	2.0
	F	0.4	0.3	0.3	0.4	0.2	0.3	0.3	0.2	0.3	0.2	0.3	0.3	0.3	0.3	< 0.1	0.3	< 0.2	0.3	0.2	0.4	< 0.1	0.3
Physical	T (°C)	NA	NA	NA	NA	NA	NA	NA	NA	NA	14.7	NA	NA	NA	14.7	18.0	NA	12.6	NA	15.3	9.6	NA	9.6
	pH (units)	NA	NA	NA	NA	NA	NA	7.6	8.0	7.9	7.9	7.6	7.7	NA	7.8	8.6	8.8	8.7	8.7	8.7	8.1	8.0	8.0
	DO	NA	NA	NA	0.2	NA	0.2	NA	NA	NA	0.6	NA	NA	NA	0.6	7.3	7.4	7.0	6.9-8.6	7.4	0.25-0.47	0.4	0.4
	EC (µS/cm)	NA	NA	NA	NA	NA	NA	NA	NA	NA	354.0	NA	NA	NA	354.0	282.0	NA	NA	NA	282.0	NA	NA	NA
Radiologic	δ^2H (‰)	NA	NA	NA	-132.0	NA	-132.0	NA	NA	NA	-128.4	NA	-129.0	-129.0	-128.8	-119.2	NA	-109.0	NA	-114.1	NA	-109.0	-109.0
	$\delta^{18}O$ (‰)	NA	NA	NA	-18.1	NA	-18.1	NA	NA	NA	-17.4	NA	-17.8	-17.8	-17.7	-16.1	NA	-14.8	NA	-15.5	NA	-14.8	-14.8
	^3H (T.U.)	NA	NA	NA	0.1	NA	0.1	NA	NA	NA	0.2	NA	0.2	-0.2	0.0	13.0	NA	NA	NA	13.0	NA	11.7 & 12.3	12.0
	$\delta^{13}C$ (‰)	NA	NA	NA	-10.0	NA	-10.0	NA	NA	NA	-11.8	NA	NA	-10.7	-11.3	-8.3	NA	NA	NA	-8.3	NA	-9.2	-9.2
	^{14}C (pmC)	NA	NA	NA	15.8	NA	15.8	NA	NA	NA	30.4	NA	NA	24.3	27.4	72.4	NA	NA	NA	72.4	NA	82.2	82.2

Note: 1) All values in mg/L unless otherwise noted
2) Location shown on Plate I
3) Filtered Samples
4) Calculated from charge imbalance
J = Analyte detected below the PQL (Practical Quantization Limit)
NA = not currently available

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TABLE 2

Estimates of Ground-Water Inflow at 10-Left

Date	Pumping Conditions	Method of Measurement	Inflow (gpm)			
			Total	9-Left gob	8-Left B	10-Left
8/16/01	JC-1 off	Stage-Volume	4,300	0	0	4,300
10/1/01	JC-1 recently on	Power Usage	3,400	0	0	3,400
10/8/01	JC-1 pumping	Power Usage	3,000	0	0	3,000
10/9/01	JC-1 pumping	Stage Volume	3,050	0	0	3,050
10/16/01	JC-1 off	Doppler Meters	3,700	0	0	3,700
10/16/01	JC-1 off	Power Usage	3,200	0	0	3,200
11/16/01	JC-1 pumping	Power Usage	3,200	200	0	3,000
12/13/01	JC-1 off	Power Usage	3,400	200	0	3,200
12/19/01	JC-1 recently on	Power Usage	3,250	200	0	3,050
12/29/01	Mine 1 inflow through 8 Left B; JC-1 pumping	Power Usage	3,750	200	500?	3,050
1/19/02	Waning inflow from Mine 1; JC-1 pumping	Power Usage	3,350	200	150?	3,000

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PHC ADDENDUM

APPENDIX D
EARTHFAX ENGINEERING, INC REPORTS
"ECCLES AND MUD CREEK CHANNEL STABILITY STUDY"
AND
"ADDENDUMS TO SKYLINE MINE DISCHARGE EVALUATION"

February 27, 2002

EarthFax

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Engineers/Scientists
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Midvale, Utah 84047
Telephone 801-561-1555
Fax 801-561-1861

Mr. Chris Hansen
Canyon Fuel Company
Skyline Mine
HC 35, Box 380
Helper, Utah 84526

Subject: Hydrologic and Channel-Stability Evaluation of Eccles and Mud Creeks

Dear Chris:

Pursuant to your request, EarthFax Engineering, Inc. has completed a hydrologic and channel-stability evaluation of Eccles Creek and Mud Creek downstream from the Skyline Mine. The purpose of this evaluation was four fold:

1. Assess the structural and erosional stability of the channel beds and banks in the subject streams due to increased mine-water discharges from the Skyline Mine.
2. Assess the effects of mine-water discharges on peak annual flows of Eccles Creek and Mud Creek.
3. Determine the impacts of increased mine-water discharges on man-made structures in Eccles Creek and Mud Creek.
4. Evaluate alternative locations for mine-water discharge points into the subject streams and the necessary steps to protect the streams at these locations.

Concurrently with this hydrologic and channel-stability evaluation, an investigation was conducted of the effects of increased discharges on the riparian communities of Eccles Creek and Mud Creek. Results of this riparian evaluation are presented in Appendix A.

Mine-Water Discharge Estimates

Prior to January 2000, the combined mine-water discharge from the Skyline Mine to Eccles Creek was generally less than 1000 gallons per minute ("gpm"). Between January 2000 and August 2001, the discharge from the mine was approximately 4100 gpm. These rates varied slightly based on the amount of water encountered underground and the water handling operations within the mine.

In early August 2001, the advancing mine encountered a fractured channel sandstone, resulting in a significant inflow of water to the mine. Due to efforts by the mine to minimize impacts to the environment and to meet effluent limitations, much of the water encountered was pumped to abandoned and currently-unused sections of the mine for temporary storage. It was initially assumed that the water encountered would have a high inflow for a short duration and then

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decrease with time, as frequently occurs with smaller rates of inflow. Under these circumstances, the underground areas which temporarily stored water would have acted as a reservoir and allowed the initial inflow surge to be discharged at a lower rate over time once the inflow decreased.

However, rather than decreasing significantly with time, the inflow has remained fairly constant. Once available underground areas for water storage were filled, the mine began pumping both the inflow water and the stored water to the surface to prevent mine flooding and allow continued operation. Since early September 2001, discharges from the mine to Eccles Creek have ranged between about 10,000 and 15,000 gpm. This water is pumped from the mine through sand filters to remove excess sediment prior to discharge to the Eccles Creek culvert that passes beneath the mine surface facilities.

The lateral extent of the sandstone yielding the water to the underground workings is unknown. Therefore, the rate and duration of inflow cannot be accurately estimated. For the purpose of this evaluation, the inflow was assumed to last for an indefinite duration at rates varying from 5,000 gpm to 30,000 gpm (11.1 to 66.9 cubic feet per second ["cfs"]).

Channel-Stability Impacts

Methods

Channel cross sections were surveyed, flow measurements were taken, and soil samples were collected on November 26, 2001 from the bed and banks of Eccles Creek and Mud Creek at the locations shown on Figure 1. At each location (except as described hereafter), one grab sample and one Shelby-tube sample were collected from the channel bank and one bulk grab sample was collected from the bed materials. Due to the predominance of cobbles and boulders in the bank, the Shelby-tube sample could not be collected at location EC-1. The extreme armoring of the channel bed at EC-2 precluded the collection of the bed sample at this location. Samples were collected as described above at all other locations.

All soil samples were submitted to CMT Engineering Laboratories in Salt Lake City, Utah for analyses. Bank samples were analyzed for the following parameters:

- Moisture content
- Bulk specific gravity
- Standard void ratio
- Gradation
- Atterberg Limits
- Soil classification (Unified Soil Classification System)

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- Direct shear cohesion and friction angle

The channel bed samples were analyzed for gradation only.

The structural stability of the channel banks was evaluated using the computer program GEOSLOPE (Version 5.0, GEOCOMP Corp., 1992). GEOSLOPE utilizes the limit equilibrium procedure of slices (Simplified Bishop's method) to determine the safety factor of potential failure surfaces for circular shapes. The following assumptions were made for this analysis:

- Results of direct shear tests were used for the analyses at all locations where a Shelby-tube sample was collected except EC-3. At this location, a more conservative cohesion intercept of 120 ponds per square foot ("psf") and a friction angle of 30 degrees was used because these values are considered more representative of the soil strengths at lower vertical pressures. Direct shear tests for EC-2 were used for EC-1 where a Shelby-tube sample could not be collected.
- The natural materials in the channel beds were assumed to be cohesionless with a saturated angle of internal friction of 32 degrees.
- The soils were assumed to drain rapidly, and excess pore pressures were assumed not to develop in response to strains and stress changes.
- The phreatic surface was assumed to extend horizontally from the water surface measured on November 26, 2001 (at a flow rate in both streams approximately equal to the long-term projected mine-water discharge of 10,000 gpm). Prior to the increased mine discharge, it is anticipated that the phreatic surface would have been coincident with the bottom of the stream channel. Thus, the assumed phreatic surface should model a more-nearly worst-case condition (i.e., soils saturated to a greater degree than normal).

The erosional stability of the channel beds and banks was estimated using an allowable-velocity approach. The allowable velocity of the channel beds was determined using methods outlined by the U.S. Soil Conservation Service (1977). The erosional stability of the channel banks and floodplains was evaluation using methods presented by Haan et al. (1994). A qualitative evaluation of the stability of the channels was made using the geomorphic classification system of Rosgen (1996).

Results

Table 1 presents the results of flow measurements collected on November 26, 2001 at each of the cross sections shown on Figure 1. This table also presents a calculated roughness coefficient based on Manning's equation and the field measurements collected at each location. The

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roughness coefficients contained in this Table were used in predicting flow velocities for various rates of mine-water discharge.

As indicated, the flow of both Eccles Creek and Mud Creek varies with distance downstream. The gain between EC-1 and EC-2 is likely due to natural groundwater contributions along the reach and surface-water inflows from South Fork. The loss between EC-2 and EC-3 is likely due to losses to the stream bank and underflow within the alluvial materials whose thickness increases significantly in the downstream reach of Eccles Creek.

Even though a small amount of unmeasured surface flow existed in Mud Creek upstream from MC-1, the flow at MC-1 is less than the flow in Eccles Creek approximately 2,000 feet upstream at EC-3. This is likely due to the underflow of Eccles Creek water into the alluvium of both Eccles Creek and Mud Creek where the thickness of the alluvial materials increases significantly near the confluence of the two streams. The flow of Mud Creek gradually increases with distance downstream, due to numerous springs that discharge to the stream in this reach and to the probable re-emergence of some of the underflow.

Results of laboratory analyses of the soil samples collected along and within Eccles and Mud Creeks are presented in Appendix B. Results of the structural stability evaluations are provided in Appendix C and summarized in Table 1. This table provides selected soil properties, the number of trial failure surfaces included in the analysis of each cross section, and the minimum (critical) safety factor against slope failure.

Generally, a safety factor in excess of 1.3 is considered stable. The lowest critical safety factor presented in Table 1 is 1.73, with a mean critical safety factor of 2.96 for the evaluated cross sections. Considering these results and the generally conservative analytical assumptions used in modeling stability, it is concluded that the stream banks of Eccles and Mud Creeks will maintain their structural stability with continued discharge of excess water from the Skyline Mine.

Results of the erosional stability evaluations are presented in Appendix D and summarized in Table 3. The channel bed of Eccles Creek is very well armored, with the cobbles that make up the bed generally being tightly lodged into the channel bottom. This armoring was sufficient at EC-2 that a sample of the bed material could not be collected at that location. Although the materials were easier to sample in Mud Creek, Table 3 indicates that the size of the particles was sufficient at all sampled locations to preclude erosion at each of the evaluated discharge rates.

The bank materials and floodplains along both streams consist of silty sands to clayey silts. These soils are well vegetated with various natural grasses and willows. Table 3 indicates that the combination of erosion-resistant soils and vegetation make the channel banks and floodplains erosionally stable at all of the evaluated discharge rates.

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Results of the geomorphic classification of the streams are presented in Table 4. This classification varies slightly from that presented in a preliminary October 24, 2001 evaluation due to the availability of site-specific data collected during the field visit on November 26. At sections EC-1 and EC-2, the entrenchment ratio is typical of a "B" stream type while the width/depth ratio and sinuosity are more typical of "A" stream types. However, the examples provided by Rosgen (1996) clearly indicate that EC-1 and EC-2 should be classified as B3a stream types rather than A3 stream types.

Similarly, the entrenchment ratio at EC-3 is higher than is typical of a "B" type stream. However, the valley of lower Eccles Creek is clearly typical of a "B" type stream and specifically not typical of a "C" type stream (the other stream type that fits the high entrenchment ratio). Therefore, EC-3 has been classified as a B3 type stream. Mud Creek could be easily classified as a "B" type stream.

According to Rosgen (1996), "B3 stream types are stable and contribute only small quantities of sediment during runoff events." Thus, the geomorphic classification would characterize stream sections EC-1, EC-2, EC-3, MC-1, and MC-2 as erosionally stable, in agreement with prior analyses. Similarly, Rosgen (1996) notes that "the B4 stream type is considered relatively stable and is not a high sediment supply stream channel", indicating that section MC-3 is also erosionally stable from a geomorphic standpoint and in agreement with prior conclusions.

It should be noted that most of the land adjacent to Mud Creek between stations MC-2 and MC-3 is privately-owned and posted to preclude trespassing. As a result, no samples or flow measurements were collected in this reach. However, observations from the road indicated that the pasture areas in this reach have been heavily grazed by livestock. Willows and grasses that extend to the edge of the active channel in reaches up- and downstream are generally absent from this section. The extent of overgrazing on this property appears to have resulted in increased erosion of the channel banks. Based on observations in up- and downstream sections of Mud Creek, as well as general observations in the past, the existing erosional instability of this reach is more likely a result of past grazing practices than of the increased discharges from the Skyline Mine.

Peak-Flow Impacts

Only five years of continuous streamflow data are available for Eccles Creek (U.S. Geological Survey Station 09310600, Eccles Creek near Scofield, Utah, period of record from October 1, 1979 through September 30, 1984). Because these data are insufficient on their own to estimate peak-flow return periods, the magnitudes of peak flows in Eccles Creek were estimated using the predictive equations of Thomas and Lindskov (1983). For the high plateaus region in which Eccles Canyon occurs, the equations are as follows:

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$$Q_2 = 10.8A^{0.800} \quad (1)$$

$$Q_5 = 25.1A^{0.740} \quad (2)$$

$$Q_{10} = 680A^{0.706}E^{-1.30} \quad (3)$$

$$Q_{25} = 10{,}300A^{0.672}E^{-2.33} \quad (4)$$

$$Q_{50} = 64{,}200A^{0.651}E^{-3.03} \quad (5)$$

$$Q_{100} = 347{,}000A^{0.631}E^{-3.68} \quad (6)$$

where Q_n = peak discharge at a return period of "n" years (cfs)
A = watershed area (mi^2)
E = mean watershed elevation (thousands of feet)

Flood peaks were calculated using the above equations for Eccles Creek above South Fork (i.e., approximately applicable to locations EC-1 and EC-2) and Eccles Creek above Mud Creek (i.e., applicable to location EC-3). Based on drainage areas of 1.77 mi^2 and 7.10 mi^2 and mean watershed elevations of 9,110 feet and 9,000 feet for the upper and entire watersheds, respectively, the peak discharges presented in Figure 2 were estimated.

Continuous streamflow records are available for Mud Creek below Winter Quarters Canyon at Scofield, Utah (USGS station 09310700, period of record from August 22, 1978 through September 30, 2000, immediately upstream from location MC-3). Annual peak-flow data from this station were evaluated to prepare Figure 3.

The equivalent return periods of the mine-water discharges are shown in Figure 4. This graph was developed by entering Figures 2 and 3 with the respective discharge rates to determine the pre-mining return periods that those discharge rates represent. As would be expected, the most significant return periods are in the upper portion of Eccles Creek where the watershed area is smallest. At the mouth of Eccles Creek, the increased mine-water discharge is equivalent to no more than a 3-year peak flow, while in Mud Creek, the increased discharge is equivalent to less than a 2-year event.

Figures 5 through 7 show the effects of the increased mine-water discharges on peak-flow return periods in Eccles Creek and Mud Creek. By increasing the baseflow of the streams with mine-water discharges, the flow at a given return period increases. For example, as shown on Figure 6, a flow of 200 cfs at the mouth of Eccles Creek has a return period of approximately 17 years

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under natural conditions. With the addition of 10,000 gpm of mine water, the return period for this same flow decreases to about 15 years. At 30,000 gpm of mine water, the return period of a 200 cfs event decreases to about 7 years. Alternatively, at this same location, the peak flow at a return period of 10 years is approximately 160 cfs under natural conditions, but increases to about 170 cfs with a mine-water discharge of 10,000 gpm and to about 230 cfs at a mine-water discharge rate of 30,000 gpm.

The effect of mine-water discharges on the return period of bankfull discharge is shown in Table 5. In the upper portion of Eccles Creek (i.e., EC-1 and EC-2), the frequency of bankfull discharge is approximately once every 20 to 30 years under natural conditions. This decreases to approximately once every 10 to 15 years at a mine-water discharge of 10,000 gpm and to once every 2 to 3 years at a mine-water discharge of 30,000 gpm. In lower Eccles Creek (as estimated at EC-3), the frequency of bankfull decreases from once every 17 years under natural conditions to once every 13 years at a discharge of 10,000 gpm and to once every 7 years at a discharge of 30,000 gpm.

In Mud Creek, the return period of bankfull discharge is estimated to be 1.3 to 1.4 years (i.e., this discharge occurs, on average, about twice in every three years). Under all of the evaluated mine-water discharge scenarios, bankfull discharge is expected to occur, on average, every year at each of the evaluated cross sections.

Impacts on Man-Made Structures

Five man-made structures exist on Eccles Creek and three on Mud Creek between the downstream end of the mine surface facilities and the town of Scofield. These structures (all corrugated metal culverts) have been installed at the locations shown on Figure 8.

Table 6 summarizes the impacts of the increased mine-water discharge on these man-made structures. The return period associated with overtopping of each of the Eccles Creek culverts is estimated to be in excess of 100 years under all scenarios. Hence, increased mine-water discharges will not adversely affect these culverts.

The capacity of the older Mud Creek culverts has a lower return period than that of all of the Eccles Creek culverts. Under natural conditions, these culverts can be expected to overtop approximately once every 20 to 30 years The frequency of overtopping can be expected to decrease by about 3 to 5 years with a mine-water discharge of 10,000 gpm and by about 7 to 12 years with a mine-water discharge of 30,000 gpm.

Water pumped from the mine is currently being treated to remove sediment and is then discharged into the Eccles Creek culvert that runs beneath the mine surface facilities. Because

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the capacity of this culvert is controlled by its inlet conditions, the discharge enters the culvert some distance downstream from the inlet, and the slope of the culvert is sufficient to prevent backwater from the discharge reaching the culvert inlet, this discharge does not alter the capacity of the facility bypass culvert.

Alternative Discharge Locations

A review of alternative discharge locations for the mine water indicates that the current discharge point into the Eccles Creek bypass culvert is the best available option. Use of this location prevents erosion at the point of discharge and, as described above, precludes impacts to the capacity of the bypass culvert. The natural channel downstream from the bypass culvert can safely accept this flow, as indicated above.

If an alternative discharge point was chosen outside of the bypass culvert, it would be necessary to construct an energy dissipater to prevent erosion at the point of discharge. This would require disturbance of the natural floodplain and/or the stream channel at the point of discharge. Given the adequacy of the existing system, it is considered unwise to create the additional disturbance that would be necessary if the discharge location was changed.

Summary

As indicated in this report, it is estimated that the stream bed and banks of Eccles Creek and Mud Creek will be both structurally and erosionally stable at the rates of mine-water discharge that were evaluated. Given the additional baseflow, the frequency will be reduced at which a given rate of discharge occurs in the two streams. Thus, flooding outside of the steam banks will occur more frequently than has occurred under conditions of limited mine-water discharge.

Man-made structures in Eccles Creek will generally be unaffected by the increased mine-water discharge. However, given the more undersized capacity of the Mud Creek culverts, the frequency at which these structures will overtop will be reduced from once every 20 to 30 years to once every 15 to 20 years, depending on the location of the structure and the rate of mine-water discharge.

It is recommended that the current mine-water discharge point be maintained. Given the potential for some impacts to downstream culverts and the uncertainties created by maintaining a high baseflow for an extended period of time, it is further recommended that periodic observations be made of Eccles Creek and Mud Creek to ensure that long-term impacts are minimized. These observations should be made each year during spring runoff (May or June) and during a period of low natural flow (September or October). General observations should be made of channel stability along the sections included in this study.

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We have appreciated the opportunity to conduct this evaluation. Please contact us if you have any questions.

Sincerely,

Richard B White

Richard B. White, P.E.
President

Attachments:
References Cited
Tables 1-5
Figures 1-8
Appendices A-C

References Cited

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TABLE 1

Flow Measurements and Calculated Roughness Coefficients
for Eccles Creek and Mud Creek

Stream Station	Discharge (cfs)	Flow Area (ft^2)	Average Velocity (ft/s)	Wetted Perimeter (ft)	Hydraulic Radius (ft)	Hydraulic Slope (ft/ft)	Manning's "n" (fraction)
EC-1	22.84	8.0	2.9	9.8	0.82	0.078	0.127
EC-2	25.15	5.9	4.3	8.1	0.73	0.048	0.062
EC-3	21.49	6.3	3.4	7.2	0.88	0.036	0.076
MC-1	18.28	5.4	3.4	13.9	0.39	0.015	0.029
MC-2	21.05	7.4	2.8	18.1	0.41	0.013	0.033
MC-3	24.44	9.6	2.5	13.3	0.72	0.008	0.042

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TABLE 2

Soil Property Parameters and Results of Slope Stability Analyses
of the Banks of Eccles and Mud Creeks

Section[a]	Direct Shear Test Values[b]		Number of Trial Failure Surfaces	Safety Factor[c]
	Cohesive Strength (psf)	Angle of Internal Friction (degrees)		
EC-1	120	32	30,000	1.93
EC-2	120	32	30,000	3.31
EC-3	120	30	30,000	2.77
MC-1	50	34	30,000	1.73
MC-2	100	31.5	30,000	2.98
MC-3 East	150	36	30,000	3.29
MC-3 West	150	36	30,000	4.73

[a] See Figure 1 for location
[b] See Appendix B
[c] See Appendix C

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TABLE 3

Results of Erosional Stability Analyses
of Eccles Creek and Mud Creek

Stream Station	Allowable Velocity (ft/s)	Actual Velocity (ft/s)[b]				Comments
		At 5,000 gpm	At 10,000 gpm	At 20,000 gpm	At 30,000 gpm	
Channel Bottom						
EC-1	10.5[a]	2.4	2.9	3.6	4.1	OK
EC-2	10.0[a]	3.1	4.0	5.0	5.2	OK
EC-3	9.3[a]	2.6	3.2	3.6	3.7	OK
MC-1	8.8[a]	3.1	3.8	4.7	5.5	OK
MC-2	9.3[a]	2.3	2.9	3.6	4.1	OK
MC-3	8.8[a]	1.9	2.4	3.1	3.3	OK
Channel Banks						
EC-1	6.0	2.4	2.9	3.6	4.1	OK
EC-2	7.0	3.1	4.0	5.0	5.2	OK
EC-3	7.0	2.6	3.2	3.6	3.7	OK
MC-1	7.0	3.1	3.8	4.7	5.5	OK
MC-2	7.0	2.3	2.9	3.6	4.1	OK
MC-3	7.0	1.9	2.4	3.1	3.3	OK
Floodplain[c]						
EC-2	7.0	–	–	–	5.2	OK
MC-1	7.0	–	–	–	4.5	OK
MC-3	7.0	–	–	–	3.4	OK

[a] Based on sediment-free conditions. Allowable velocity for sediment-laden conditions is higher
[b] Average velocity at indicated flow
[c] Evaluated for those sections where flows ≤ 30,000 gpm impact the floodplain

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TABLE 4

Eccles and Mud Creeks Stream Classification
(according to the method of Rosgen, 1996)

Cross Section	Entrenchment Ratio			Width/Depth Ratio		
	W_{fpa}[a] (ft)	W_{bkf}[b] (ft)	Ratio	W_{bkf} (ft)	D_{bkf}[c] (ft)	Ratio
EC-1	16.4	9.3	1.8	9.3	2.8	3.3
EC-2	51.2	7.4	1.8	7.4	1.3	5.7
EC-3	63.7	20.2	3.2	20.2	1.9	10.6
MC-1	24.6	15.5	1.6	15.5	1.2	12.9
MC-2	25.7	19.7	1.3	19.7	1.0	19.7
MC-3	26.1	14.3	1.8	14.3	1.7	8.4

Cross Section	Sinuosity			Slope (fraction)	Bed Material[f]	Stream Class
	L_s[d] (ft)	L_v[e] (ft)	Ratio			
EC-1	2250	2150	1.0	0.078	Cobble	B3a
EC-2	2850	2800	1.0	0.048	Cobble	B3a
EC-3	2700	2400	1.1	0.036	Cobble	B3
MC-1	2750	2650	1.0	0.015	Cobble	B3c
MC-2	4000	3400	1.2	0.013	Cobble	B3c
MC-3	2650	2400	1.1	0.008	Gravel	B4c

[a] Width of the floodplain area at a depth of twice bankfull depth
[b] Width of flow at bankfull depth
[c] Depth of flow at bankfull stage
[d] Length of stream for a given reach
[e] Valley length for the above reach
[f] Based on the median diameter of the bed material

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TABLE 5

Comparison of Pre- and Post-Mine Discharge
Bankfull Return Periods

Station	Natural Bankfull Discharge		Post-Mine Discharge Return Period (yr)[e]			
	Flow (cfs)	Return Period (yr)	at 5,000 gpm	at 10,000 gpm	at 20,000 gpm	at 30,000 gpm
EC-1[b]	93	29	21	15	7	3
EC-2[b]	81	21	15	11	5	1.7
EC-3[c]	199	17	15	13	10	7
MC-1[d]	71	1.4	1.1	1.1	1.1	1.1
MC-2[d]	66	1.4	1.1	1.1	1.1	1.1
MC-3[d]	59	1.3	1.1	1.1	1.1	1.1

[a] Based on a review of mean daily flows for the period of record
[b] Return periods from Figure 2, Eccles Creek above South Fork
[c] Return periods from Figure 2, Eccles Creek above Mud Creek
[d] Return periods from Figure 3
[e] Post-mine discharge return period determined by subtracting the indicated mine discharge and entering the appropriate figure with the result

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TABLE 6

Evaluation of Man-Made Structures

Structure		Capacity (cfs)[b]	Culvert Capacity Return Period (yr)[c]				
No.[a]	Type		Natural	at 5,000 gpm	at 10,000 gpm	at 20,000 gpm	at 30,000 gpm
ECS-1	84" CMP, projecting inlet	450	>100	>100	>100	>100	>100
ECS-2	84" CMP, projecting inlet	450	>100	>100	>100	>100	>100
ECS-3	48" CMP, projecting inlet	240	>100	>100	>100	>100	>100
ECS-4	72" CMP, concrete headwall & wingwalls	680	>100	>100	>100	>100	>100
ECS-5	120" CMP, projecting inlet	1,000	>100	>100	>100	>100	>100
MCS-1	72" CMP, concrete headwall & wingwalls	360	17	15	14	11	10
MCS-2	2-60" CMPs, projecting inlet	440	31	29	26	22	19
MCS-3	72" CMP, concrete headwall & wingwalls	360	17	15	14	11	10

[a] See Figure 8

[b] Based on 5 ft of headwater depth over the top of the culvert, except ECS-3 and ECS-4, where a headwater depth of 20 ft over the top of the culvert was used. Capacities were determined from Chart 5 of Herr (1965)

[c] Flood-frequency curves used as follows:

ECS-1, ECS-2, and ECS-3 - Figure 2 (Eccles Creek above South Fork)
ECS-4 and ECS-5 - Figure 2 (Eccles Creek above Mud Creek)
MCS-1, MCS-2, and MCS-3 - Figure 3

Return periods at various mine-water discharge rates determined by subtracting the designated rate from the culvert capacity under natural conditions, and entering the result into the appropriate figure.

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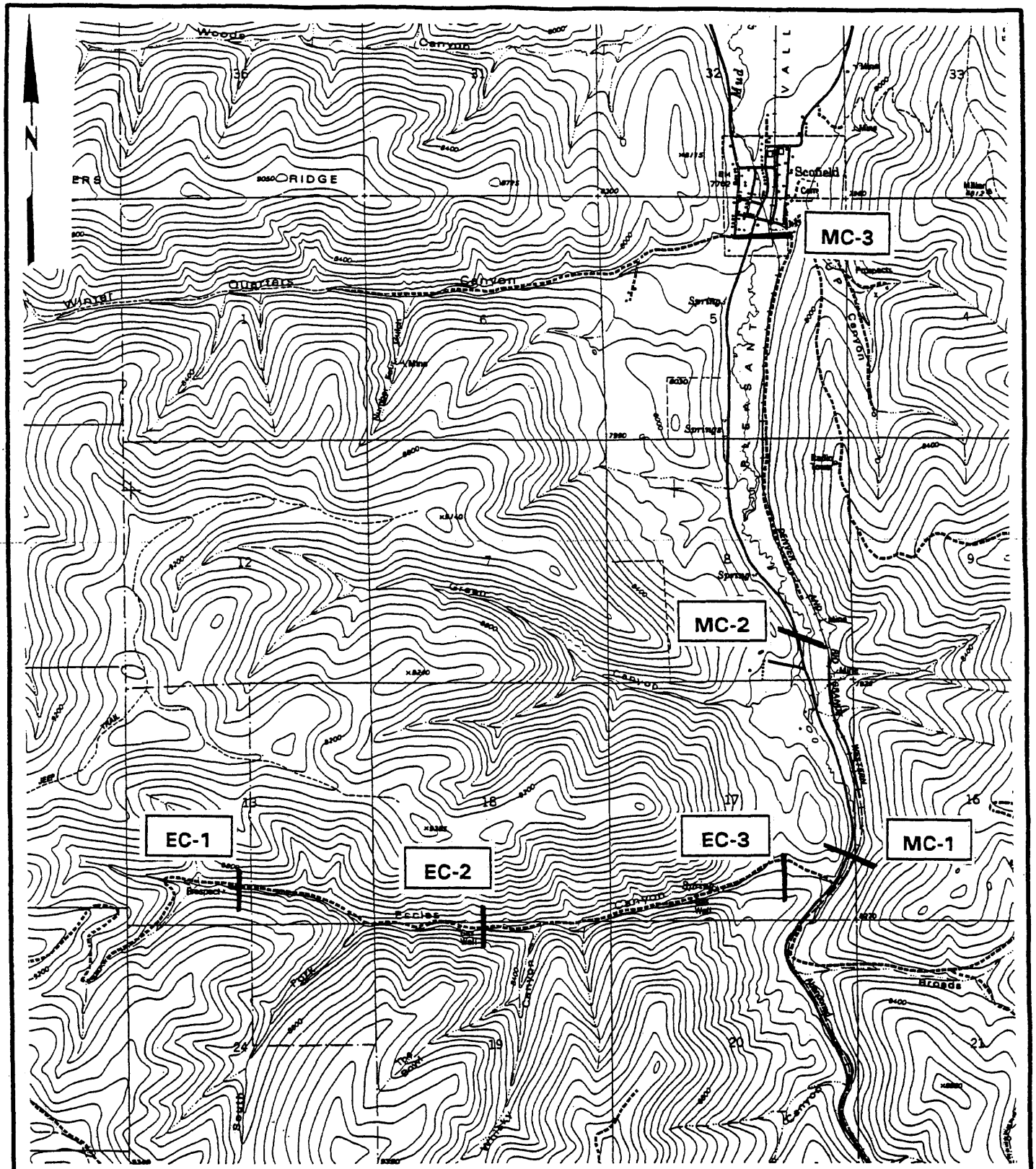

BASE MAP: SCOFIELD, UTAH 7½ MIN
USGS QUADRANGLE (1979)

SCALE: 1" = 3,000'

FIGURE 1. LOCATION OF CHANNEL CROSS SECTIONS

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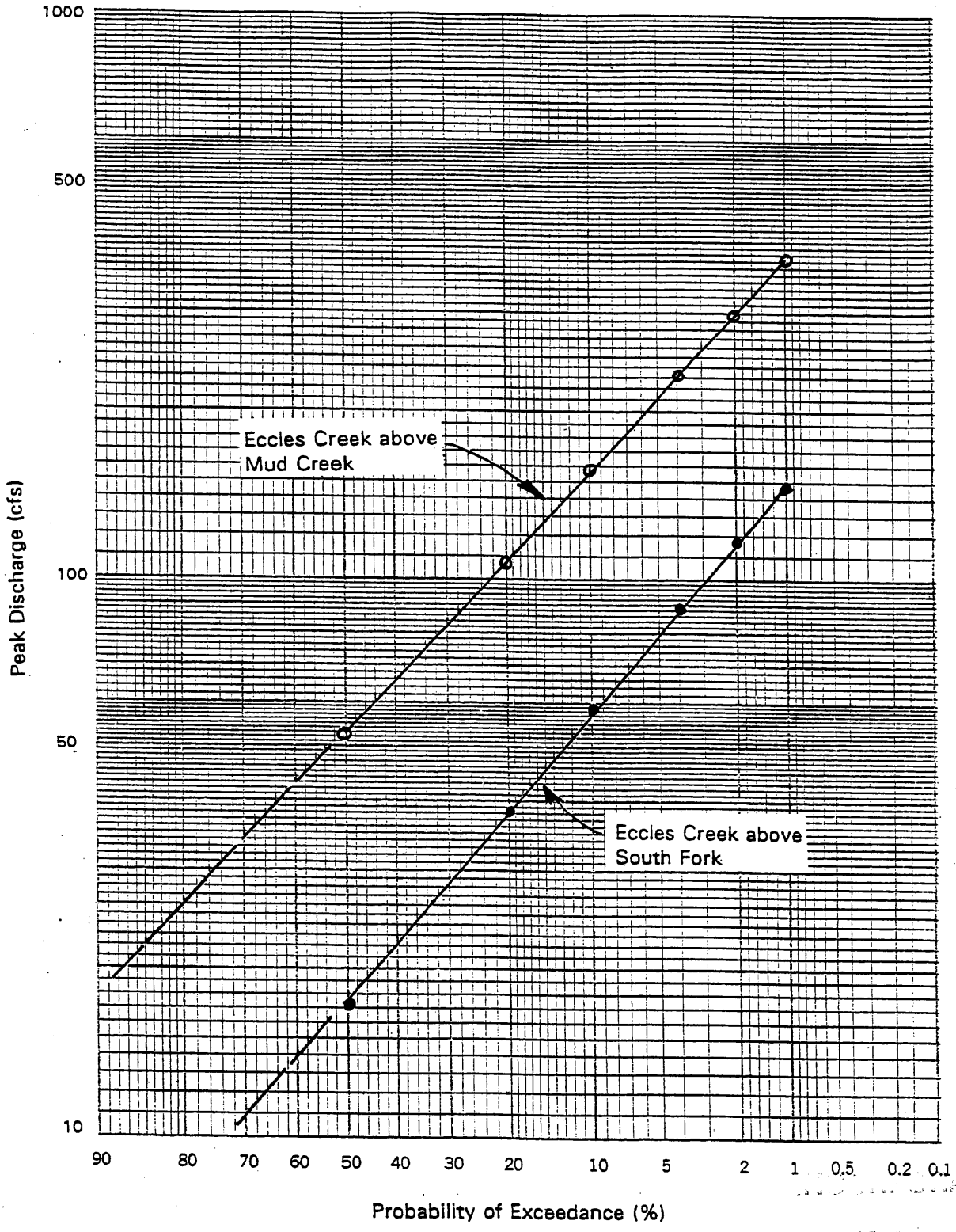

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FIGURE 2. ESTIMATED PEAK FLOW FREQUENCIES FOR ECCLES CREEK.

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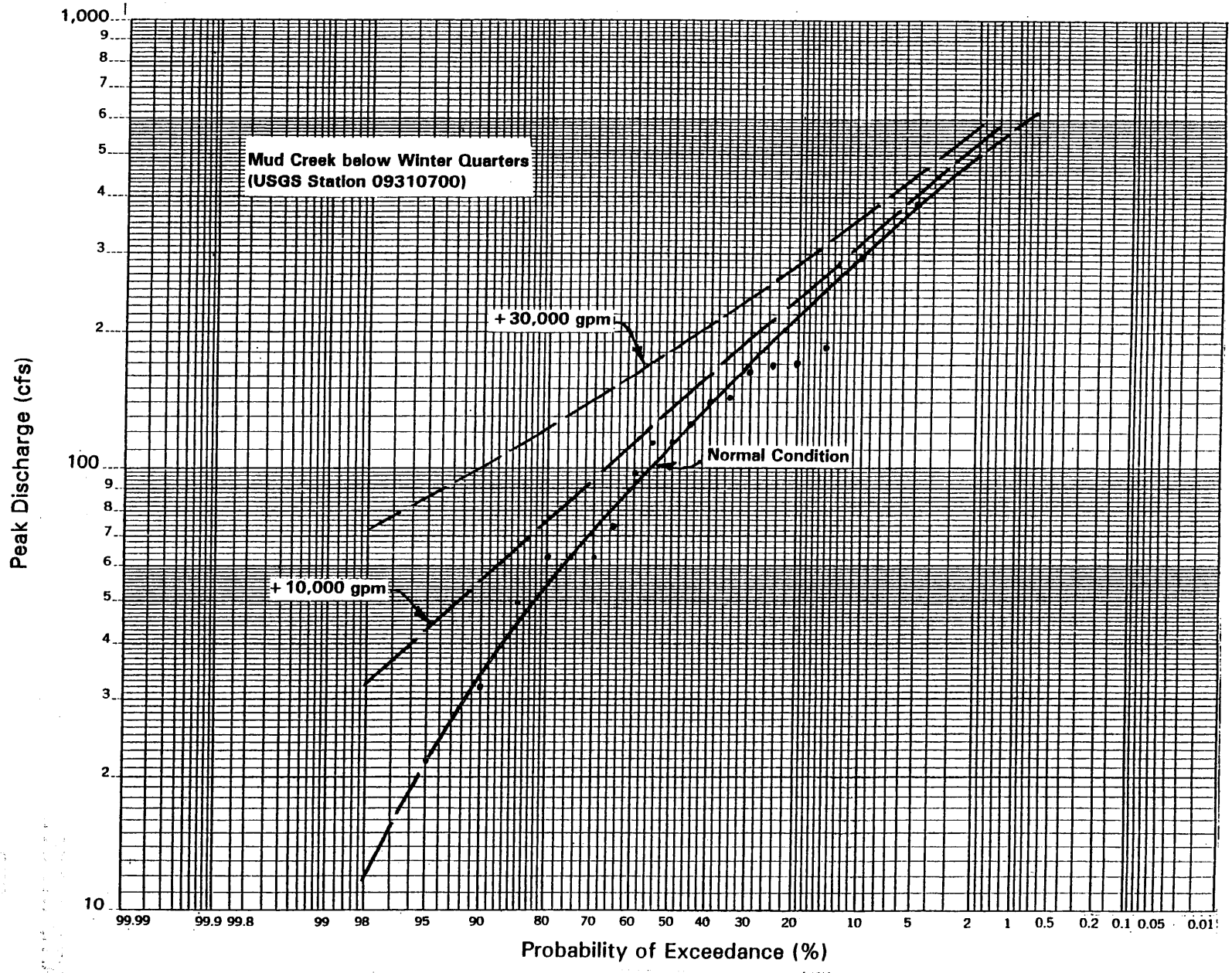

FIGURE 3. IMPACT OF INCREASED FLOW ON MUD CREEK FLOW FREQUENCY.

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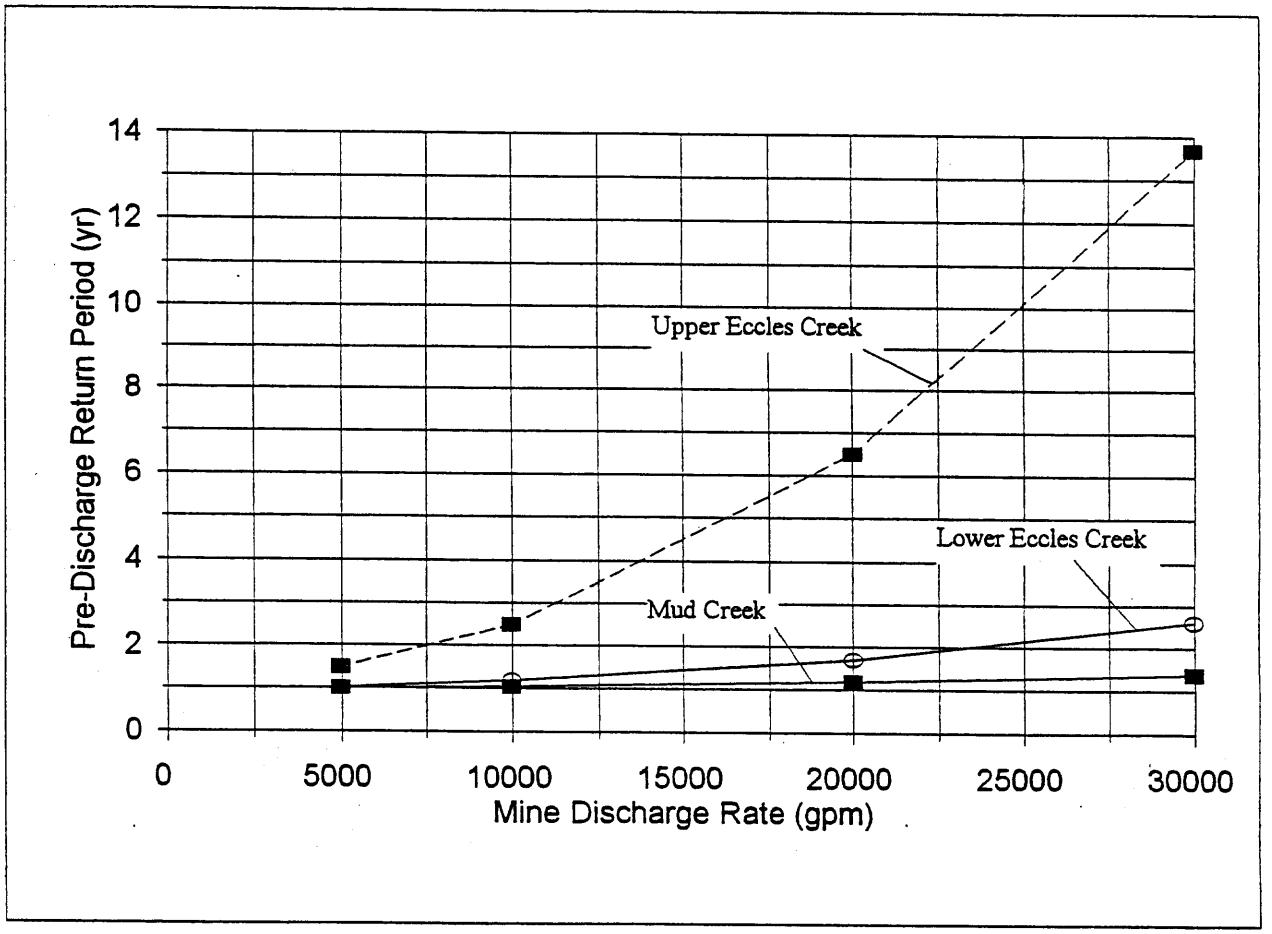

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FIGURE 4. RETURN PERIODS OF MINE-WATER DISCHARGES

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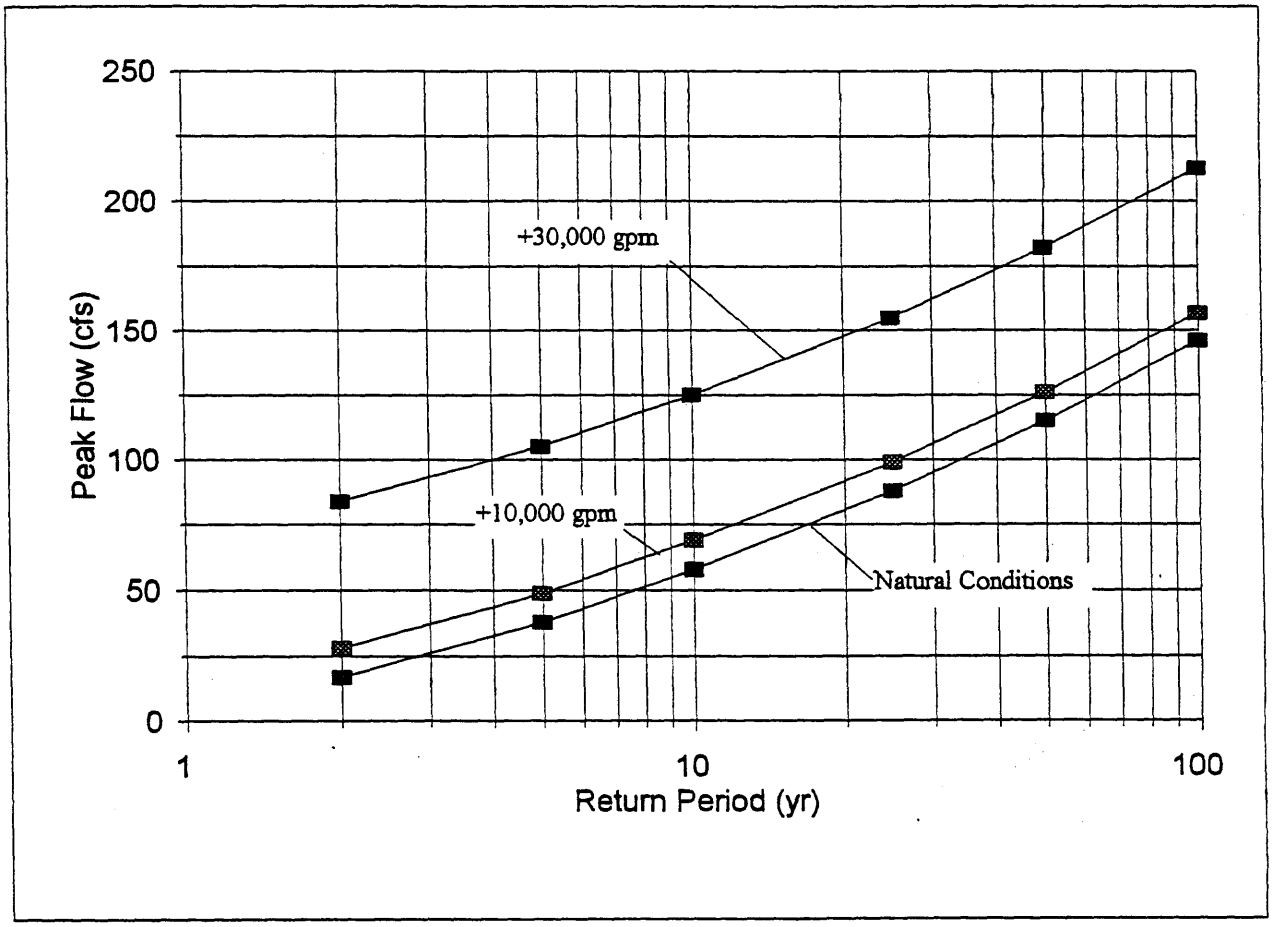

FIGURE 5. FLOOD FREQUENCY OF ECCLES CREEK AB. SOUTH FORK.

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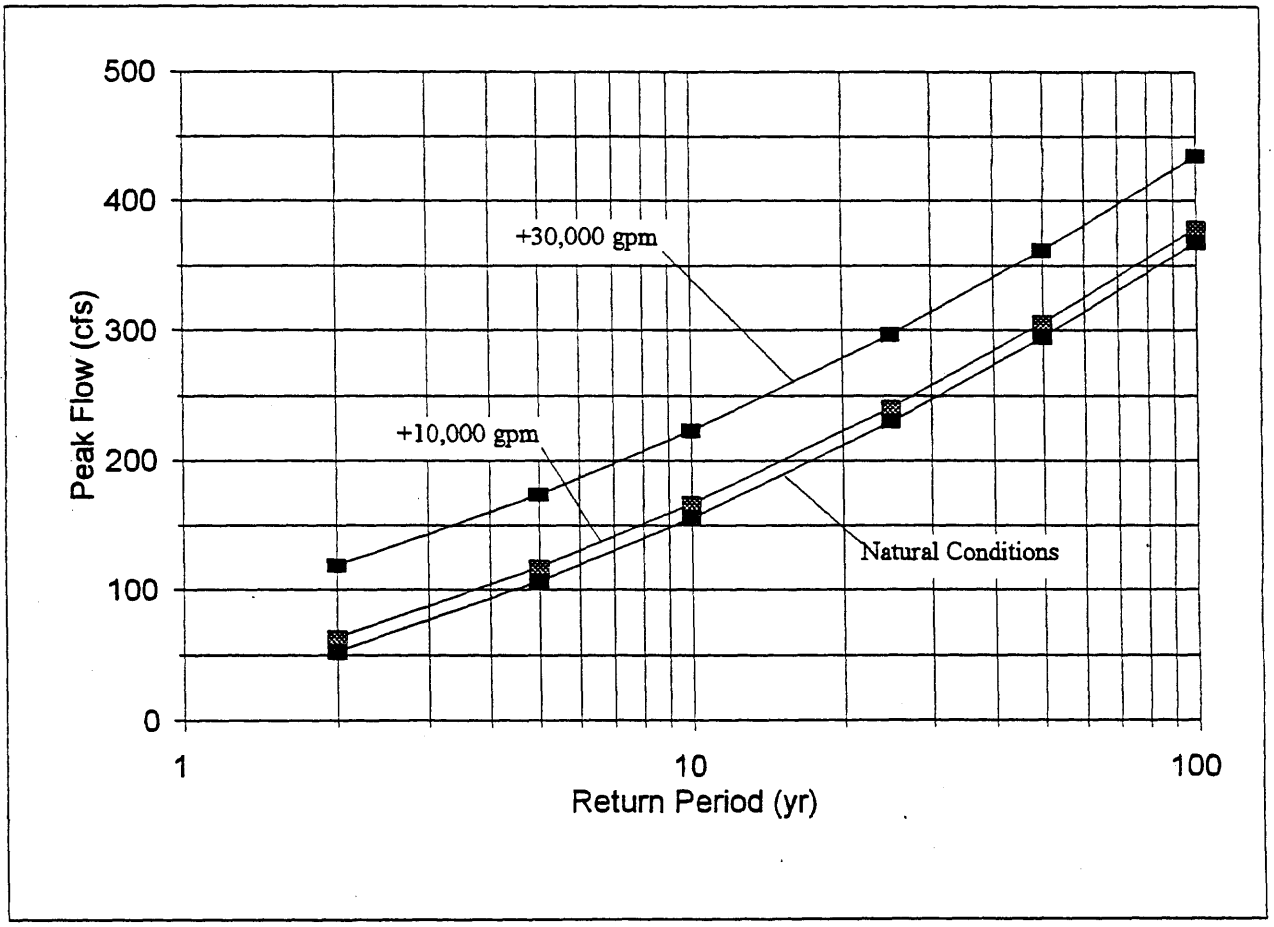

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FIGURE 6. FLOOD FREQUENCY OF ECCLES CREEK AB. MUD CREEK.

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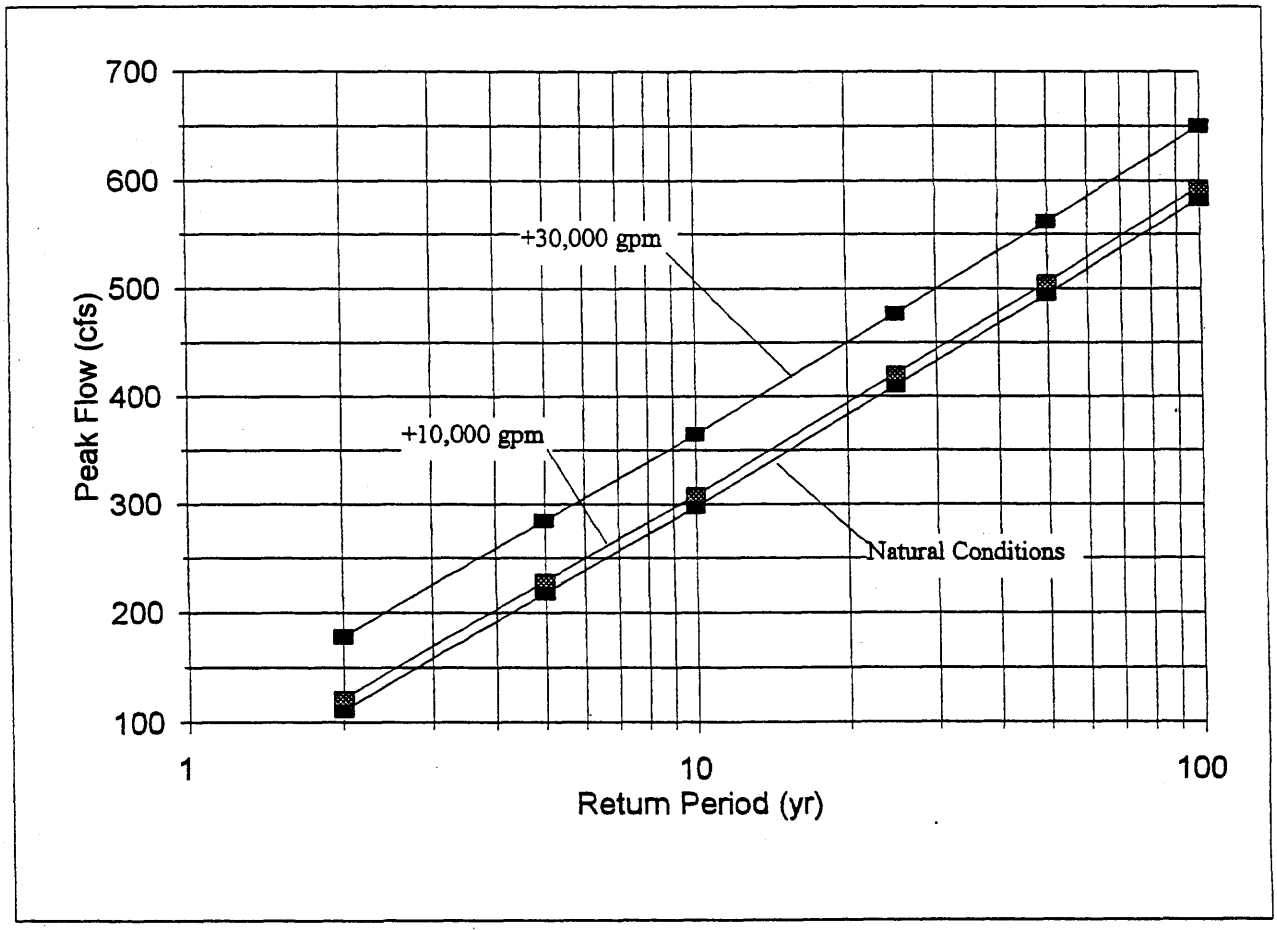

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FIGURE 7. FLOOD FREQUENCY OF MUD CREEK BL. WINTER QUARTERS.

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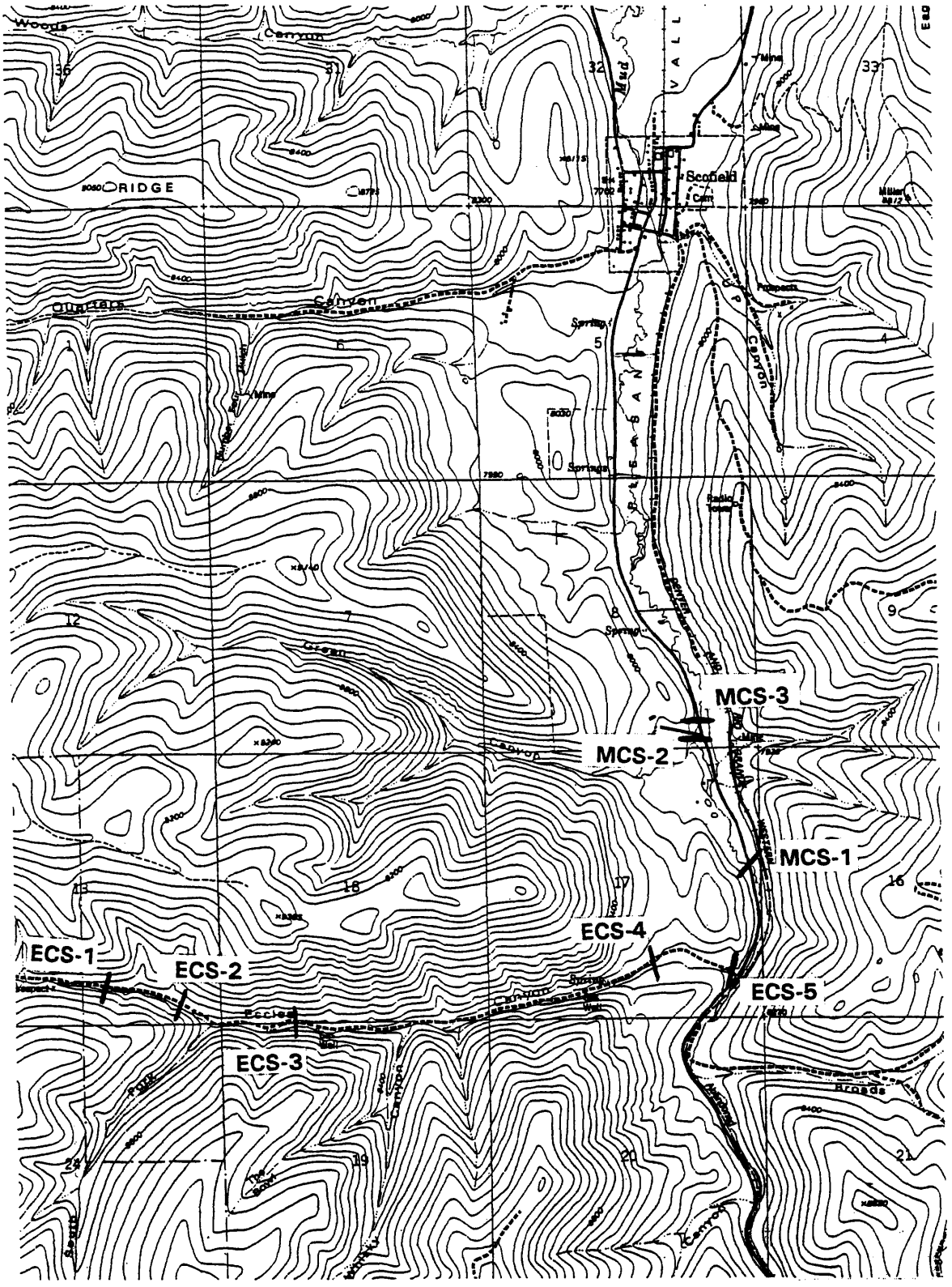

BASE MAP: SCOFIELD, UTAH 7½ MIN
USGS QUADRANGLE (1979)

SCALE: 1" = 3,000'

FIGURE 8. LOCATIONS OF MAN-MADE STRUCTURES.

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APPENDIX A

Mt. Nebo Scientific Report on Riparian Communities
at Eccles Creek and Mud Creek

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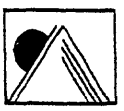
THE EFFECTS OF INCREASED FLOWS ON RIPARIAN COMMUNITIES AT ECCLES CREEK & MUD CREEK

PREPARED
FOR THE
SKYLINE MINES



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THE EFFECTS OF INCREASED FLOWS ON RIPARIAN COMMUNITIES AT ECCLES CREEK & MUD CREEK

INTRODUCTION

Brief History

During recent coal mining activities at the Skyline Mine, an unexpected large amount of subsurface water was intercepted. This caused a significant inflow of water to the mine which made it necessary for mine personnel to de-water it so that mining could be resumed. The excess water was first channeled to previously mined areas that functioned as temporary holding reservoirs. However, the available underground holding capacity for the excess water was depleted before all of the intercepted water could be contained. Therefore, it was necessary for the mine to begin releasing excess waters to the surface via Eccles Creek. At present, water continues to be released with uncertainty as to when the intercepted mine waters will be depleted and normal flows will be returned to Eccles Creek.

Flow Rates

It has not been an unusual practice for the Skyline Mine to release small amounts of excess mine water to the surface through Eccles Canyon. Prior to January 2000 the combined mine water discharge and Eccles Creek normal flows was usually less that 1,000 gallons per minute. Between January 2000 and August 2001 the combined waters was approximately 4,000 gpm. In early August 2001 when the unexpected water was intercepted, the flows increased dramatically and have remained relatively constant at a rate between 10,000 to 15,000 gpm since early September 2001 through December 2001 (Canyon Fuel Company 2001; Earthfax Engineering 2001).

Study Area

The Skyline Mine at the location where the water is released to Eccles Creek is less than 6 miles southwest of the town of Scofield on the Wasatch Plateau in central Utah. Eccles Creek generally flows east from the mine until it enters into Mud Creek. Mud Creek flows north through the town of Scofield, then continues north where it enters Scofield Reservoir located approximately 1.3 miles north of the town. Elevation of the study area ranged from 8,560 ft to 7,650 ft above sea level.

A study of the riparian plant communities has been conducted in representative areas of Eccles and Mud Creeks between the Skyline Mine and Scofield Reservoir.

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Study Objectives

The objectives of the study was to conduct preliminary research to determine what the potential impacts of increased flows that have been discharged to Eccles and Mud Creek could have on the riparian plant and animal communities of these creeks – with emphasis on the plant communities. Primary objectives of the study were to: 1) identify riparian complexes in the field, 2) assess current condition of the riparian plant communities, 3) assess preliminary impacts of increased flows on these communities, 4) provide general estimates of existing vegetation status, aquatic resource condition and channel stability, 5) acquire the minimum level of information needed to address several riparian issues, and 6) provide a database and structure for more intensive studies if needed in the future.

Fish studies were not conducted during this period. The impact on other wildlife species was considered for the study, but again emphasis was made on the riparian communities.

METHODS

A Level II investigation was conducted for the riparian plant communities in the area by using the methods of the USDA Forest Service (1992). Fieldwork was conducted in December 2001. Using the Forest Service methods, data from representative "reaches" along both Eccles and Mud Creeks were recorded. Field parameters are shown on Table 1. Additionally, several other reaches were observed to note any differences from the sample reach. Any differences were adjusted according on the data sheets. Once all reaches were observed the data were confirmed or changed accordingly. Specific locations were described on the data sheet summaries submitted in the tables of this report.

TABLE 1: Field parameters for Eccles & Mud Creeks

COMPLEX	RIPARIAN AREA
WATERBODY NAME	SPECIES OBSERVED
LOCATION	POOL ATTRIBUTES
DATE	% area in pools
OBSERVER(S)	% pool area made up of pools > 2' deep
QUAD NAME	AQUATIC VEGETATION
GEOLOGIC PARENT MATERIAL	% streambed with filamentous algae
ASPECT	% stream margin with rooted aquatic
VALLEY BOTTOM TYPE	BANK TYPE & VEGETATION OVERHANG
STREAM TYPE (Rosgen 1996)	% bank length undercut (<90°)
STREAM GRADIENT	% bank length gently sloping (>135°)
ELEVATION	% bank length with overhanging vegetation
SIZE OF COMPLEX	BANK CONDITION
SOIL FAMILY	% bank length vegetated, stable
ADJACENT UPLAND VEGETATION	% bank length unvegetated, stable
VEGETATIVE DESCRIPTION	% bank length vegetated, unstable
SUCCESSIONAL STATUS	% bank length unvegetated, unstable
APPARENT FORAGE TREND	CHANNEL MORPHOLOGY* (Rosgen 1996)
ESTIMATED FORAGE PRODUCTION	Entrenchment Ratio
BEAVER ACTIVITY	Width/Depth Ratio
GREEN LINE (Hydric):	Sinuosity
PHOTOGRAPH TAKEN	Stream Classification
LAND USE ACTIVITIES THAT COULD INFLUENCE RIPARIAN AREA	ADDITIONAL NOTES

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RESULTS

Although some of the more symptomatic results are summarized in the text below, much more biological, ecological and other environmental data from the field work on Eccles Creek and Mud Creek are shown on Tables 2-6. These data were recorded in five primary locations on representative reaches of the two creeks [3 reaches on Eccles Creek (Nos. 1-3) and 2 reaches on Mud Creek (Nos. 4-5)]. The study began in the upper elevations (near the Skyline Mine) and concluded at the lowest elevations (near Scofield Reservoir). However, as mentioned in the METHODS sections of this report, several other reaches were observed to note differences between them and the reaches used to record the field data.

It should be mentioned that because of the time of year (December) and the relatively high amounts of snow, plant species identification was difficult, at least to the species level. Although some snow was removed from areas to get an idea of the species present and their relative composition and dominance values, the results are no doubt less accurate than they would have been if the data were recorded during the growing season. Yet, identification to the species level is probably less important than identification of taxa by lifeform (e.g. trees, shrubs, graminoids and forbs) and other biologic and environmental variables.

Some stream geomorphologic data were collected for this study by Mt. Nebo Scientific, Inc., but most of the geomorphologic data reported in the tables were taken from the *draft* report by Earthfax Engineering (December 21, 2001).

Photographs along each section of the creeks where data were recorded were taken and included in this report (see FIGURES).

Reach No. 1

Reach No. 1 was located near the Skyline Mine below the culverts that carries Eccles Creek below the mine's surface facilities. This section of the stream is the steepest stretch (8.0 %) of the study and the stream is more deeply entrenched. It was classified as an B3a stream using Rosgen's (1996) methods. The approximate width of the riparian area including the stream width was 21 ft. This section of the stream flows through a spruce-fir plant community, and consequently organic material i.e. tree branches and fallen trees may influence the dynamics of the stream more than the reaches below it.

Herbaceous communities such as sedge-grass and rush-grass dominated the riparian plants in this area. Using qualitative methods it was estimated that about 16% of the riparian zones appeared to be "unstable" (Table 2). (Streambank stability is normally observed along the steepest sloped portion of the channel between the bankfull and existing water level. Because the flow at the time of the study was close to bankfull capacities, the stream stability was observed near water level. Instability referred to banks that showed signs of active erosion, breakdown, tension cracking, shearing or slumping. For this study most of the "unstable" portions of the streams were the .

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result of observing slight undercutting, erosion, or recently exposed root masses of the riparian vegetation).

Reach No. 2

Reach No. 2 was located beginning about 0.5 miles downstream from the Skyline Mine's surface facilities and continued to about 0.5 miles from the confluence of Eccles and Mud Creeks. This section of the stream was also relatively steep and entrenched. It could also be classified as an B3a stream. The approximate width of the riparian area including the stream width was 22.5 ft. This section of the stream was more "open" than the upper reach but also went through a spruce-fir plant community on one side of the it and a mountain brush community on the other.

Herbaceous communities such as sedge-grass and rush-grass dominated the riparian plants in this area, but it also had a fair representation of willow communities (25%) Using qualitative methods it was estimated that about 30% of the riparian zones appeared to be "unstable" (Table 3).

Reach No. 3

Reach No. 3 was located on Eccles Creek just above its confluence with Mud Creek. Although a relatively short section, the stream type changed in this area. The stream gradient was more gentle (3.6%) and could be classified as a B3 stream using Rosgen's methods. The approximate width of the riparian area including the stream width was 36.5 ft. This section was more "open" than the previous two reaches with greater areas for riparian and wetland community establishment.

Herbaceous communities such as sedge-grass dominated the riparian plants in this area, but the area had fair stands of willow and riverbirch communities Using the same qualitative methods, it was estimated that about 25% of the riparian zones appeared to be "unstable" (Table 4).

Reach No. 4

Reach No. 4 was located on Mud Creek beginning near the confluence of it with Eccles Creek and ended about 1.3 miles downstream (the private property south of the town of Scofield where cattle had severely over-grazed the riparian areas was not sampled) . This section of the stream had a relatively gently gradient (3.0%) and was only moderately entrenched. It could be classified as a B3c stream. The approximate width of the riparian area including the stream width was 91 ft. but in the riparian communities and wetland areas near them, *it was difficult to ascertain what water was most influential to the riparian communities* – the stream waters of Mud Creek or the springs that feed this "gaining" stream. There were relatively wide areas (~ 250 ft) that were dominated by willow communities. This section of the stream dissected spruce-fir and aspen communities, but these communities were relatively distant due to the flat, wide nature of the valley.

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Herbaceous communities such as sedge-grass and rush-grass dominated the riparian plants in this area, but willows were also a major component of the riparian communities. Using the same qualitative methods as above, it was estimated that about 15% of the riparian zones appeared to be "unstable" (Table 5).

Reach No. 5

Reach No. 5 was located north of the town of Scofield and south of Scofield Reservoir. This section of the stream was much different than the previous described stream reaches. It could be classified as a C5 stream. The approximate width of the riparian area including the stream width was 120 ft., but *it was very difficult to determine at what point the ground water or the stream water most influenced the riparian and wetland plant communities.* This section of the stream basically dissected herbaceous and willow pasturelands, where willows dominated much of the area. Using qualitative methods, it was estimated that about 20% of the riparian zones appeared to be "unstable" (Table 6).

Wildlife Species

Other wildlife species were considered in the study such as big game and small mammals. At present, the impact of the increased stream flows are expected to be minimal for these species. Beaver activities may be affected but they are expected to adapt. Other species such as amphibians may be more impacted by flow changes, but the scope of this report did not include detailed studies for these species.

Wildlife species that use the riparian plants such as small mammals and birds could be impacted. Their impacts would be a function of the long-term changes to the riparian plant community composition and monitoring would entail additional companion studies to be conducted over time.

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TABLE 2: RIPARIAN COMPLEX DATA SHEET (LEVEL II)

COMPLEX: Riverine - Reach No. 1

WATERBODY NAME: Eccles Canyon Creek

LOCATION: Upper Section (from Skyline Mine to 0.3 miles downstream)

DATE: 19 December 2001

OBSERVER(S): P.D. Collins

QUAD NAME: Scofield 7.5

GEOLOGIC PARENT MATERIAL: Sandstone and shale from the Blackhawk Formation

ASPECT: East

VALLEY BOTTOM TYPE: Valley Type II

STREAM TYPE (Rosgen 1996): B3a

STREAM GRADIENT: 8.0%

ELEVATION: Downstream Elev.- 8,440 ft. Upstream Elev.- 8,560 ft. Midstream Elev.- 8,500ft.

SIZE OF COMPLEX: Length - 1,760 ft. Width - 21 ft. Area - 0.85 acres.

SOIL FAMILY:

- *Trag-Croydon complex* (50% Trag stony loam; 30% Croydon loam; 20% other soils).
- *Curecanti family-Pathead complex* (30% Curecanti family loam; 25% Pathead extremely bouldery fine sandy loam; 25% Pathead extremely stony loam; 20% other soils).
- *Uinta-Toze families complex* (35% Uinta family loam; 30% Toze family fine sandy loam; 35% other soils).

ADJACENT UPLAND VEGETATION (looking downstream)

Left: Mtn. Brush Right: Spruce-Fir

VEGETATIVE DESCRIPTION (Dominance by Community Types)

Community Name	% of Complex	Est. Potential Comm. Name
Willow/Grass	20	Willow/Grass
Sedge/Grass	40	Sedge/Grass
Rush/Grass	40	Rush/Grass

SUCCESSIONAL STATUS: Late

APPARENT FORAGE TREND: n/a

ESTIMATED FORAGE PRODUCTION: 500 lbs/ac

BEAVER ACTIVITY: probably present, but none observed

GREEN LINE (Hydric): 80%

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TABLE 2 (continued)
Eccles Creek
Upper Section

PHOTOGRAPH TAKEN: yes

LAND USE ACTIVITIES THAT COULD INFLUENCE RIPARIAN AREA: Mining

SPECIES OBSERVED:

Trees	Shrubs	Forbs	Graminoids
Abies lasiocarpa	*Rosa woodsii*		*Agoseris stolonifera*
Alnus incana	*Salix spp.*		*Carex aquatilis*
Picea pungens	*Symphoricarpos oreophilus*		*Bromus carinatus*
Pseudotsuga menziesii			*Juncus spp.*
Salix spp.			

POOL ATTRIBUTES

% area in pools: 15
% pool area made up of pools > 2' deep: 20

AQUATIC VEGETATION

% streambed with filamentous algae: 5
% stream margin with rooted aquatic: 10

BANK TYPE & VEGETATION OVERHANG

% bank length undercut (<90°): 15
% bank length gently sloping (>135°): 85
% bank length with overhanging vegetation: 20

BANK CONDITION

% bank length vegetated, stable: 80
% bank length unvegetated, stable: 4
% bank length vegetated, unstable: 15
% bank length unvegetated, unstable: 1

CHANNEL MORPHOLOGY* (Rosgen 1996)

	Entrenchment Ratio			*Width/Depth Ratio*		
Cross Section No.	Flood-Prone Width	Bankfull Width (ft)	Ratio	Bankfull Width (ft)	Bankfull Depth (ft)	Ratio
EC-1	16.4	9.3	1.8	9.3	2.8	3.3

	Sinuosity			*Stream Classification*		
Cross Section No.	Given Reach Length (ft)	Given Valley length (ft)	Ratio	Slope (fraction)	Bed Material	Stream Class
EC-1	2250	2150	1.0	0.078	cobble	B3a

* Data taken from Earthfax Engineering, Inc. field measurements.

NOTES:

- Recorded data on most of this section of the stream taking measurements in representative areas along it.

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TABLE 3: RIPARIAN COMPLEX DATA SHEET (LEVEL II)

COMPLEX: Riverine - Reach No. 2

WATERBODY NAME: Eccles Canyon Creek

LOCATION: Middle Section (downstream from Skyline Mine)

DATE: 19 December 2001

OBSERVER(S): P.D. Collins

QUAD NAME: Scofield 7.5

GEOLOGIC PARENT MATERIAL: Sandstone and shale from the Blackhawk Formation

ASPECT: East

VALLEY BOTTOM TYPE: Valley Type I

STREAM TYPE (Rosgen 1996): B3a

STREAM GRADIENT: 6%

ELEVATION: Downstream - Elev.8,000 ft. Upstream Elev.- 8440 ft. Midstream Elev.- 8220 ft.

SIZE OF COMPLEX: Length - 9,200 ft. Width - 22.5 ft. Area - 4.8 acres.

SOIL FAMILY:

- *Trag-Croydon complex* (50% Trag stony loam; 30% Croydon loam; 20% other soils).
- *Curecanti family-Pathead complex* (30% Curecanti family loam; 25% Pathead extremely bouldery fine sandy loam; 25% Pathead extremely stony loam; 20% other soils).
- *Uinta-Toze families complex* (35% Uinta family loam; 30% Toze family fine sandy loam; 35% other soils).

ADJACENT UPLAND VEGETATION (looking downstream)

Left: Mtn. Brush then upward to Aspen Right: Spruce-Fir

VEGETATIVE DESCRIPTION (Dominance by Community Types)

Community Name	% of Complex	Est. Potential Comm. Name
Sedge/Grass	50	Sedge/Grass
Rush/Sedge	35	Rush/Sedge
Willow/Grass	25	Willow/Grass

SUCCESSIONAL STATUS: Mid to Late

APPARENT FORAGE TREND: n/a

ESTIMATED FORAGE PRODUCTION: 1000 lbs/ac

BEAVER ACTIVITY: probably present, but none observed

GREEN LINE (Hydric): 85%

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TABLE 3 (continued)
Eccles Creek
Middle Section

PHOTOGRAPH TAKEN: yes

LAND USE ACTIVITIES THAT COULD INFLUENCE RIPARIAN AREA: Mining
SPECIES OBSERVED:

Trees	Shrubs	Forbs	Graminoids
Abies lasiocarpa	*Rosa woodsii*	*Urtica dioica*	*Agoseris stolonifera*
Betula occidentalis	*Salix spp.*		*Bromus carinatus*
Picea pungens			*Carex aquatilis*
Picea engelmannii			*Carex spp.*
Pseudotsuga menziesii			*Deschampsia caespitosa*
Salix spp.			*Juncus spp.*
Salix lutea			

POOL ATTRIBUTES
% area in pools: < 20%
% pool area made up of pools > 2' deep: 0

AQUATIC VEGETATION
% streambed with filamentous algae: 0
% stream margin with rooted aquatic: 17

BANK TYPE & VEGETATION OVERHANG
% bank length undercut (<90°): 35
% bank length gently sloping (>135°): 65
% bank length with overhanging vegetation: 20

BANK CONDITION
% bank length vegetated, stable: 65
% bank length unvegetated, stable: 5
% bank length vegetated, unstable: 25
% bank length unvegetated, unstable: 5

CHANNEL MORPHOLOGY* (Rosgen 1996)

	Entrenchment Ratio			*Width/Depth Ratio*		
Cross Section No.	Flood-Prone Width	Bankfull Width (ft)	Ratio	Bankfull Width (ft)	Bankfull Depth (ft)	Ratio
EC-2	51.2	7.4	1.8	7.4	1.3	5.7

	Sinuosity			*Stream Classification*		
Cross Section No.	Given Reach Length (ft)	Given Valley length (ft)	Ratio	Slope (fraction)	Bed Material	Stream Class.
EC-2	2850	2800	1.0	0.048	cobble	B3a

* Data taken from Earthfax Engineering, Inc. field measurements.

NOTES:

- Recorded data on much of this section of the stream taking measurements in representative areas along it. Began sampling ant Whiskey Canyon, then sampled upstream. After, made several stops along entire length down to just above Skyline loadout area near mouth.

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TABLE 4: RIPARIAN COMPLEX DATA SHEET (LEVEL II)

COMPLEX: Riverine - Reach No. 3

WATERBODY NAME: Eccles Canyon Creek

LOCATION: Lower section (Near Skyline loadout and mouth of Eccles Canyon)

DATE: 19 December 2001

OBSERVER(S): P.D. Collins

QUAD NAME: Scofield 7.5

GEOLOGIC PARENT MATERIAL: Alluvium sandstone and shale from the Blackhawk Formation

ASPECT: East

VALLEY BOTTOM TYPE: Valley Type II

STREAM TYPE (Rosgen 1996): B3

STREAM GRADIENT: 3.6%

ELEVATION: Downstream Elev.- 7,900 ft. Upstream Elev.- 8,000 ft. Midstream Elev.7,950 - ft.

SIZE OF COMPLEX: Length - 2,500 ft. Width - 36.5 ft. Area - 2.1 acres.

SOIL FAMILY:

- *Silas - Brycan loams* - (65% Silas loam; 20% Brycan loam; 15% other soils)

ADJACENT UPLAND VEGETATION (looking downstream)

Left: Aspen Right: Spruce-Fir

VEGETATIVE DESCRIPTION (Dominance by Community Types)

Community Name	% of Complex	Est. Potential Comm. Name
River Birch/Grass	5	River Birch/Grass
Willow/Grass	20	Willow/Grass
Grass/Sedge	75	Grass/Sedge

SUCCESSIONAL STATUS: Late

APPARENT FORAGE TREND: n/a

ESTIMATED FORAGE PRODUCTION: 1,400 lbs/ac

BEAVER ACTIVITY: probably present, but none observed

GREEN LINE (Hydric): 90%

PHOTOGRAPH TAKEN: yes

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TABLE 4 (continued)
Eccles Creek
Lower Section

LAND USE ACTIVITIES THAT COULD INFLUENCE RIPARIAN AREA: Mining

SPECIES OBSERVED:

Trees	Shrubs	Forbs	Graminoids
Abies lasiocarpa	*Salix spp.*		*Agoseris stolonifera*
Betula occidentalis			*Bromus carinatus*
Picea pungens			*Calamagrostis canadensis*
Salix spp.			*Poa pratensis*
Salix exigua			

POOL ATTRIBUTES

% area in pools: 15
% pool area made up of pools > 2' deep: 0

AQUATIC VEGETATION

% streambed with filamentous algae: 0
% stream margin with rooted aquatic: 10

BANK TYPE & VEGETATION OVERHANG

% bank length undercut (<90°): 40
% bank length gently sloping (>135°): 60
% bank length with overhanging vegetation: 50

BANK CONDITION

% bank length vegetated, stable: 75
% bank length unvegetated, stable: 0
% bank length vegetated, unstable: 23
% bank length unvegetated, unstable: 2

CHANNEL MORPHOLOGY* (Rosgen 1996)

	Entrenchment Ratio			*Width/Depth Ratio*		
Cross Section No.	Flood-Prone Width	Bankfull Width (ft)	Ratio	Bankfull Width (ft)	Bankfull Depth (ft)	Ratio
EC-3	63.7	20.2	3.2	20.2	1.9	10.6

	Sinuosity			*Stream Classification*		
Cross Section No.	Given Reach Length (ft)	Given Valley length (ft)	Ratio	Slope (fraction)	Bed Material	Stream Class.
EC-3	2700	2400	1.1	0.036	cobble	B3

* Data taken from Earthfax Engineering, Inc. field measurements.

NOTES:

- Recorded data on most of this section of the stream taking measurements in representative areas along it.

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TABLE 5: RIPARIAN COMPLEX DATA SHEET (LEVEL II)

COMPLEX: Riverine - Reach No. 4

WATERBODY NAME: Mud Creek

LOCATION: Upper Section (below confluence with Eccles Creek)

DATE: 19 December 2001

OBSERVER(S): P.D. Collins

QUAD NAME: Scofield 7.5

GEOLOGIC PARENT MATERIAL: Alluvium sandstone and shale from the Blackhawk Formation

ASPECT: North

VALLEY BOTTOM TYPE: Valley Type II

STREAM TYPE (Rosgen 1996): B3c

STREAM GRADIENT: 3.0%

ELEVATION: Downstream Elev.- 7,800 ft. Upstream Elev.- 7,900 ft. Midstream Elev.- 7,700 ft.

SIZE OF COMPLEX: Length - 7,000 ft. Width - 91 ft. Area - 14.6 acres.

SOIL FAMILY:

- *Silas - Brycan loams* - (65% Silas loam; 20% Brycan loam; 15% other soils)

ADJACENT UPLAND VEGETATION (looking downstream)

Left: Spruce-Fir Right: Aspen/Sagebrush

VEGETATIVE DESCRIPTION (Dominance by Community Types)

Community Name	% of Complex	Est. Potential Comm. Name
Grass/Sedge	40	Grass/Sedge
Rush/Grass	30	Rush/Grass
Willow/Grass	20	Willow/Grass

SUCCESSIONAL STATUS: Late

APPARENT FORAGE TREND: n/a

ESTIMATED FORAGE PRODUCTION: 1,400 lbs/ac

BEAVER ACTIVITY: probably present, but none observed

GREEN LINE (Hydric): 85%

PHOTOGRAPH TAKEN: yes

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TABLE 5 (continued)
Mud Creek
Upper Section

LAND USE ACTIVITIES THAT COULD INFLUENCE RIPARIAN AREA: Mining, grazing.

SPECIES OBSERVED:

Trees	Shrubs	Forbs	Graminoids
Abies lasiocarpa	*Artemisia cana*		*Agoseris stolonifera*
Betula occidentalis	Salix spp.		*Bromus carinatus*
Picea pungens			*Juncus articus*
Salix spp.			*Triglochin maritima*
Salix exigua			

POOL ATTRIBUTES

% area in pools: 20
% pool area made up of pools > 2' deep: 5

AQUATIC VEGETATION

% streambed with filamentous algae: 5
% stream margin with rooted aquatic: 10

BANK TYPE & VEGETATION OVERHANG

% bank length undercut (<90°): 40
% bank length gently sloping (>135°): 60
% bank length with overhanging vegetation: 5%

BANK CONDITION

% bank length vegetated, stable: 80
% bank length unvegetated, stable: 5
% bank length vegetated, unstable: 14
% bank length unvegetated, unstable: 1

CHANNEL MORPHOLOGY* (Rosgen 1996)

	Entrenchment Ratio			*Width/Depth Ratio*		
Cross Section No.	Flood-Prone Width	Bankfull Width (ft)	Ratio	Bankfull Width (ft)	Bankfull Depth (ft)	Ratio
MC-1	24.6	15.5	1.6	15.5	1.2	12.9
MC-2	25.7	19.7	1.3	19.7	1.0	19.7

	Sinuosity			*Stream Classification*		
Cross Section No.	Given Reach Length (ft)	Given Valley length (ft)	Ratio	Slope (fraction)	Bed Material	Stream Class
MC-1	2750	2650	1.0	0.015	cobble	B3c
MC-2	4000	3400	1.2	0.013	cobble	B3c

* Data taken from Earthfax Engineering, Inc. field measurements.

NOTES:

- Recorded data from confluence of Eccles and Mud Creeks about 1.3 miles downstream. Did not measure on private property on this stream stretch that was north of Scofield, UT. The riparian communities of this private property were in poor shape due to overgrazing practices.
- The riparian communities were sometimes difficult to decipher from the adjacent wetlands created by springs. This was a gaining stream.

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TABLE 6: RIPARIAN COMPLEX DATA SHEET (LEVEL II)

COMPLEX: Riverine - Reach No. 5

WATERBODY NAME: Mud Creek

LOCATION: Between town of Scofield, UT and Scofield Reservoir

DATE: 19 December 2001

OBSERVER(S): P.D. Collins

QUAD NAME: Scofield 7.5

GEOLOGIC PARENT MATERIAL: Sandstone and shale alluvium from the Price River Blackhawk Fms.

ASPECT: North

VALLEY BOTTOM TYPE: Valley Type IV

STREAM TYPE (Rosgen 1996): C5

STREAM GRADIENT: 1.0%

ELEVATION: Downstream Elev.- 7650 ft. Upstream Elev.- 7680 ft. Midstream Elev.- 7580 ft.

SIZE OF COMPLEX: Length - 6000 ft. Width - ~120 ft. Area - 17 acres? (see "Notes" below).

SOIL FAMILY:
- *Silas loams* - (100% Silas loam)

ADJACENT UPLAND VEGETATION (looking downstream)

Left: Willow/Grass Right: Willow/Grass

VEGETATIVE DESCRIPTION (Dominance by Community Types)

Community Name	% of Complex	Est. Potential Comm. Name
Willow/Grass	65	Willow/Grass
Sedge'Grass	35	Sedge/Grass

SUCCESSIONAL STATUS: Early

APPARENT FORAGE TREND: n/a

ESTIMATED FORAGE PRODUCTION: 1,400 lbs/ac

BEAVER ACTIVITY: 12 beavers according to landowner.

GREEN LINE (Hydric): 70%

PHOTOGRAPH TAKEN: yes

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TABLE 6 (continued)
Mud Creek
Lower Section

LAND USE ACTIVITIES THAT COULD INFLUENCE RIPARIAN AREA: Mining, Grazing

SPECIES OBSERVED:

Trees	Shrubs	Forbs	Graminoids
Salix spp.	*Salix spp*		*Agoseris stolonifera*
			Bromus carinatus
			Juncus articus
			Triglochin maritima
			Poa pratensis

POOL ATTRIBUTES

% area in pools: 35
% pool area made up of pools > 2' deep: 5

AQUATIC VEGETATION

% streambed with filamentous algae: 0
% stream margin with rooted aquatic: 15

BANK TYPE & VEGETATION OVERHANG

% bank length undercut (<90°): 25
% bank length gently sloping (>135°): 75
% bank length with overhanging vegetation: 60

BANK CONDITION

% bank length vegetated, stable: 60
% bank length unvegetated, stable: 20
% bank length vegetated, unstable:10
% bank length unvegetated, unstable:10

CHANNEL MORPHOLOGY** (Rosgen 1996)

	Entrenchment Ratio			*Width/Depth Ratio*		
Cross Section No	Flood-Prone Width	Bankfull Width (ft)	Ratio	Bankfull Width (ft)	Bankfull Depth (ft)	Ratio

	Sinuosity			*Stream Classification*		
Cross Section No	Given Reach Length (ft)	Given Valley length (ft)	Ratio	Slope (fraction)	Bed Material	Stream Class

** No field measurements taken by Earthfax Engineering, Inc. on this reach of the stream.

NOTES:

- Recorded data on most of this section of the stream taking measurements in representative areas along it.

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DISCUSSION

The Level II Riparian Evaluation provides much biological, ecological and other environmental data. A number of factors can influence changes in stream stability including flow rates and existing riparian vegetation.

Riparian Vegetation

Riparian vegetation can play a major role in the stability of streams. Changes in vigor, composition, diversity, vegetative cover, rooting depth, and density of plants can significantly influence stability of streambanks. The role of vegetation can be more important in some stream types when compared to others. For example, riparian vegetation influence appears to be greater in C stream type and less in A stream type (Rosgen 1996). Also width to depth ratios generally increase in most streams if the riparian vegetation is converted from woody to herbaceous species making them more susceptible to bank erosion. The resultant channel instability often also means a degradation of fish habitat.

There were no obvious signs of *severe* riparian degradation (i.e. mass wasting composed of earth and rooting masses or vegetative cover) at the time of the study. However, there is little doubt that some degradation has occurred with the significant increase in flows and as indicated by the estimated bank percentage that appeared "unstable" (15-25%). Areas such as shown in Figures I and J suggest that undercutting is occurring.

Flooding in areas such as shown in Figure H, if sustained for an atypical period of time, can also influence vegetation composition and patterns. Often plant species – especially those in riparian and wetland communities – have adapted to the relative aerobic and anaerobic conditions. The oxidization and reduction principles are greatly dependant on the amount of soil saturation and duration of time these soils are saturated. Therefore, sustained flows that saturate or flood areas on Eccles and Mud Creek can influence the plant community composition and structure. This does not mean the changes will all be negative impacts, but if the high flows are maintained for much longer or an indefinite period of time, it would most likely mean instability and successional changes to the patterns of the riparian vegetation.

Width to Depth Ratios

The distribution of energy is different depending on the stream type. For example, when the width to depth ratio increases (or a channel is wider and shallower), the energy of the water is placed more on the banks. This means bank stress is increased thus creating more erosion in these areas (Rosgen 1996). Most of the reaches surveyed in Eccles Creek had relatively low width/depth ratios whereas this ratios increased significantly in Mud Creek suggesting this stream may be less stable.

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Channel Materials

Channel materials refer to the surface particles that make up both the bank and stream channel. These materials obviously can have an impact on stability of a given stream reach. Earthfax Engineering suggested that the banks and channels are both structurally and erosionally stable at the rates of mine-water discharge that were evaluated in their report (Earthfax Engineering 2001). The rates of mine-water discharge analyzed in their study were well within the high-flow limits that the water has been flowing since August 2001.

Stream Types

Stream types of Eccles Creek were mostly B3 according to Rosgen's classification methods: This stream type is generally associated with residual material derived from resistant rock types or from alluvial or colluvial deposition. These streams have channel materials composed primarily of a cobbles with a few boulders and *usually represent stable channels*. Moreover, the bed and bank materials of B3 streams are generally stable and do not carry large amounts of sediments during high flows (Rosgen 1996). [A companion study of the macro-invertebrates of Eccles Creek (in progress) also substantiate these characteristics about the stream]. This stream type is usually characterized by a series of rapids and irregularly spaced scour pools. Organic material as observed especially in the upper reaches of Eccles Creek can contribute important habitat in these stream types.

Although no quantitative measurements for stream profiles were measured for this area, the lower reaches of Mud Creek near Scofield Reservoir could be classified as a C5 type stream. This stream type displays a high width to depth ratio, is composed of sandy channel and bank material and is susceptible to shifts in both lateral and vertical stability caused by changes in flow (Rosgen 1996). However, vegetation can be a major influence in these streams and lower Mud Creek is well-vegetated with both woody and herbaceous plant species.

CONCLUSIONS

A number of factors can influence a change in stream stability including flow rates and existing riparian vegetation. With appropriate methods it can be possible to determine a stream's existing condition, its departure from baseline condition and predict its potential for recovery.

There have been some changes in the riparian vegetation at Eccles Creek and Mud Creek. It is too early to determine how much change, but evidence of flooding and bank erosion have been observed and suggest the potential for additional future impacts. However, the bank and channel stability study conducted by Earthfax Engineering, Inc. state that the banks and channels in these areas are relatively stable – certainly an argument for less future impact to the riparian vegetation along these streams.

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Some of the data suggest that to-date there may have been little impact to the stream by the increased flows from the mine. Yet, it is difficult to imagine due to the mere volume of the additional discharges and its consequences to the normal flow regimes, that there will be little or no impact to these streams over time. It may be that the excess mine waters will be depleted soon at the Skyline Mine and flows will return to more normal rates. If this happens by Spring 2002, there is the likelihood that the recent increased flows ultimately had little negative impact on the associated plant and wildlife communities of Eccles Creek and Mud Creek.

If the present high flows to Eccles Creek and Mud Creek continue, the studies done to-date provide excellent data to conduct future companion studies to quantify these changes. The riparian study conducted by Mt. Nebo Scientific, Inc. and the geotechnical study conducted by Earthfax Engineering, Inc. provide excellent preliminary data and baseline information for future monitoring and companion studies on Eccles Creek and Mud Creek. Specifically, the information provided in this Level II Riparian Evaluation can be used for the more intensive Level III Riparian Evaluation when quantitative vegetation data is recorded to describe the current status of the vegetation, quantify its potential, provide defensible quantitative data sets, and identify impacts to the communities over time. The Level III Riparian Evaluation would be done during the growing season. Similarly, if the uncertainty and duration of the high stream flows persist, the stream geomorphology measurements can be used as a basic physical stream template that could be employed for additional studies such as a "Level III: Assessment of Stream Condition and Departure From it Potential" as described by Rosgen (1996) and other hydrological, biological and ecological studies if determined necessary.

Additionally, other streams in the area that have not received the increased flows and are shown to have similar hydrologic, geologic and biological patterns could be used for baseline comparisons as a means to monitor future impacts of flow changes in Eccles Creek and Mud Creek.

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FIGURES - Color Photographs of Representative Stream Reaches

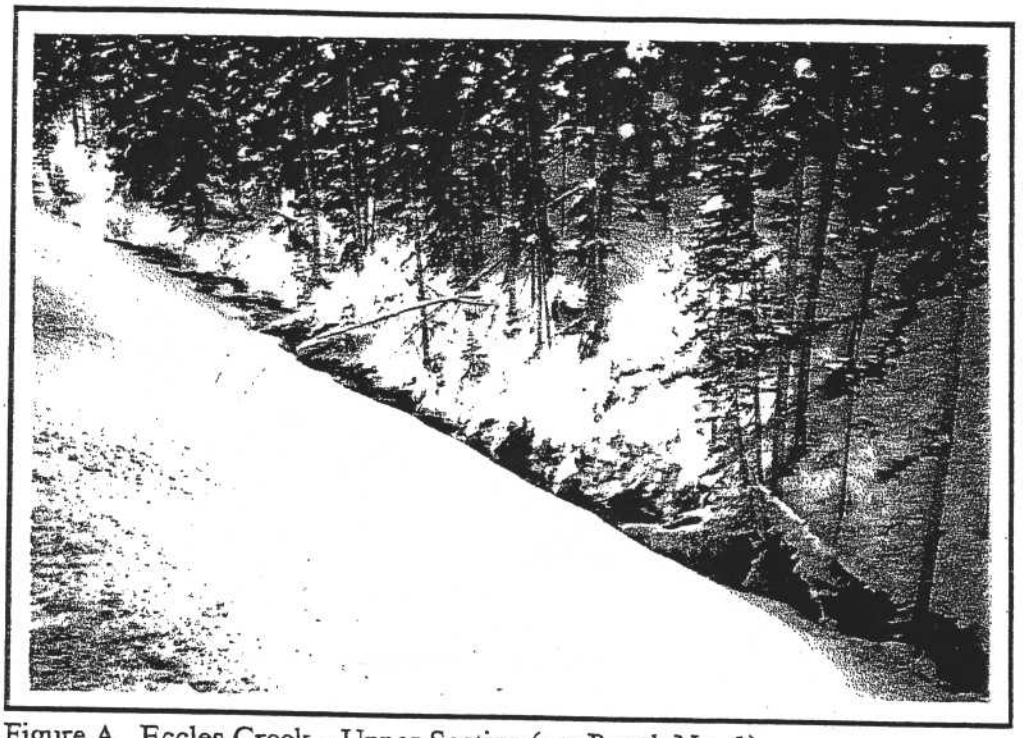

Figure A. Eccles Creek - Upper Section (see Reach No. 1)

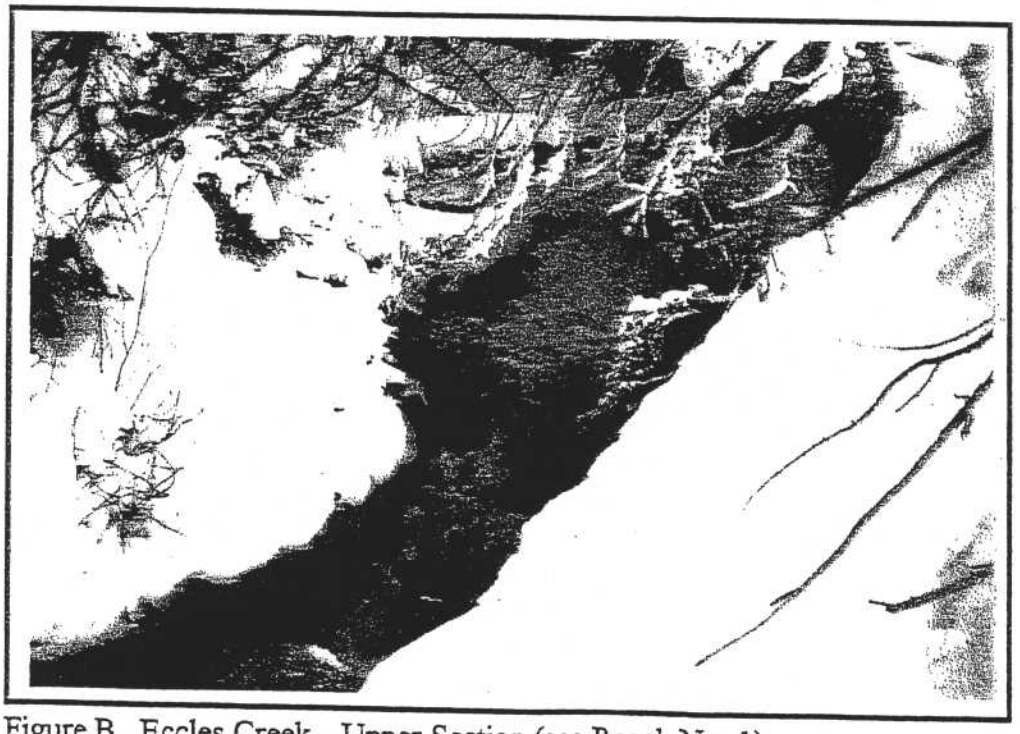

Figure B. Eccles Creek - Upper Section (see Reach No. 1)

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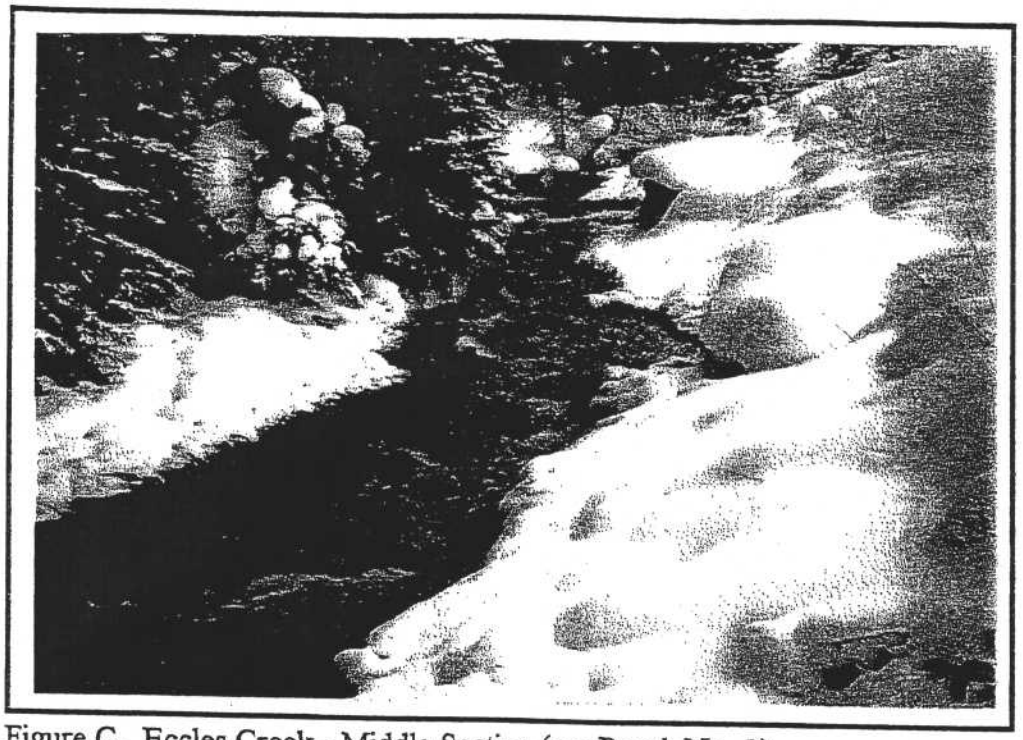

Figure C. Eccles Creek - Middle Section (see Reach No. 2)

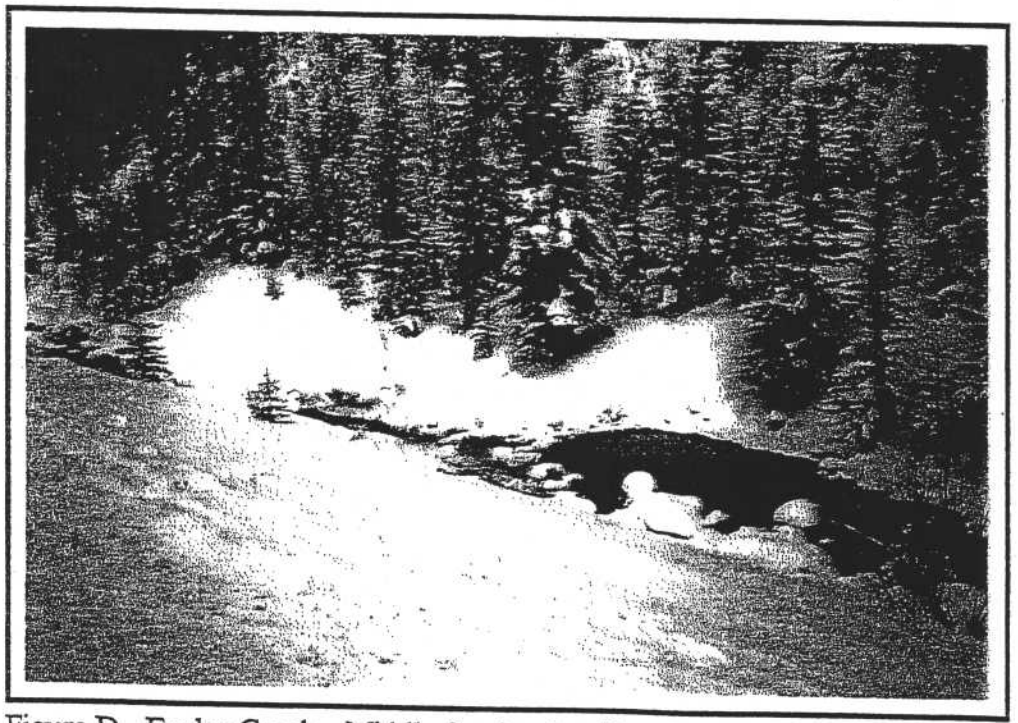

Figure D. Eccles Creek - Middle Section (see Reach No. 2)

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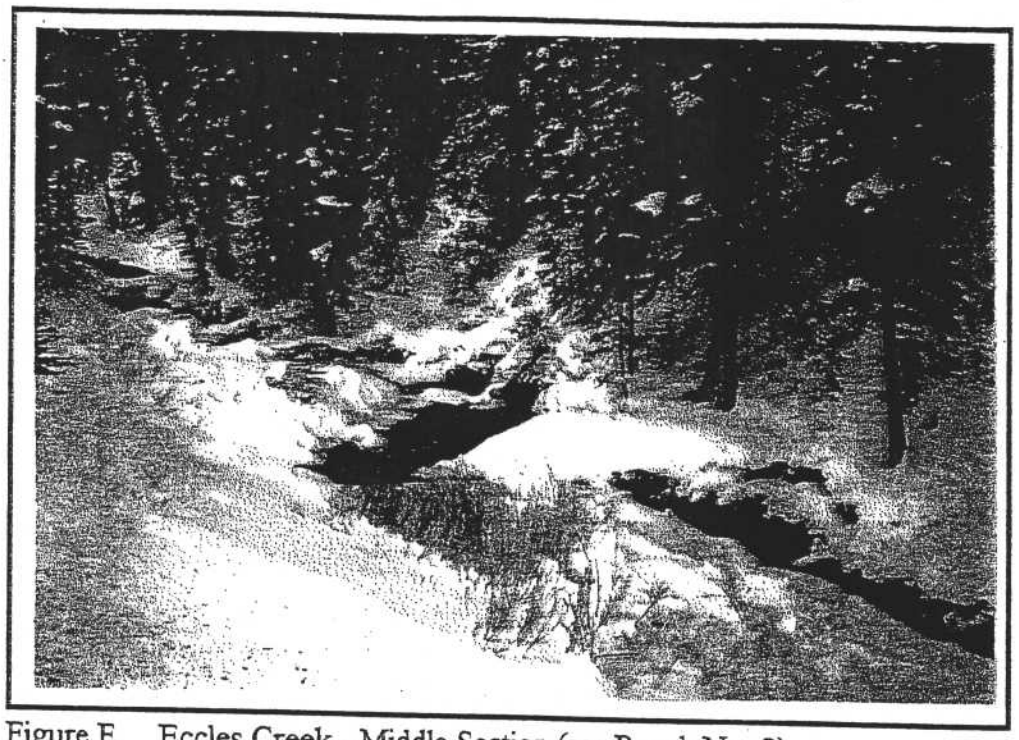

Figure E. Eccles Creek - Middle Section (see Reach No. 2)

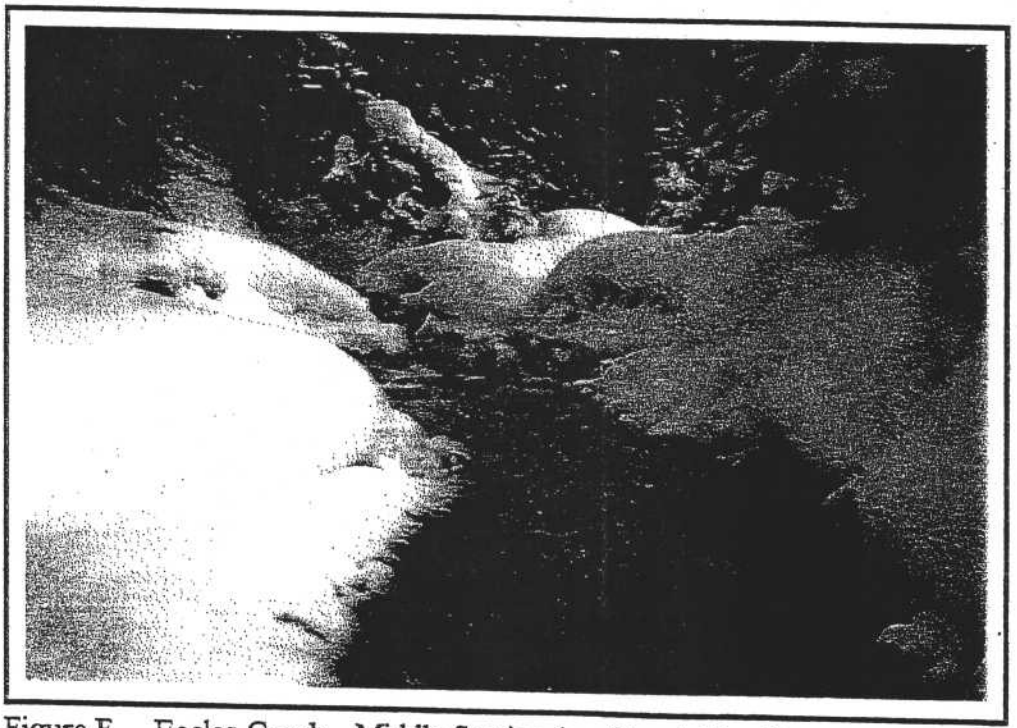

Figure F. Eccles Creek - Middle Section (see Reach No. 2)

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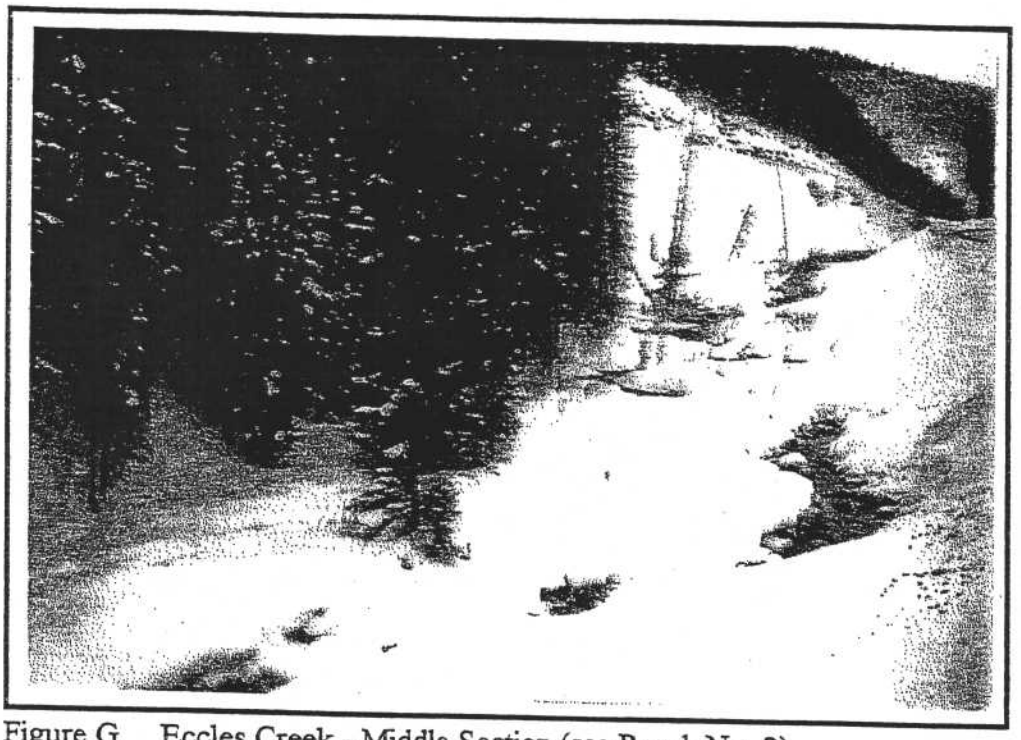

Figure G. Eccles Creek - Middle Section (see Reach No. 2)

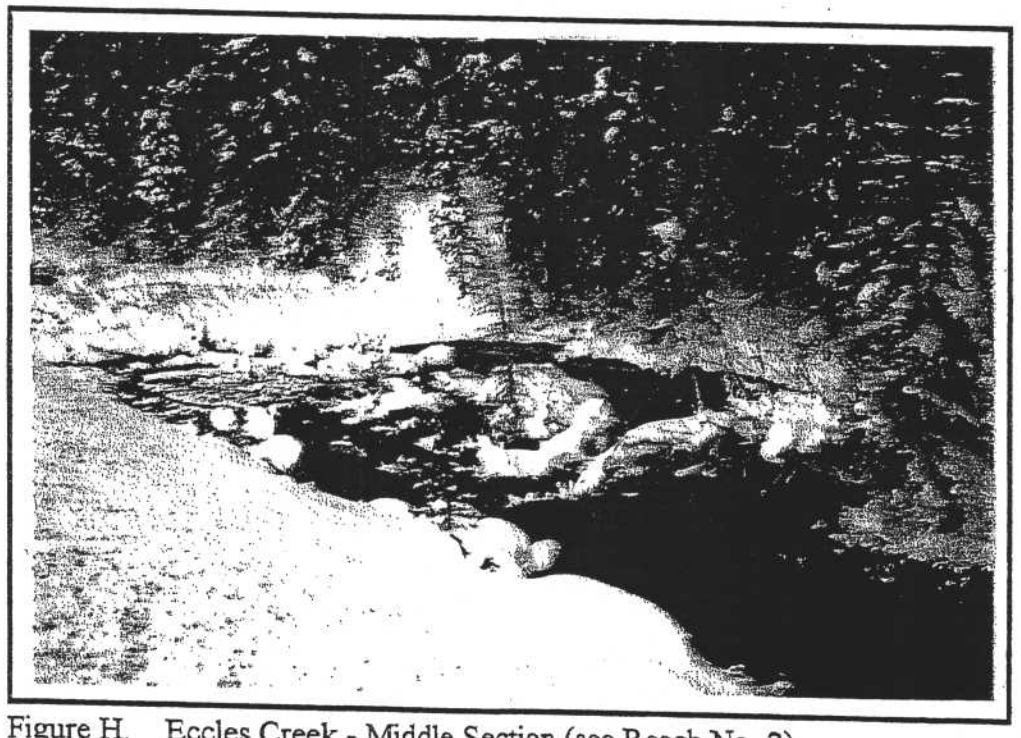

Figure H. Eccles Creek - Middle Section (see Reach No. 2)

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DEC 0 2 2002

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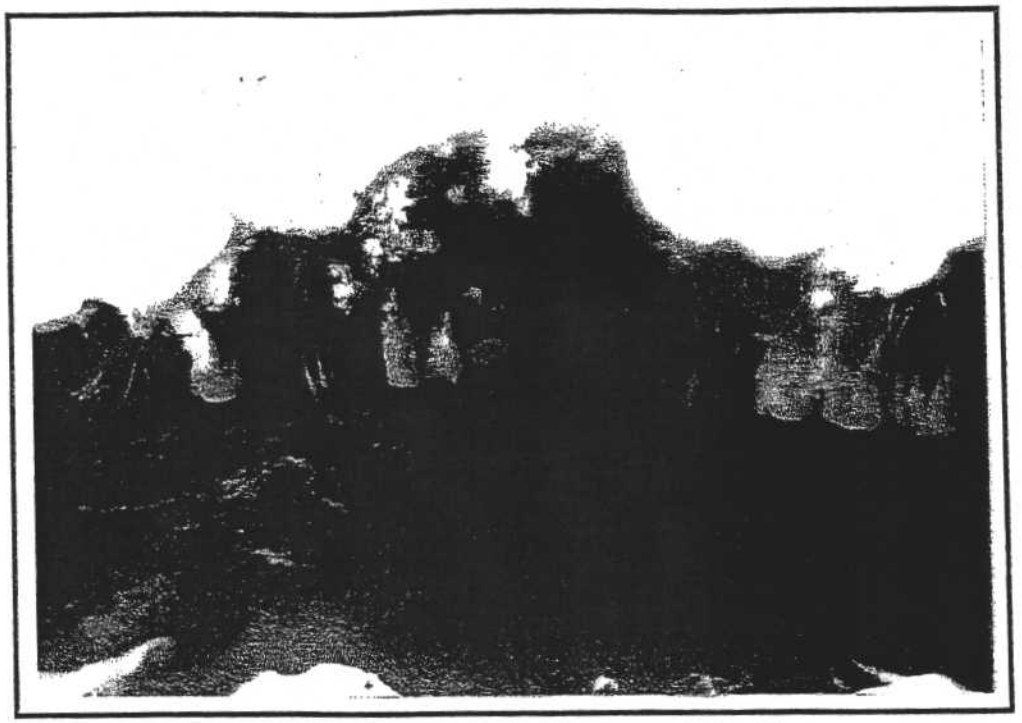

Figure I. Eccles Creek - Middle Section (see Reach No. 2)

Figure J. Eccles Creek - Middle Section (Reach No. 2)

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DEC 0 2 2002

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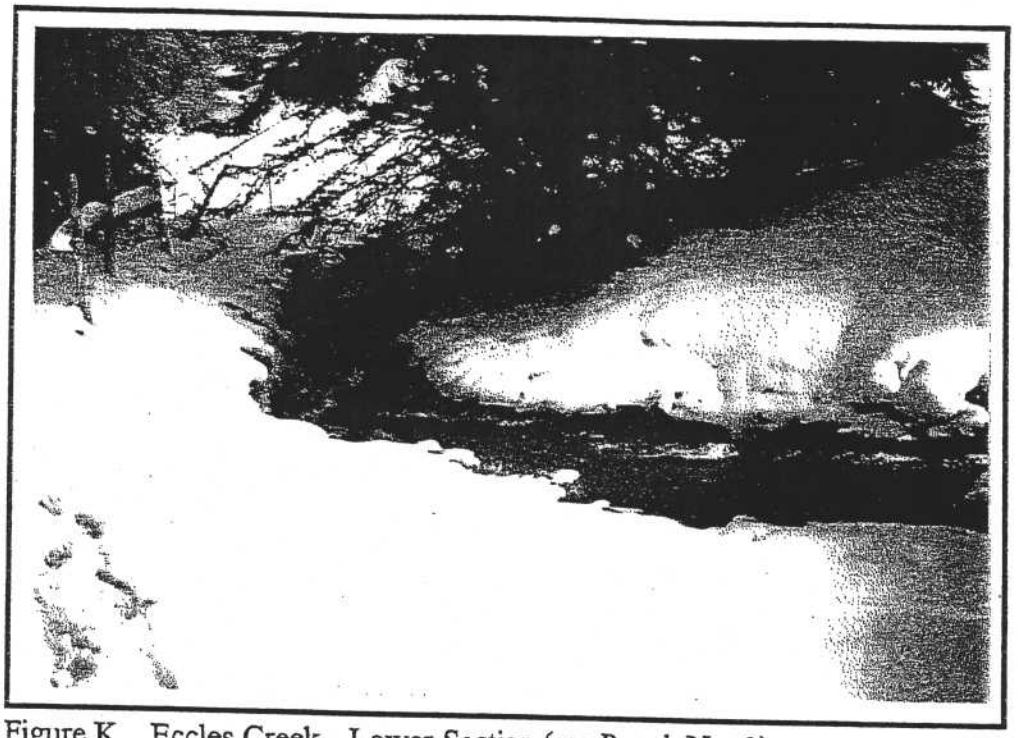

Figure K. Eccles Creek - Lower Section (see Reach No. 3)

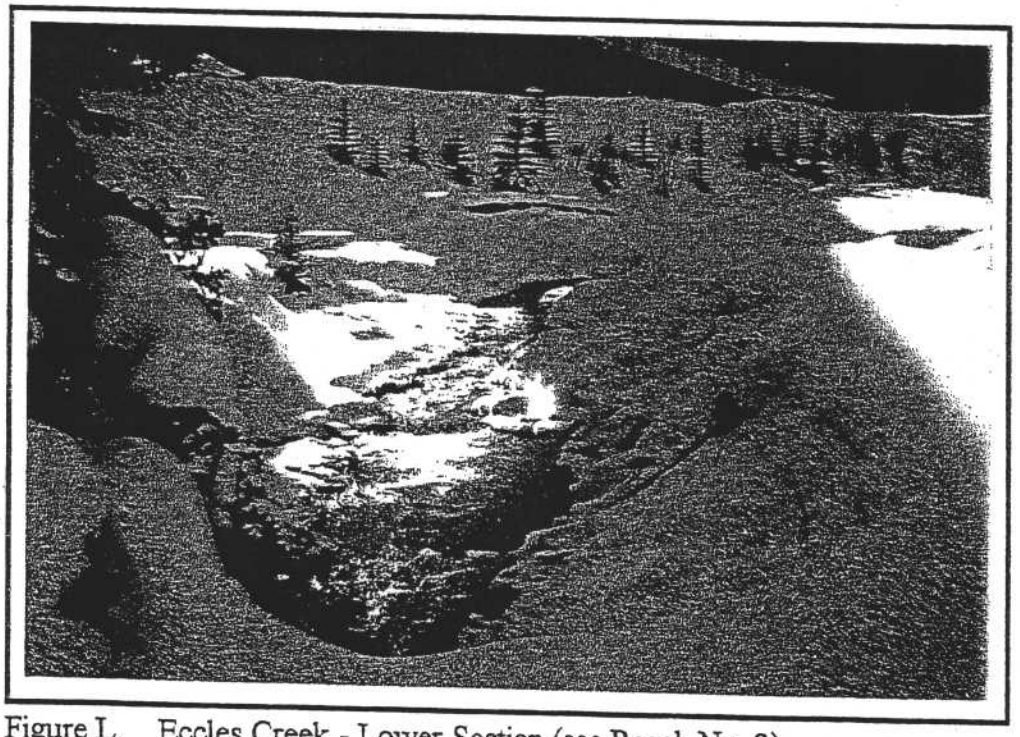

Figure L. Eccles Creek - Lower Section (see Reach No. 3)

INCORPORATED

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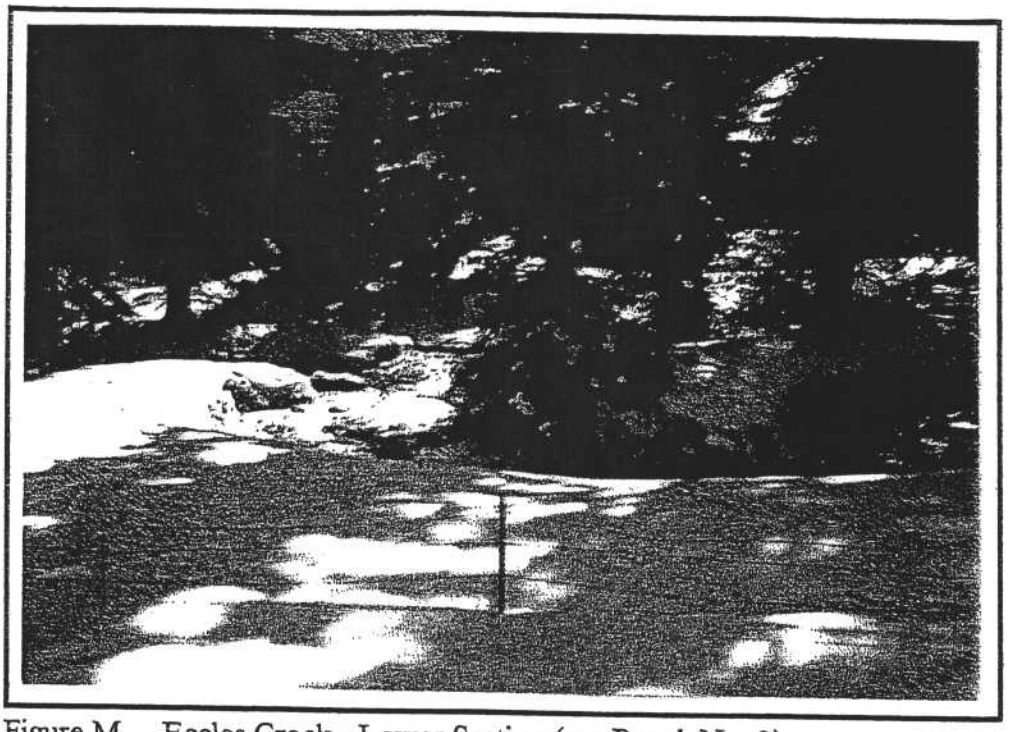

Figure M. Eccles Creek - Lower Section (see Reach No. 3)

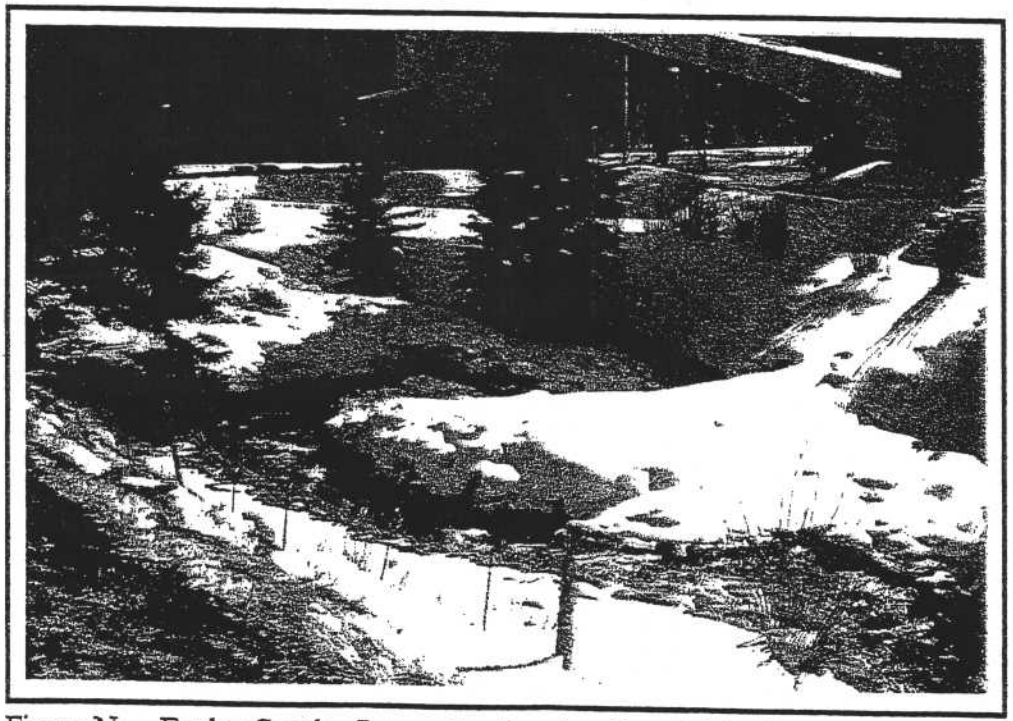

Figure N. Eccles Creek - Lower Section (see Reach No. 3)

INCORPORATED

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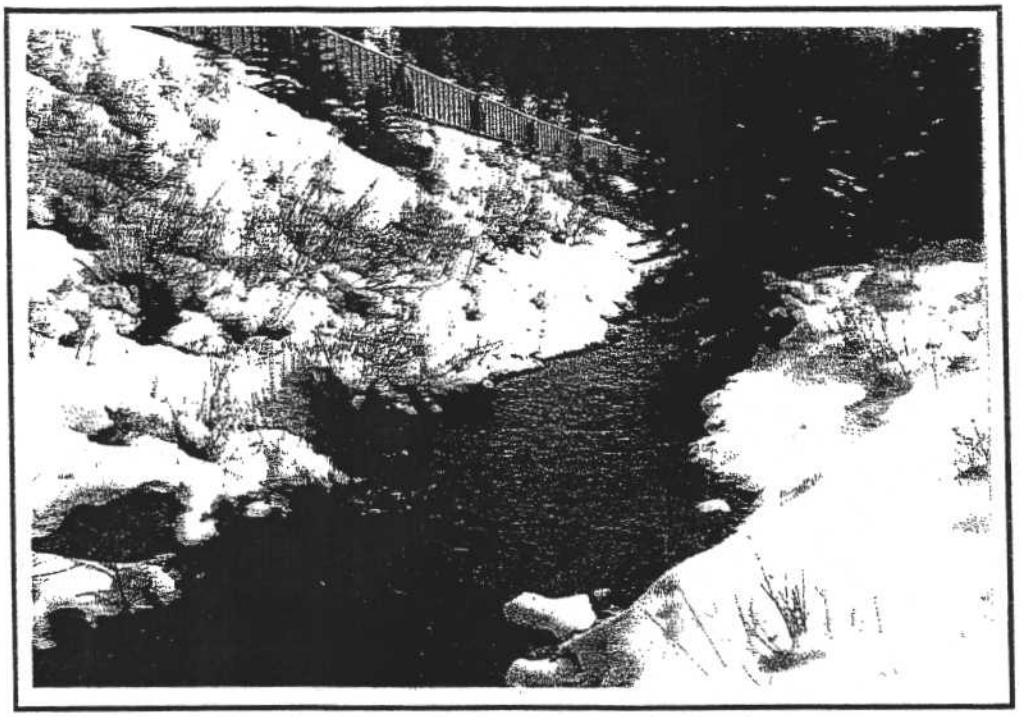

Figure O. Mud Creek - Upper Section (see Reach No. 4)

Figure P. Mud Creek - Middle Section (see Reach No. 4)

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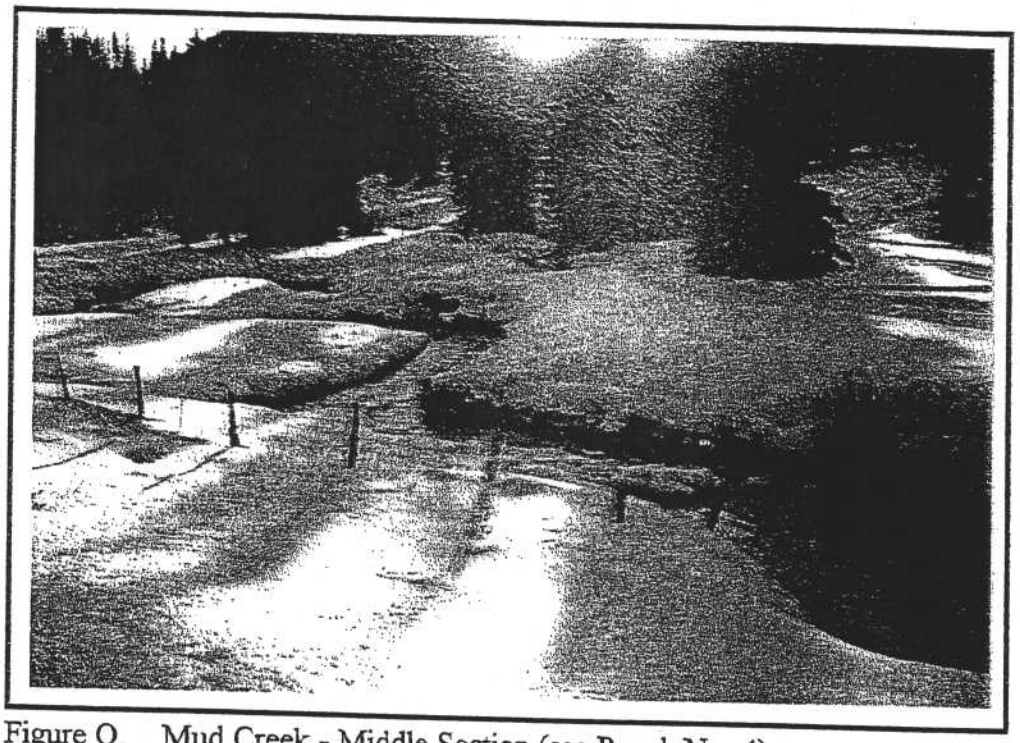

Figure Q. Mud Creek - Middle Section (see Reach No. 4)

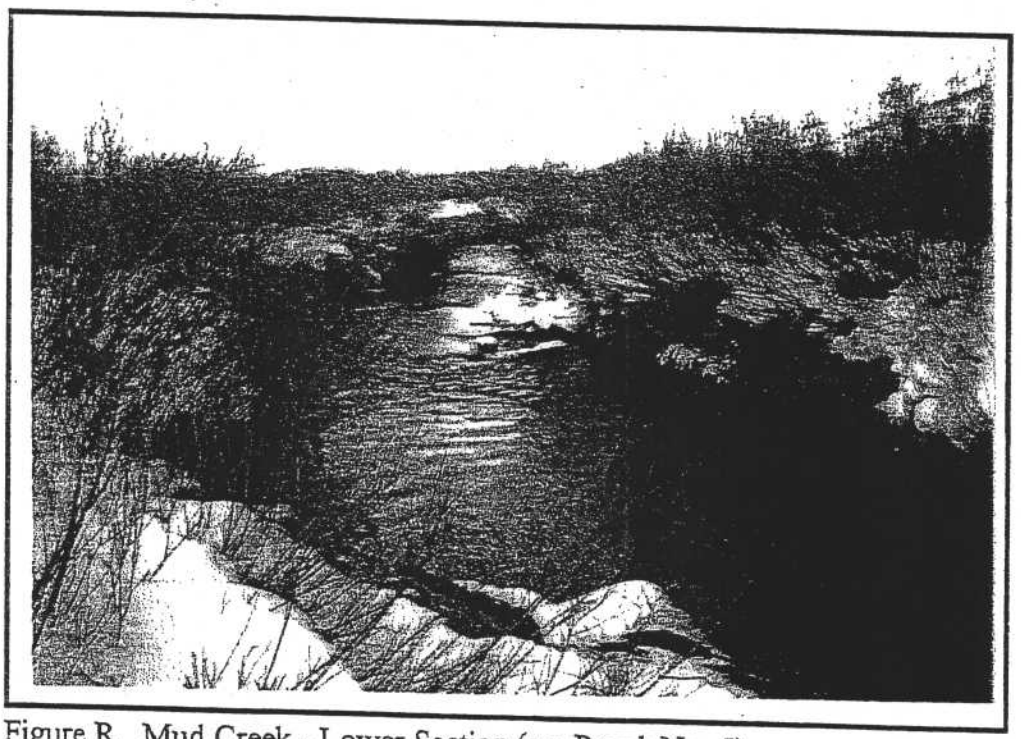

Figure R. Mud Creek - Lower Section (see Reach No. 5)

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APPENDIX B

Results of Soil Laboratory Analyses

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SUMMARY OF TEST DATA

HOLE NO./ SAMPLE NO.	DEPTH BELOW GROUND SURFACE	STANDARD VOID RATIO e	IN-PLACE DENSITY		GRADATION			ATTERBERG LIMITS			SOIL CLASSIFICATION UNIFIED SYSTEM
			BULK SPECIFIC GRAVITY	MOISTURE PERCENT	% SAND	% GRAVEL	% PASSING NO. 200 SIEVE	L.L.	P.L.	P.I.	
EC-1S	NA			21.0	47.0	31.0	22.0	NON-PLASTIC			SM
EC-2S	NA	2.2	2.454	23.0	37.0	43.0	20.0	NON-PLASTIC			SM
EC-3S	NA			36.0	50.0	0.0	50.0	40.7	-	-	SM-ML
MC-1S	NA	2.7	2.575	28.0	37.0	0.0	63.0	30.7	31.1	-	ML
MC-2S	NA			25.0	37.0	0.0	63.0	34.0	21.6	12.4	CL
MC-3S	NA	2.8	2.499	49.0	39.0	7.0	54.0	38.6	-	-	ML-SM

SKYLINE MINES DISCHARGE STUDY
EARTHFAX ENGINEERING

INCORPORATED
DEC
DIV OF OIL GAS & MINING

Project: Skyline Mines Discharge Study
Client: Earthfax Engineering
Project #: 401356

LABORATORY SUMMARY

	SPECS	
Sample Location		EC-1S
Laboratory Number		277
Sample Type		Baggie
Date Received		11/27/01
Sampled By		Earthfax
Method Used		ASTM C136, C566, C117 & D4318
Plastic Limit		The sample was non-plastic

GRADING

SIEVE SIZE	% PASSING	SPECS	
1/2"			100.0%
3/8"			77.7%
#4			69.4%
#8			63.4%
#16			55.5%
#30			49.7%
#50			44.1%
#100			34.7%
#200			21.9%

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CMT ENGINEERING LABORITORIES

Project: Skyline Mines Discharge Study
Client: Earthfax Engineering
Project #: 401356

LABORATORY SUMMARY

		SPECS
Sample Location		EC-2S
Laboratory Number		277
Sample Type		Baggie
Date Received		11/27/01
Sampled By		Earthfax
Method Used		ASTM C136, C566, C117, D4318
Plastic Limit		The sample was granular and non-plastic
GRADING		
SIEVE SIZE	% PASSING	
1/2"		100.0%
3/8"		66.8%
#4		56.6%
#8		50.4%
#16		44.9%
#30		41.1%
#50		35.3%
#100		25.5%
#200		19.7%

CMT ENGINEERING LABORATORIES

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NOV 30 2001
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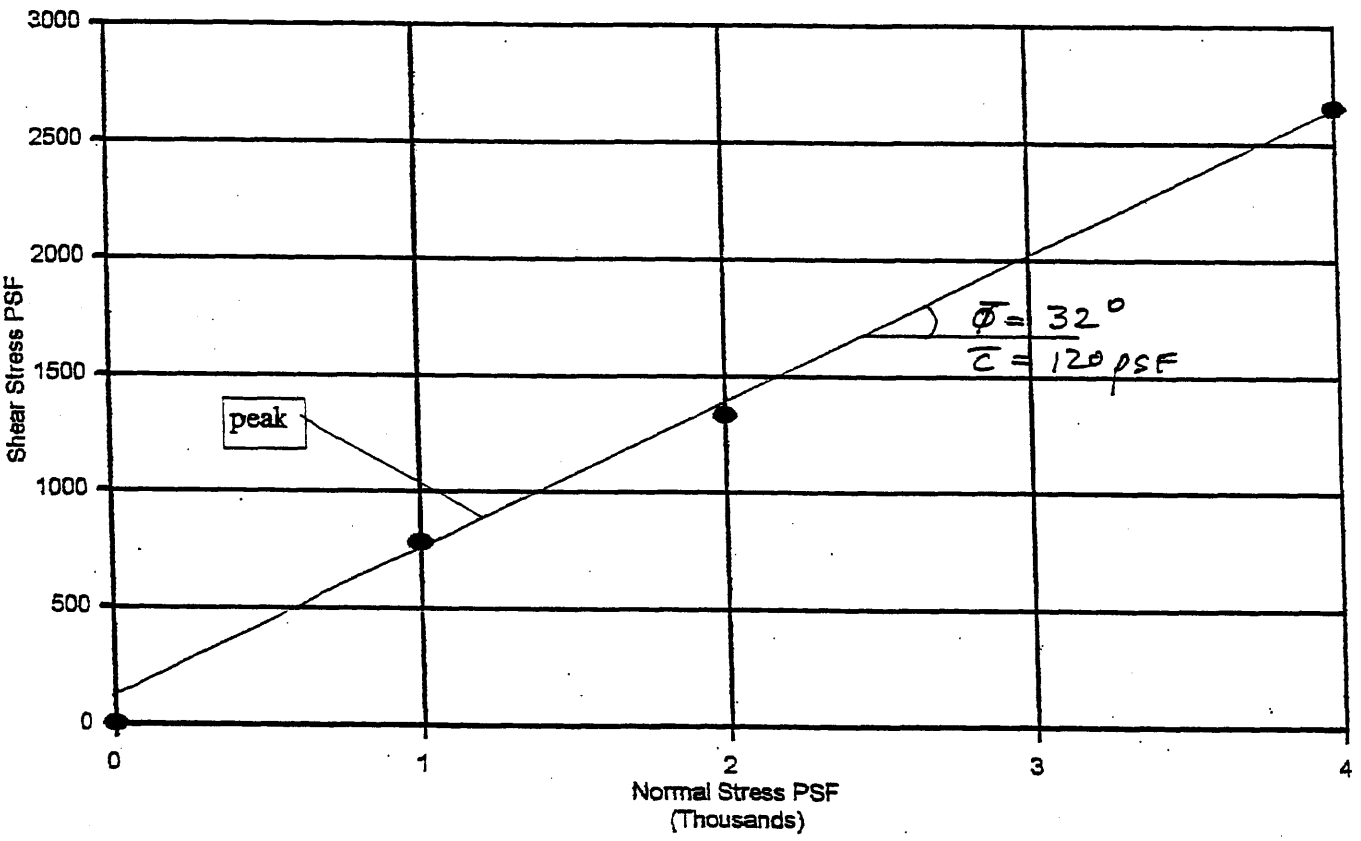
DIRECT SHEAR - Consolidated Drained

EC-2 S

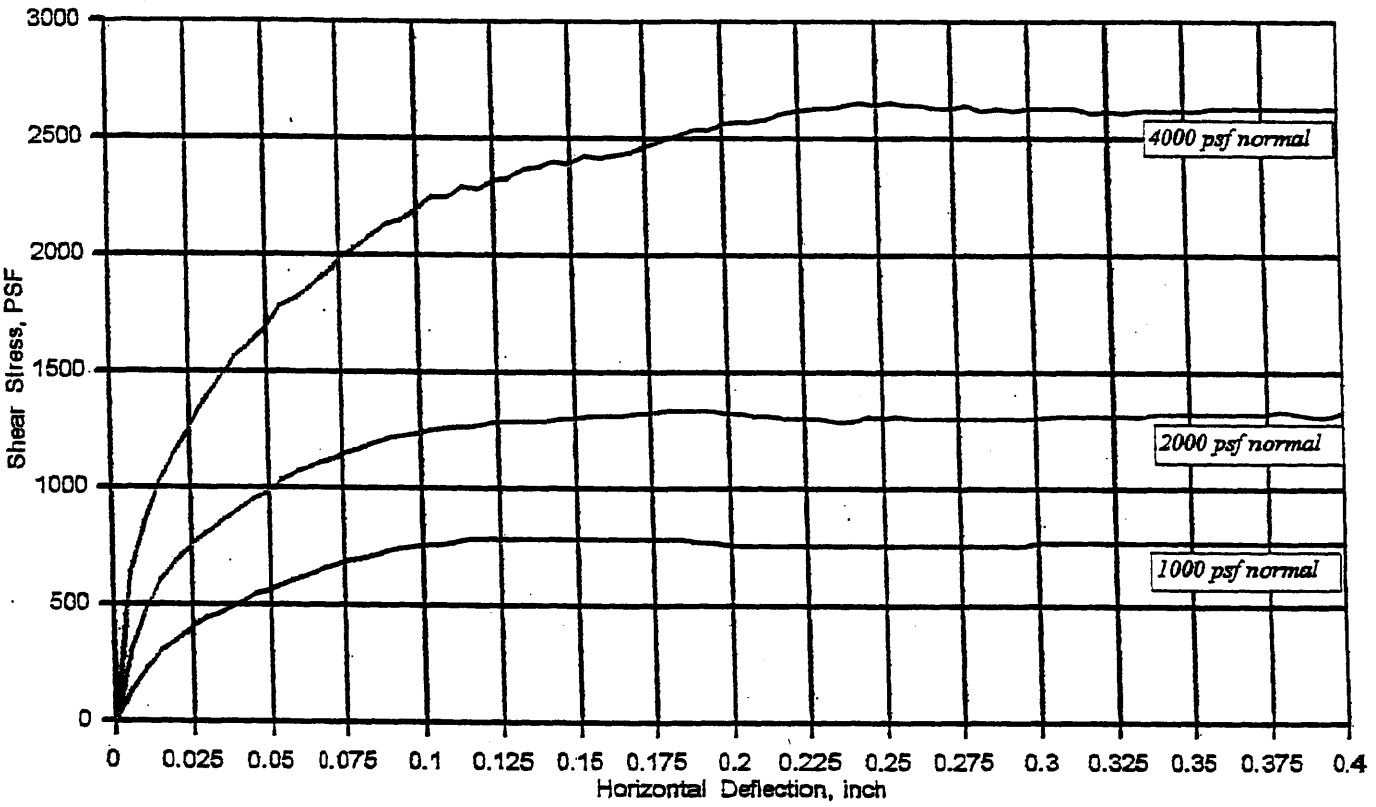


INCORPORATED

DIV OF OIL GAS & MINING

Direct Shear

Sample EC-2 S



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DIV OF OIL GAS & MINING

Project: Skyline Mines Discharge Study
Client: Earthfax Engineering
Project #: 401356

LABORATORY SUMMARY

	SPECS	
Sample Location		EC-3S
Laboratory Number		277
Sample Type		Baggie
Date Received		11/27/01
Sampled By		Earthfax
Method Used		ASTM C136, C566, C117 & D4318
Plastic Limits		The sample was non-plastic
GRADING		
SIEVE SIZE	% PASSING	
3/8"		100.0%
#4		99.8%
#8		99.2%
#16		97.5%
#30		95.2%
#50		91.3%
#100		75.8%
#200		49.5%

CMT ENGINEERING LABORATORIES

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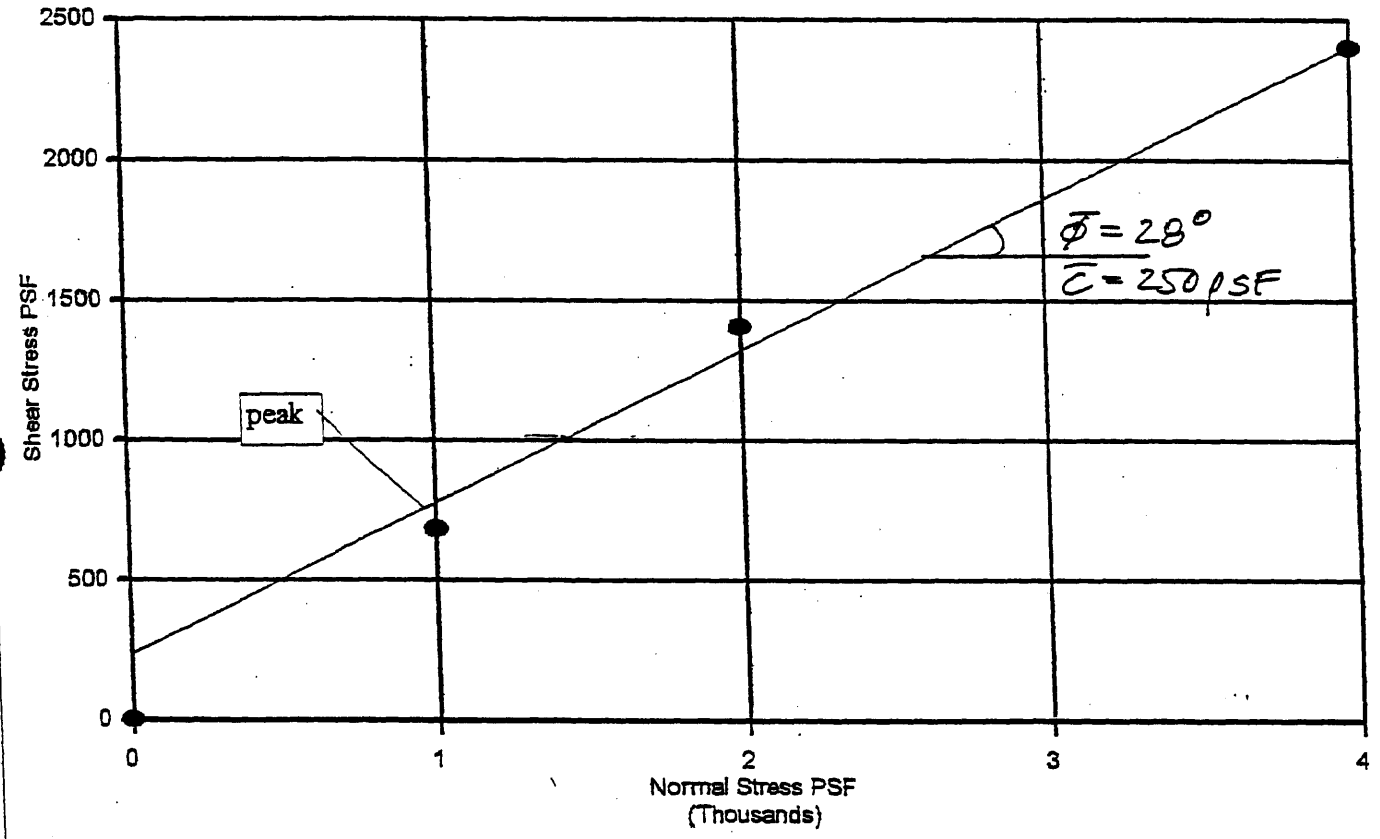
DIRECT SHEAR - Consolidated Drained

EC-3 S



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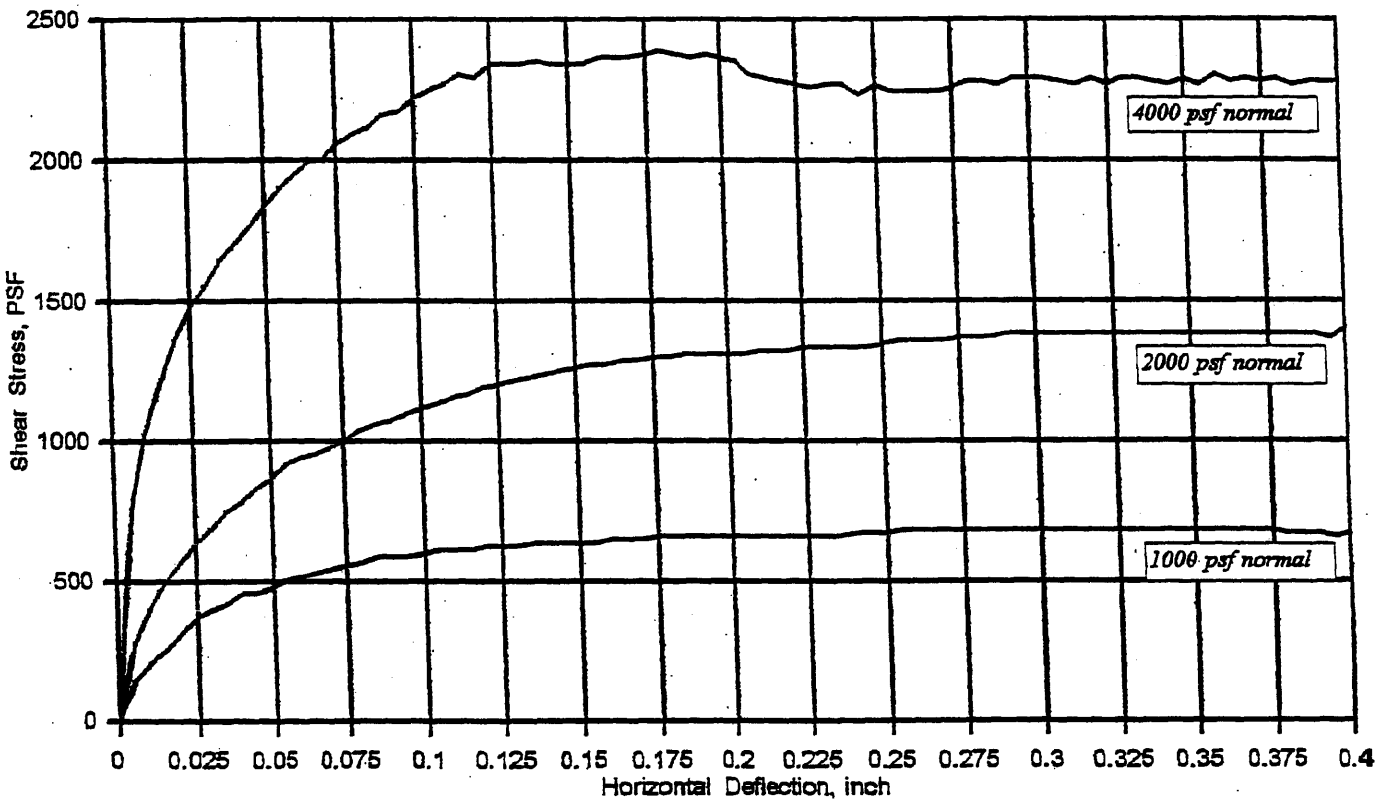
Direct Shear

Sample EC-3 S



INCORPORATED

DEC

DIV OF OIL GAS & MINING

Project: Skyline Mines Discharge Study
Client: Earthfax Engineering
Project #: 401356

LABORATORY SUMMARY

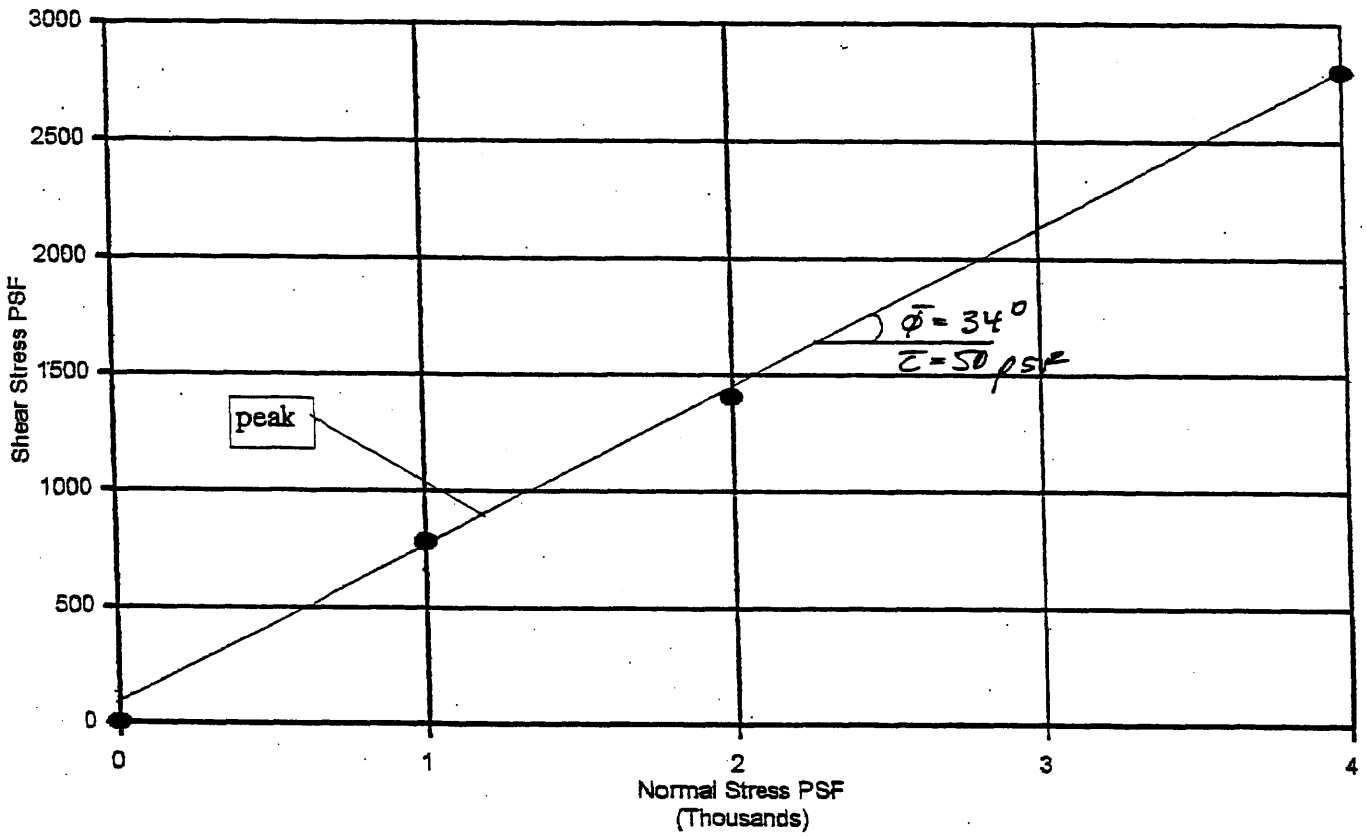
	SPECS	
Sample Location		MC-1S
Laboratory Number		277
Sample Type		Baggie
Date Received		11/27/01
Sampled By		Earthfax
Method Used		ASTM C136, C566, C117 & D4318
Plastic Limit	LL	PL
	30.7	31.1
GRADING		
SIEVE SIZE	% PASSING	
#16		100.0%
#30		98.1%
#50		95.8%
#100		82.1%
#200		62.7%

CMT ENGINEERING LABORATORIES

DIV OF OIL GAS & MINING
INCORPORATED

DIRECT SHEAR - Consolidated Drained

MC-1 S



INCORPORATED

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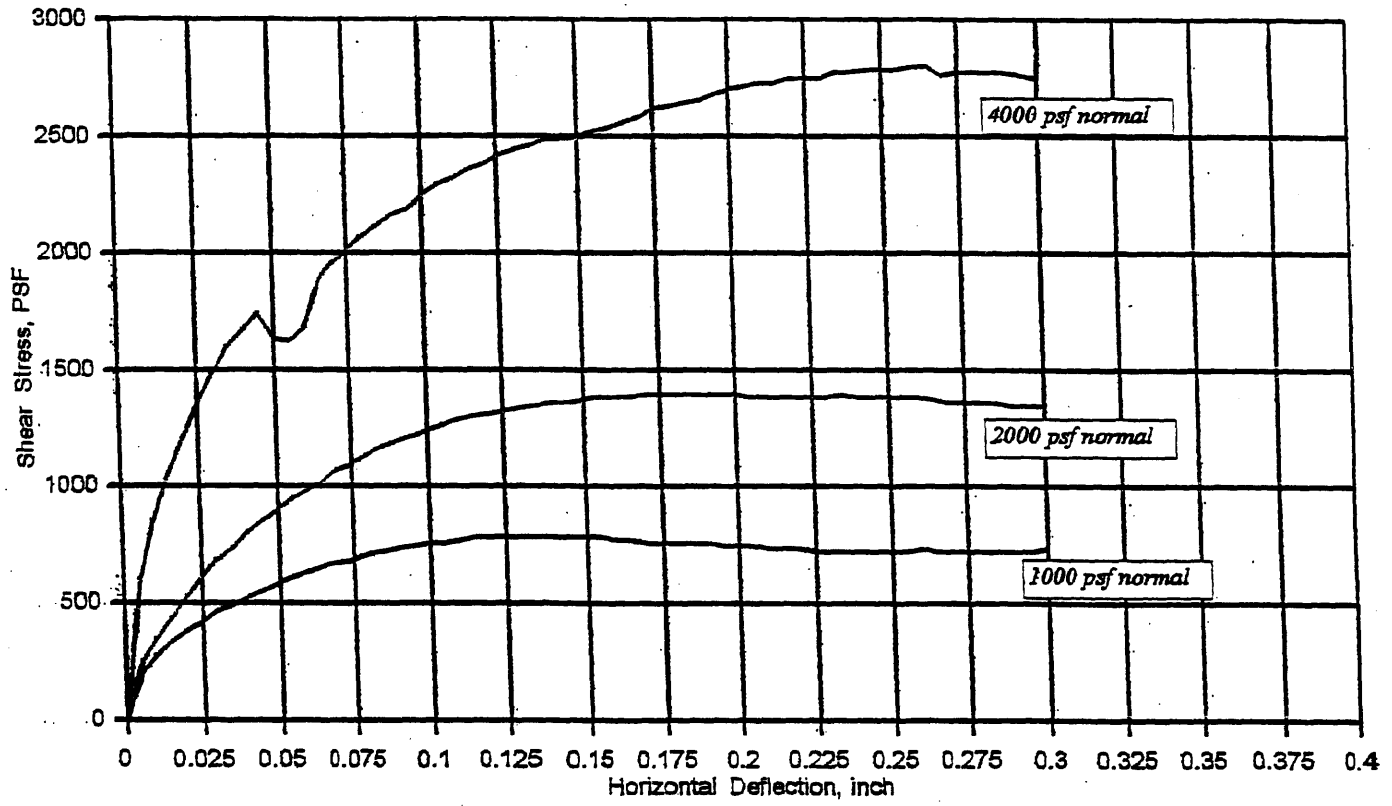
Direct Shear

Sample MC-1 S



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Project: Skyline Mines Discharge Study
Client: Earthfax Engineering
Project #: 401356

LABORATORY SUMMARY

	SPECS		
Sample Location		MC-2S	
Laboratory Number		277	
Sample Type		Baggie	
Date Received		11/27/01	
Sampled By		Earthfax	
Method Used		ASTM C136, C566, C117 & D4318	
Plastic Limits	LL	PL	PI
	34.0	21.6	12.4
GRADING			
SIEVE SIZE / % PASSING			
3/8"		100.0%	
#4		99.6%	
#8		99.3%	
#16		98.5%	
#30		94.5%	
#50		91.1%	
#100		81.9%	
#200		63.4%	

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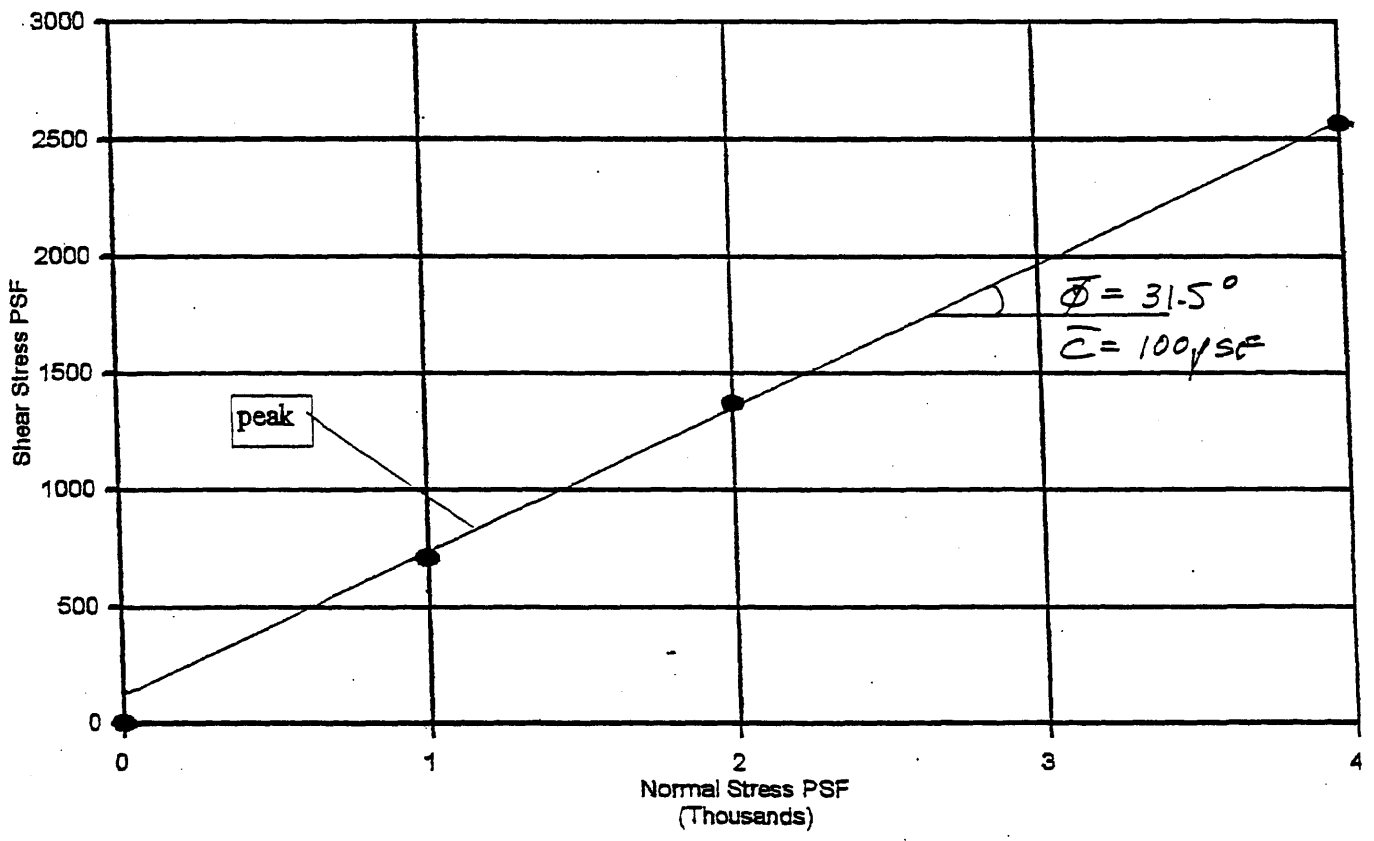
DIRECT SHEAR - Consolidated Drained

MC-2 S

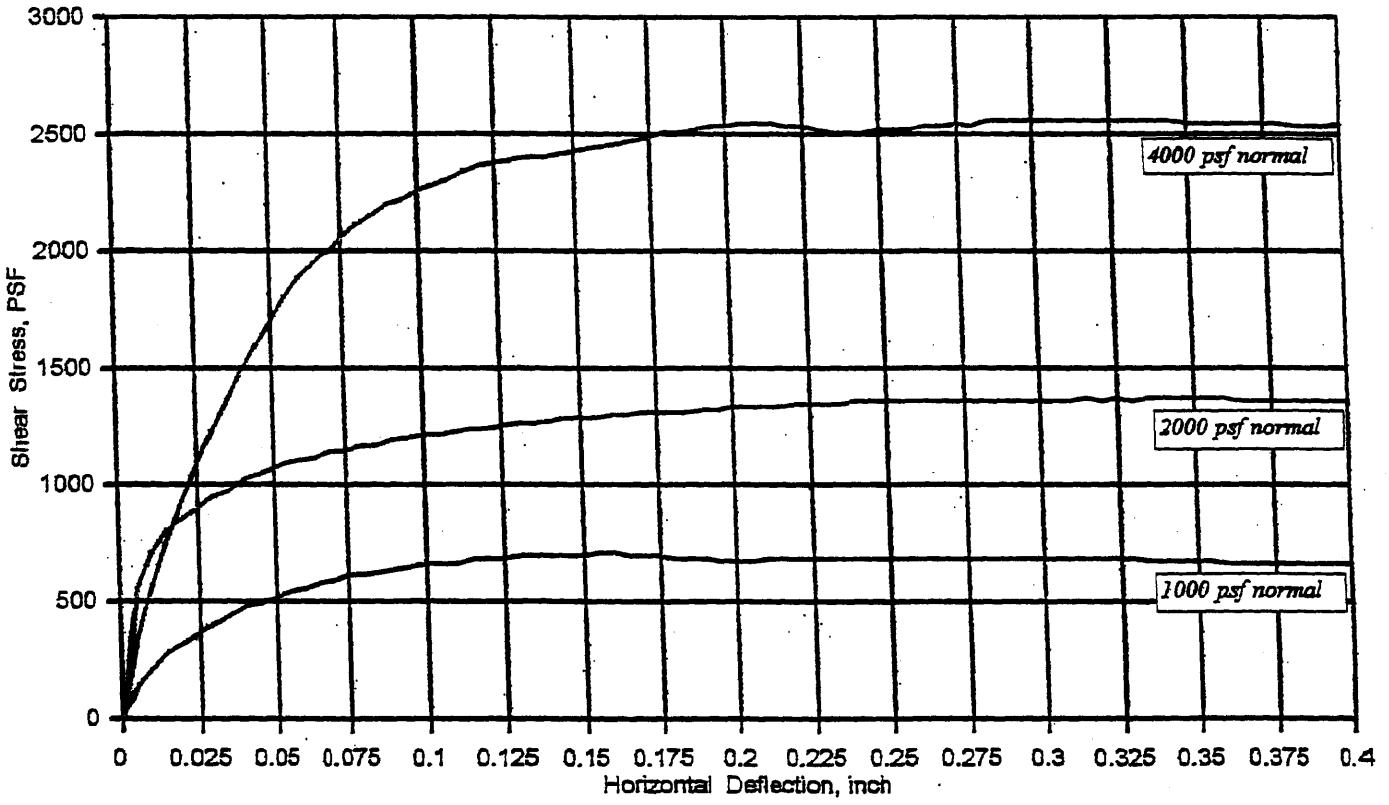


RECEIVED

DIV OF OIL GAS & MINING

Direct Shear

Sample MC-2 S



INCORPORATED

DIV OF OIL GAS & MINING

Project: Skyline Mines Discharge Study
Client: Earthfax Engineering
Project #: 401356

LABORATORY SUMMARY

	SPECS		
Sample Location		MC-3S	
Laboratory Number		277	
Sample Type		Baggie	
Date Received		11/27/01	
Sampled By		Earthfax	
Method Used		ASTM C136, C566, C117 & D4318	
Plastic Limits		The sample was non-plastic	
GRADING			
SIEVE SIZE	% PASSING		
1/2"		100.0%	
3/8"		96.3%	
#4		93.0%	
#8		90.6%	
#16		88.3%	
#30		84.2%	
#50		80.0%	
#100		70.1%	
#200		54.3%	

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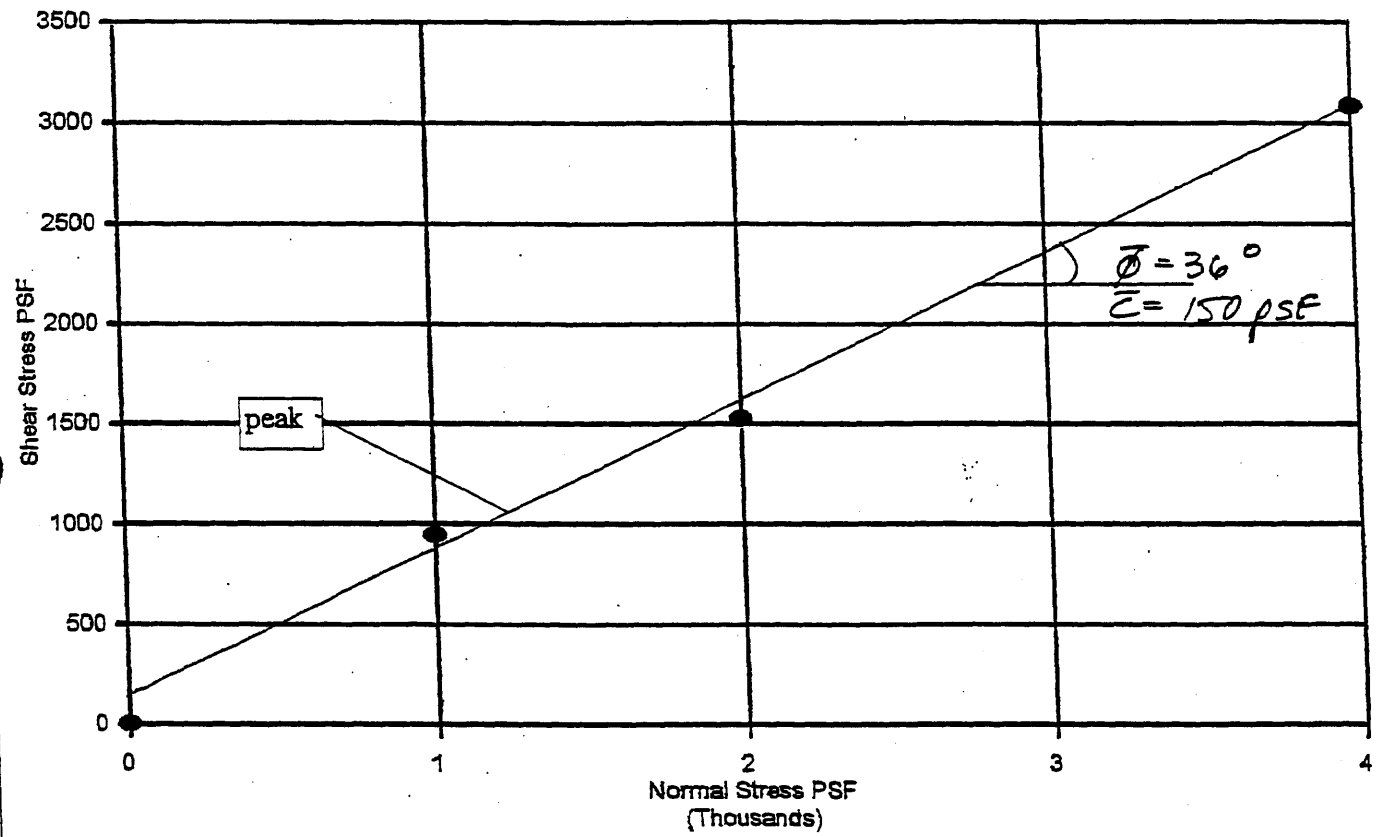
DIRECT SHEAR - Consolidated Drained

MC-3 S



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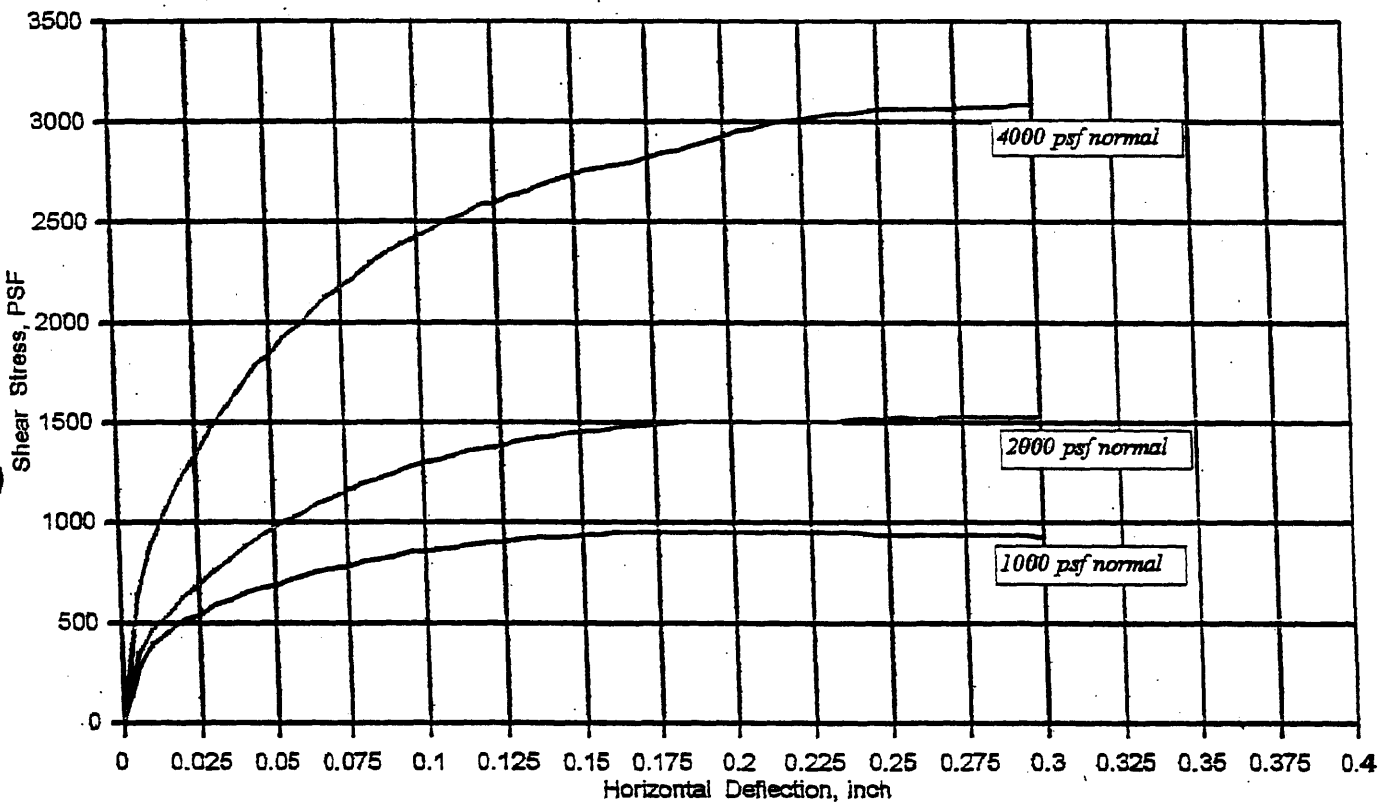
Direct Shear

Sample MC-3 S



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Project: Skyline Mine Discharge Study (UC-794-02)
Client: Earthfax Engineering
Project #: 401356

LABORATORY SUMMARY

	278				
	Bucket				
	11/26/01				
	ASTM C136, C566 & C117				
	EC-3B	MC-3B	MC-2B	MC-1B	EC-1B
	100.0%	79.6%	100.0%	100.0%	75.3%
	66.1%	N/A	67.8%	81.9%	66.1%
	35.3%	66.2%	39.1%	49.7%	49.4%
	20.8%	46.0%	21.9%	31.7%	31.8%
	20.4%	24.4%	13.2%	23.5%	22.6%
	18.3%	17.7%	10.4%	18.1%	18.0%
	16.2%	13.4%	8.3%	16.0%	15.1%
	13.9%	9.0%	5.9%	12.5%	12.4%
	12.3%	7.3%	5.1%	11.5%	10.9%
	7.7%	5.0%	3.5%	7.5%	6.8%
	5.3%	4.0%	2.6%	5.3%	4.5%
	3.0%	3.2%	1.9%	3.4%	2.8%
	1.7%	2.6%	1.5%	2.1%	1.8%
	1.0%	2.0%	1.1%	1.2%	1.1%
	0.4%	1.5%	0.7%	0.8%	0.6%
	0.2%	1.1%	0.5%	0.5%	0.3%

CMT ENGINEERING LABORATORIES

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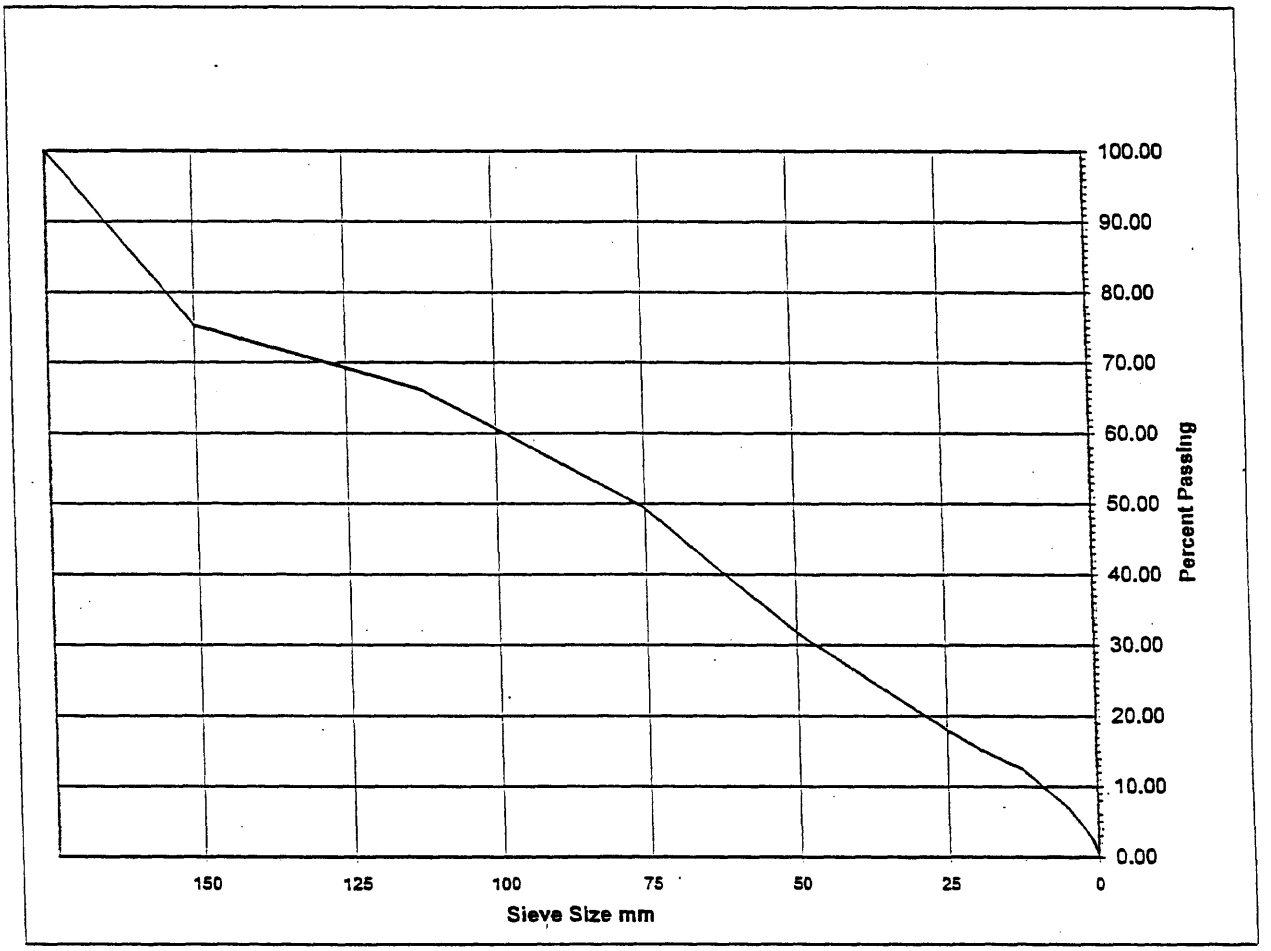
Gradation Curve

Project	Skyline Mine Discharge Study (UC-794-02)	**Date**	11/26/01
Client	Earthfax Engineering	**Project No.**	401356
Contractor		**Lab No.**	278
Soil Description	EC-1B	**Tech.**	Jeanne Richter
Source		**Method**	ASTM C 136
Use Of Material			



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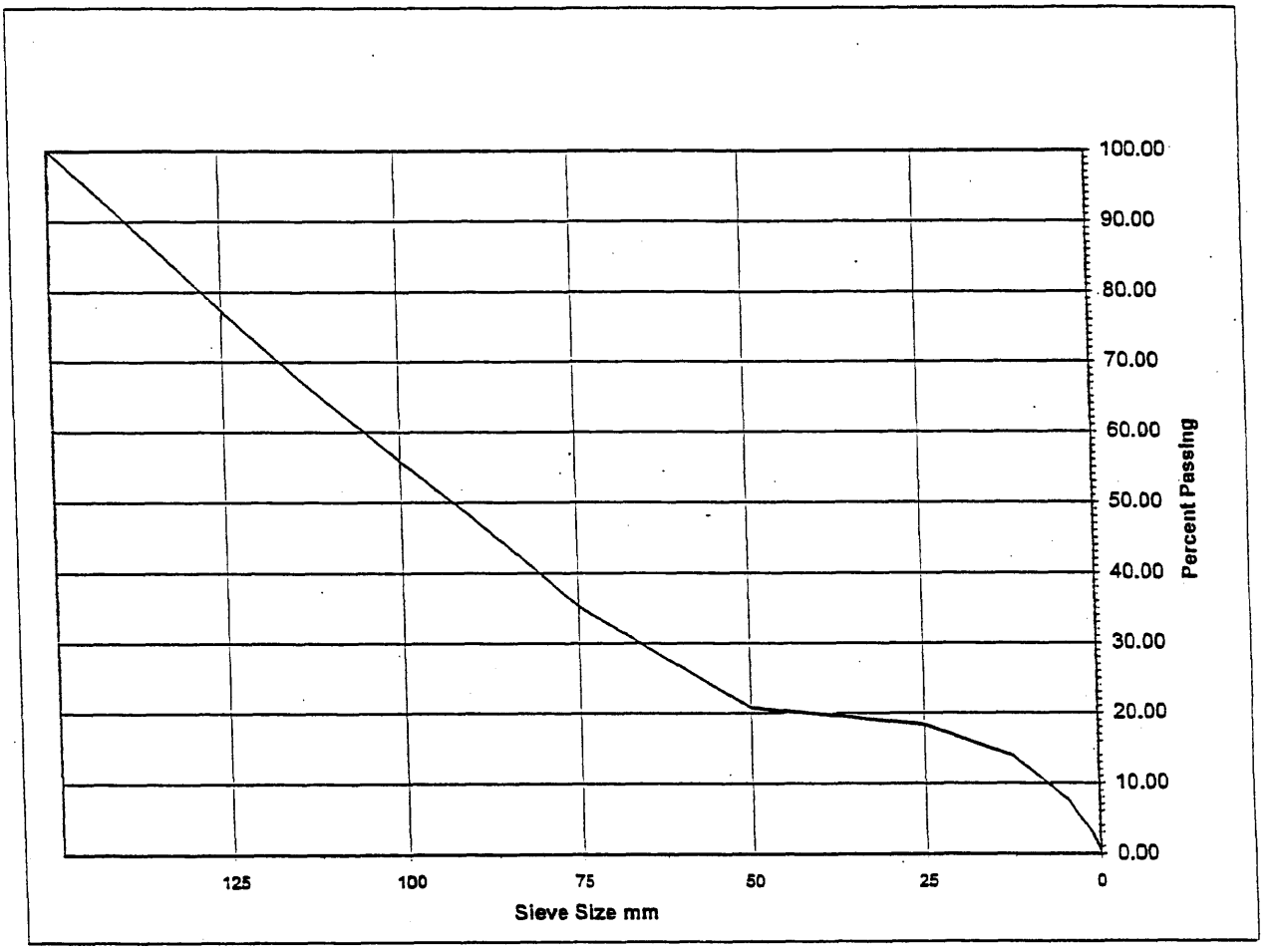
Gradation Curve

Project	Skyline Mine Discharge Study (UC-794-02)	**Date**	11/26/01
Client	Earthfax Engineering	**Project No.**	401356
Contractor		**Lab No.**	278
Soil Description	EC-3B	**Tech.**	Jeanne Richter
Source		**Method**	ASTM C 136
Use Of Material			



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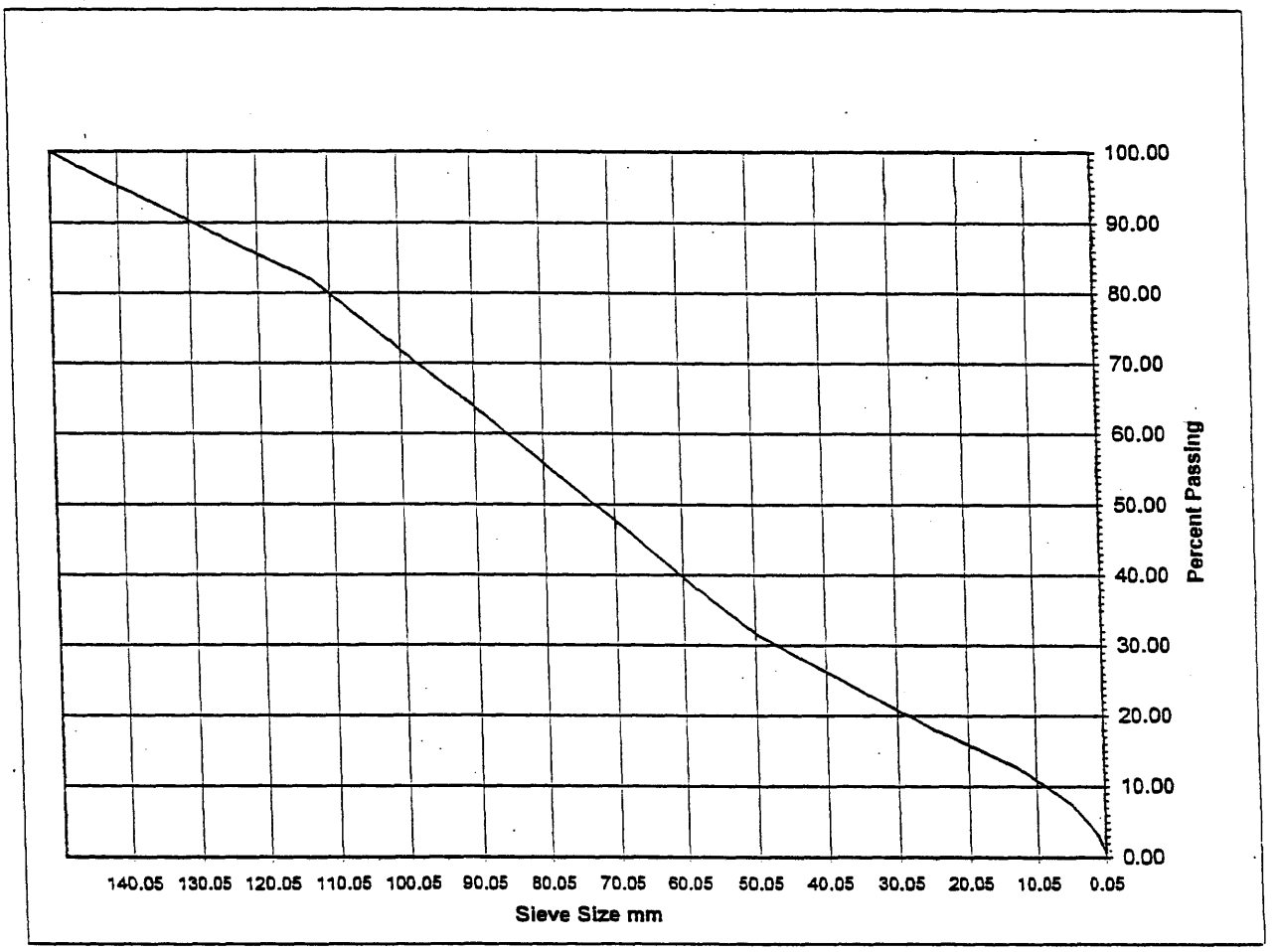
Gradation Curve

Project	Skyline Mine Discharge Study (UC-794-02)	**Date**	11/26/01
Client	Earthfax Engineering	**Project No.**	401356
Contractor		**Lab No.**	278
Soil Description	MC-1B	**Tech.**	Jeanne Richter
Source		**Method**	ASTM C 136
Use Of Material			



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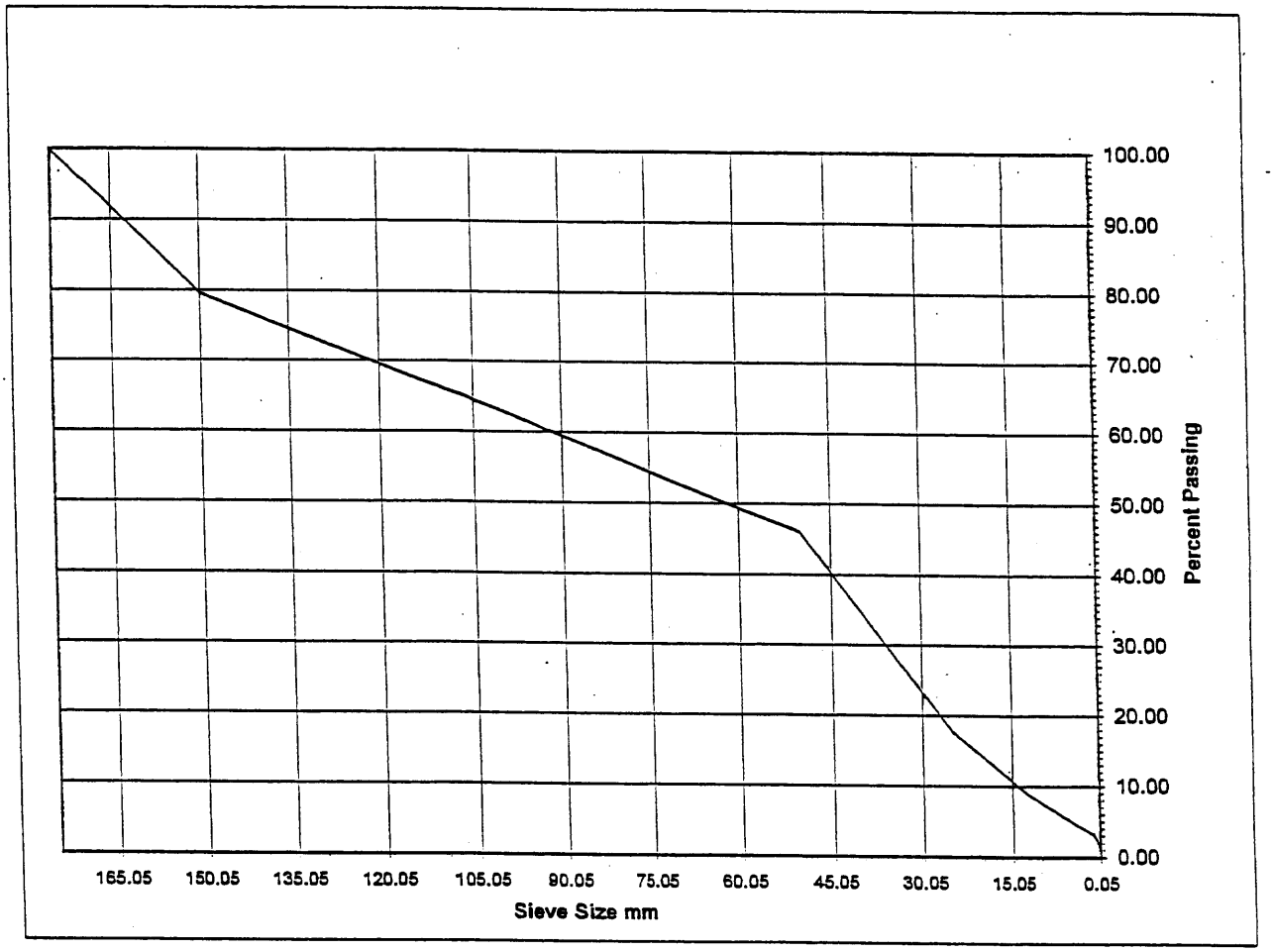
Gradation Curve

Project	Skyline Mine Discharge Study (UC-794-02)	**Date**	11/26/01
Client	Earthfax Engineering	**Project No.**	401356
Contractor		**Lab No.**	278
Soil Description	MC-3B	**Tech.**	Jeanne Richter
Source		**Method**	ASTM C 136
Use Of Material			



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APPENDIX C

Results of Channel Structural Stability Evaluations

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RESULTS OF SLOPE-STABILITY ANALYSES FOR ECCLES CREEK AND MUD CREEK

Following are cross sections and results of slope-stability analyses for Eccles Creek and Mud Creek. The following assumptions were made for these analyses:

1. Results of direct shear tests on soil samples collected from the channel bank were used for the analyses, with the exception that a cohesion intercept of 120 psf and a friction angle of 30 degrees were used at EC-3, rather than the measured values of 250 psf and 28 degrees, respectively. The revised values are considered more representative of the soil strengths at lower vertical pressures. Direct shear results from EC-2 were used for analyses at EC-1 (where a direct-shear sample could not be collected). Soil parameters used in the evaluation are summarized in Table 1 of this appendix.

2. The soils at the bottom of the creeks were assumed to be cohesionless, with a saturated angle of internal friction of 32 degrees.

3. The soils were assumed to drain rapidly, without excess pore pressures developing in response to changes in strain and stress.

4. The phreatic surface was assumed to extend horizontally from the creek level into the soil.

5. The steepest slope was analyzed at each section.

Slope-stability analyses were performed using the computer program GEOSLOPE (Version 5.0). GEOSLOPE utilizes the limit of equilibrium procedure of slices (Simplified Bishop's method) to determine the safety factor of potential failure surfaces for circular shapes.

Using the above assumption, the results of the slope-stability analyses are attached and summarized in Table 1 of this appendix. The results of the analyses include cross sections with the critical failure surface, the data files, and the output files. Table 1 includes the number of trial failure surfaces and the critical safety factor against slope failure.

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TABLE 1

SOIL PROPERTY PARAMETERS AND RESULTS OF SLOPE STABILITY ANALYSES

Section	Direct Shear Test Values		Number of Trial Failure Surfaces	Safety Factor
	Cohesive Strength (psf)	Angle of Internal Friction (degrees)		
EC-1	120	32	30,000	1.93
EC-2	120	32	30,000	3.31
EC-3	120	30	30,000	2.77
MC-1	50	34	30,000	1.73
MC-2	100	31.5	30,000	2.98
MC-3 EAST	150	36	30,000	3.29
MC-3 WEST	150	36	30,000	4.73

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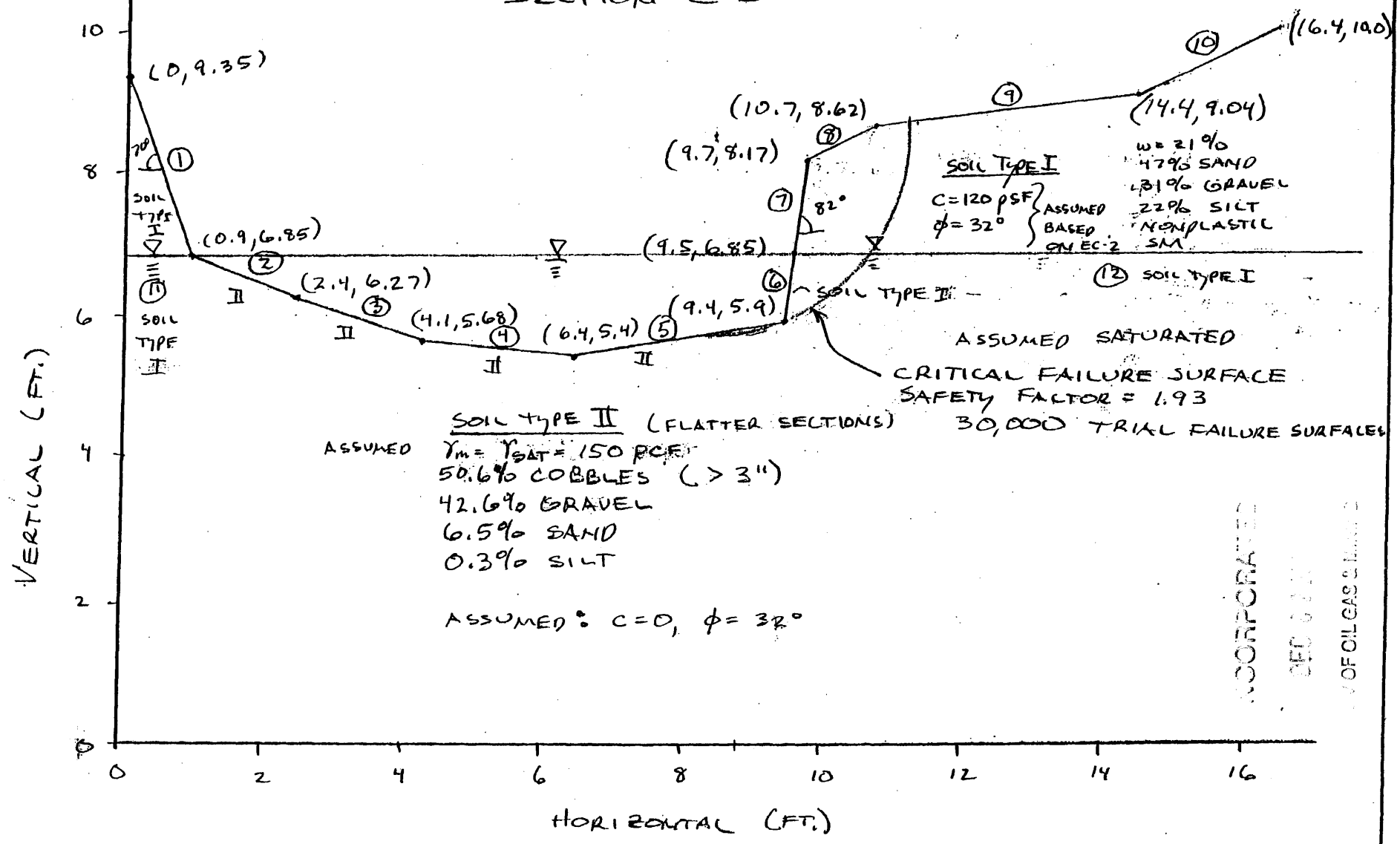
PROJECT EC 79402 PAGE 1 OF
COMPUTED RKB DATE 12/15/81
CHECKED DATE

EARTHFAX ENGINEERING, INC.
ENGINEERS / SCIENTISTS

SKYLINE MINE DISCHARGE STUDY

SECTION EC-1



SOIL TYPE II (FLATTER SECTIONS)

ASSUMED $\gamma_m = \gamma_{SAT} = 150$ PCF
50.6% COBBLES (> 3")
42.6% GRAVEL
6.5% SAND
0.3% SILT

ASSUMED: $C = 0$, $\phi = 38°$

```
TITLE
SKYLINE MINES DISCHARGE STUDY
ECCLES CREEK CROSS SECTION EC-1
MEASURED WATER LEVEL; EC1.DAT
PROFIL
12 10
0 9.35 0.9 6.85 1
0.9 6.85 2.4 6.27 2
2.4 6.27 4.1 5.68 2
4.1 5.68 6.4 5.4 2
6.4 5.4 9.4 5.9 2
9.4 5.9 9.5 6.85 1
9.5 6.85 9.7 8.17 1
9.7 8.17 10.7 8.62 1
10.7 8.62 14.4 9.04 1
14.4 9.04 16.4 10 1
0 6.85 0.9 6.85 1
9.5 6.85 16.4 6.85 1
SOIL
2
150 150 120 32 0 0 1
150 150 0 32 0 0 1
WATER
1 62.4
4
0 6.85
0.9 6.85
9.5 6.85
16.4 6.85
CIRCL2
300 100 8 9.55 9.7 12.5 0 0.5 82 -50
END
```

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Problem Title: SKYLINE MINES DISCHARGE STUDY
Description: ECCLES CREEK CROSS SECTION EC-1
Remarks: MEASURED WATER LEVEL; EC1.DAT

****
***** INPUT DATA *****
****

Profile Boundaries

Number of Boundaries: 12
Number of Top Boundaries: 10

Boundary No.	X-Left (ft)	Y-Left (ft)	X-Right (ft)	Y-Right (ft)	Soil Type Below Bnd
1	0.00	9.35	0.90	6.85	1
2	0.90	6.85	2.40	6.27	2
3	2.40	6.27	4.10	5.68	2
4	4.10	5.68	6.40	5.40	2
5	6.40	5.40	9.40	5.90	2
6	9.40	5.90	9.50	6.85	1
7	9.50	6.85	9.70	8.17	1
8	9.70	8.17	10.70	8.62	1
9	10.70	8.62	14.40	9.04	1
10	14.40	9.04	16.40	10.00	1
11	0.00	6.85	0.90	6.85	1
12	9.50	6.85	16.40	6.85	1

Soil Parameters

Number of Soil Types: 2

Soil Type No.	Total Unit Wt. (pcf)	Saturated Unit Wt. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Param.	Pressure Constant (psf)	Piez. Surface No.
1	150.0	150.0	120.0	32.0	0.00	0.0	1
2	150.0	150.0	0.0	32.0	0.00	0.0	1

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Piezometric Surfaces

Number of Surfaces: 1
Unit Weight of Water: 62.40 pcf

Piezometric Surface No.: 1
Number of Coordinate Points: 4

Point No.	X-Water (ft)	Y-Water (ft)
1	0.00	6.85
2	0.90	6.85
3	9.50	6.85
4	16.40	6.85

****
***** TRIAL SURFACE GENERATION *****
****

Data for Generating Circular Surfaces

Number of Initiation Points:	300
Number of Surfaces From Each Point:	100
Left Initiation Point:	8.00 ft
Right Initiation Point:	9.55 ft
Left Termination Point:	9.70 ft
Right Termination Point:	12.50 ft
Minimum Elevation:	0.00 ft
Segment Length:	0.50 ft
Positive Angle Limit:	82.00 deg
Negative Angle Limit:	-50.00 deg

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****
***** RESULTS *****
****

Critical Surfaces

No.	Safety Factor	Center X (ft)	Center Y (ft)	Circle Radius (ft)
1	1.933	8.39	8.45	2.80
2	1.945	8.46	8.49	2.82
3	1.951	8.29	8.57	2.90
4	1.951	8.42	8.54	2.86
5	1.954	8.40	8.54	2.87
6	1.956	8.27	8.55	2.89
7	1.957	8.33	8.59	2.91
8	1.959	8.40	8.56	2.89
9	1.960	8.40	8.56	2.89
10	1.963	8.29	8.56	2.91

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PROJECT WC794.02 PAGE ___ OF ___
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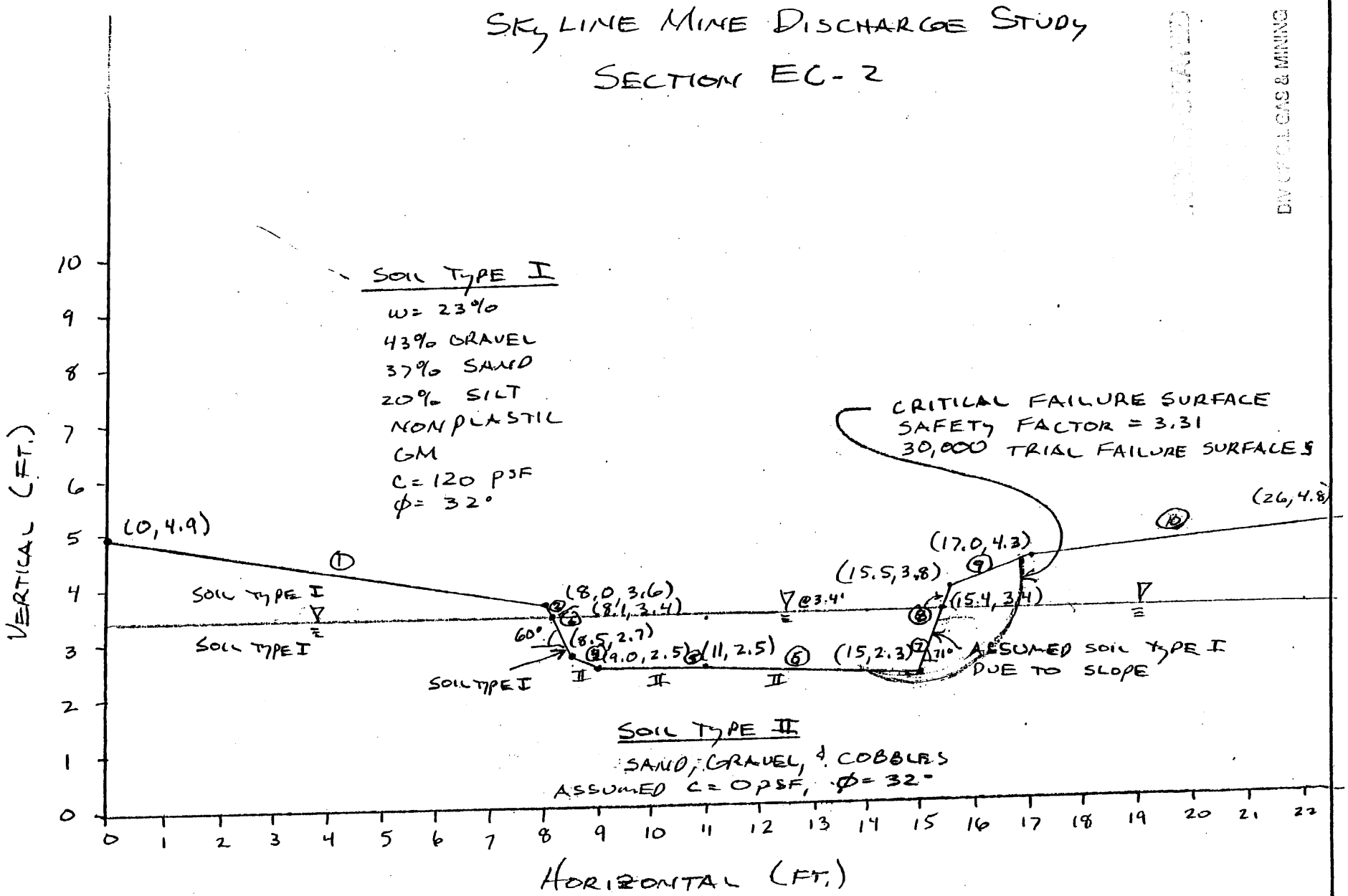
SKYLINE MINE DISCHARGE STUDY
SECTION EC-2



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TITLE
SKYLINE MINES DISCHARGE STUDY
ECCLES CREEK CROSS SECTION EC-2
MEASURED WATER LEVEL; EC2.DAT
PROFIL
12 10
0 4.9 8 3.6 1
8 3.6 8.1 3.4 1
8.1 3.4 8.5 2.7 1
8.5 2.7 9 2.5 2
9 2.5 11 2.5 2
11 2.5 15 2.3 2
15 2.3 15.4 3.4 1
15.4 3.4 15.5 3.8 1
15.5 3.8 17 4.3 1
17 4.3 26 4.8 1
0 3.4 8.1 3.4 1
15.4 3.4 26 3.4 1
SOIL
2
150 150 120 32 0 0 1
150 150 0 32 0 0 1
WATER
1 62.4
4
0 3.4
8.1 3.4
15.4 3.4
26 3.4
CIRCL2
300 100 14 15.3 15.5 18 0 0.5 71 -50
END
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Problem Title: SKYLINE MINES DISCHARGE STUDY
Description: ECCLES CREEK CROSS SECTION EC-2
Remarks: MEASURED WATER LEVEL; EC2.DAT

INPUT DATA

Profile Boundaries

Number of Boundaries: 12
Number of Top Boundaries: 10

Boundary No.	X-Left (ft)	Y-Left (ft)	X-Right (ft)	Y-Right (ft)	Soil Type Below Bnd
1	0.00	4.90	8.00	3.60	1
2	8.00	3.60	8.10	3.40	1
3	8.10	3.40	8.50	2.70	1
4	8.50	2.70	9.00	2.50	2
5	9.00	2.50	11.00	2.50	2
6	11.00	2.50	15.00	2.30	2
7	15.00	2.30	15.40	3.40	1
8	15.40	3.40	15.50	3.80	1
9	15.50	3.80	17.00	4.30	1
10	17.00	4.30	26.00	4.80	1
11	0.00	3.40	8.10	3.40	1
12	15.40	3.40	26.00	3.40	1

Soil Parameters

Number of Soil Types: 2

Soil Type No.	Total Unit Wt. (pcf)	Saturated Unit Wt. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Param.	Pressure Constant (psf)	Piez. Surface No.
1	150.0	150.0	120.0	32.0	0.00	0.0	1
2	150.0	150.0	0.0	32.0	0.00	0.0	1

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Piezometric Surfaces

Number of Surfaces: 1
Unit Weight of Water: 62.40 pcf

Piezometric Surface No.: 1
Number of Coordinate Points: 4

Point No.	X-Water (ft)	Y-Water (ft)
1	0.00	3.40
2	8.10	3.40
3	15.40	3.40
4	26.00	3.40

****
***** TRIAL SURFACE GENERATION *****
****

Data for Generating Circular Surfaces

Number of Initiation Points:	300
Number of Surfaces From Each Point:	100
Left Initiation Point:	14.00 ft
Right Initiation Point:	15.30 ft
Left Termination Point:	15.50 ft
Right Termination Point:	18.00 ft
Minimum Elevation:	0.00 ft
Segment Length:	0.50 ft
Positive Angle Limit:	71.00 deg
Negative Angle Limit:	-50.00 deg

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****
***** RESULTS *****
****

Critical Surfaces

No.	Safety Factor	Center X (ft)	Center Y (ft)	Circle Radius (ft)
1	3.314	14.87	3.99	1.85
2	3.317	14.83	4.01	1.86
3	3.318	14.89	3.98	1.84
4	3.323	14.88	3.99	1.85
5	3.332	14.78	4.07	1.89
6	3.332	14.78	4.08	1.89
7	3.332	14.89	3.99	1.85
8	3.332	15.05	4.10	2.03
9	3.333	14.86	4.02	1.87
10	3.335	14.84	4.03	1.87

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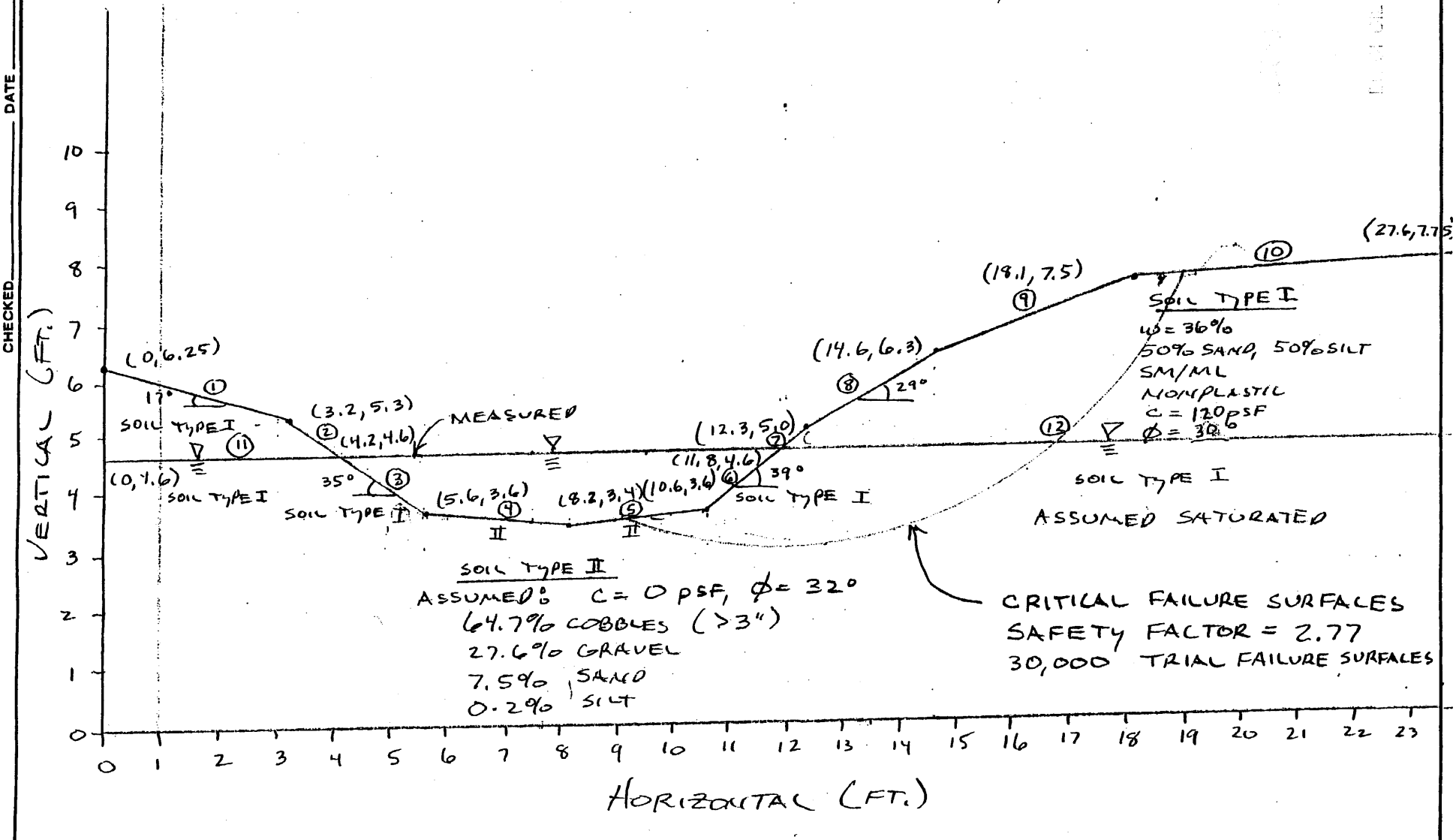
SKYLINE MINE DISCHARGE STUDY
SECTION EC-3



2.7
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TITLE
SKYLINE MINES DISCHARGE STUDY
ECCLES CREEK CROSS SECTION EC-3
MEASURED WATER LEVEL; EC3.DAT
PROFIL
12 10
0 6.25 3.2 5.3 1
3.2 5.3 4.2 4.6 1
4.2 4.6 5.6 3.6 1
5.6 3.6 8.2 3.4 2
8.2 3.4 10.6 3.6 2
10.6 3.6 11.8 4.6 1
11.8 4.6 12.3 5 1
12.3 5 14.6 6.3 1
14.6 6.3 18.1 7.5 1
18.1 7.5 27.6 7.75 1
0 4.6 4.2 4.6 1
11.8 4.6 27.6 4.6 1
SOIL
2
150 150 120 30 0 0 1
150 150 0 32 0 0 1
WATER
1 62.4
4
0 4.6
4.2 4.6
11.8 4.6
27.6 4.6
CIRCL2
300 100 9 11.5 12.3 22 0 0.5 30 -50
END
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Problem Title: SKYLINE MINES DISCHARGE STUDY
Description: ECCLES CREEK CROSS SECTION EC-3
Remarks: MEASURED WATER LEVEL; EC3.DAT

****
***** INPUT DATA *****
****

Profile Boundaries

Number of Boundaries: 12
Number of Top Boundaries: 10

Boundary No.	X-Left (ft)	Y-Left (ft)	X-Right (ft)	Y-Right (ft)	Soil Type Below Bnd
1	0.00	6.25	3.20	5.30	1
2	3.20	5.30	4.20	4.60	1
3	4.20	4.60	5.60	3.60	1
4	5.60	3.60	8.20	3.40	2
5	8.20	3.40	10.60	3.60	2
6	10.60	3.60	11.80	4.60	1
7	11.80	4.60	12.30	5.00	1
8	12.30	5.00	14.60	6.30	1
9	14.60	6.30	18.10	7.50	1
10	18.10	7.50	27.60	7.75	1
11	0.00	4.60	4.20	4.60	1
12	11.80	4.60	27.60	4.60	1

Soil Parameters

Number of Soil Types: 2

Soil Type No.	Total Unit Wt. (pcf)	Saturated Unit Wt. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Param.	Pressure Constant (psf)	Piez. Surface No.
1	150.0	150.0	120.0	30.0	0.00	0.0	1
2	150.0	150.0	0.0	32.0	0.00	0.0	1

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Piezometric Surfaces

Number of Surfaces: 1
Unit Weight of Water: 62.40 pcf

Piezometric Surface No.: 1
Number of Coordinate Points: 4

Point No.	X-Water (ft)	Y-Water (ft)
1	0.00	4.60
2	4.20	4.60
3	11.80	4.60
4	27.60	4.60

****
***** TRIAL SURFACE GENERATION *****
****

Data for Generating Circular Surfaces

Number of Initiation Points:	300
Number of Surfaces From Each Point:	100
Left Initiation Point:	9.00 ft
Right Initiation Point:	11.50 ft
Left Termination Point:	12.30 ft
Right Termination Point:	22.00 ft
Minimum Elevation:	0.00 ft
Segment Length:	0.50 ft
Positive Angle Limit:	30.00 deg
Negative Angle Limit:	-50.00 deg

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****
***** RESULTS *****
****

Critical Surfaces

No.	Safety Factor	Center X (ft)	Center Y (ft)	Circle Radius (ft)
1	2.768	11.96	10.58	7.70
2	2.774	12.17	10.54	7.75
3	2.776	12.15	10.14	7.34
4	2.776	11.90	9.99	7.12
5	2.776	11.86	9.84	6.98
6	2.779	12.02	9.54	6.76
7	2.780	11.85	10.98	8.00
8	2.783	11.81	10.33	7.37
9	2.783	12.21	10.56	7.75
10	2.784	11.86	11.14	8.16

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Skyline Mine Discharge Study
Section MC-1

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TITLE
SKYLINE MINES DISCHARGE STUDY
MUD CREEK CROSS SECTION MC-1
MEASURED WATER LEVEL; MC1.DAT
PROFIL
10 8
0 6.83 0.4 6.7 1
0.4 6.7 3.6 5.6 1
3.6 5.6 8.3 5.65 2
8.3 5.65 12.8 6.15 2
12.8 6.15 15.2 6.7 2
15.2 6.7 15.4 6.75 2
15.4 6.75 17.8 9.28 1
17.8 9.28 26.8 12.1 1
0 6.7 0.4 6.7 1
15.2 6.7 26.8 6.7 1
SOIL
2
150 150 50 34 0 0 1
150 150 0 32 0 0 1
WATER
1 62.4
4
0 6.7
0.4 6.7
15.2 6.7
26.8 6.7
CIRCL2
300 100 11 16 17.8 26 0 1 45 -50
END
```

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Problem Title: SKYLINE MINES DISCHARGE STUDY
Description: MUD CREEK CROSS SECTION MC-1
Remarks: MEASURED WATER LEVEL; MC1.DAT

****
***** INPUT DATA *****
****

Profile Boundaries

Number of Boundaries: 10
Number of Top Boundaries: 8

Boundary No.	X-Left (ft)	Y-Left (ft)	X-Right (ft)	Y-Right (ft)	Soil Type Below Bnd
1	0.00	6.83	0.40	6.70	1
2	0.40	6.70	3.60	5.60	1
3	3.60	5.60	8.30	5.65	2
4	8.30	5.65	12.80	6.15	2
5	12.80	6.15	15.20	6.70	2
6	15.20	6.70	15.40	6.75	2
7	15.40	6.75	17.80	9.28	1
8	17.80	9.28	26.80	12.10	1
9	0.00	6.70	0.40	6.70	1
10	15.20	6.70	26.80	6.70	1

Soil Parameters

Number of Soil Types: 2

Soil Type No.	Total Unit Wt. (pcf)	Saturated Unit Wt. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Param.	Pressure Constant (psf)	Piez. Surface No.
1	150.0	150.0	50.0	34.0	0.00	0.0	1
2	150.0	150.0	0.0	32.0	0.00	0.0	1

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Piezometric Surfaces

Number of Surfaces: 1
Unit Weight of Water: 62.40 pcf

Piezometric Surface No.: 1
Number of Coordinate Points: 4

Point No.	X-Water (ft)	Y-Water (ft)
1	0.00	6.70
2	0.40	6.70
3	15.20	6.70
4	26.80	6.70

****
***** TRIAL SURFACE GENERATION *****
****

Data for Generating Circular Surfaces

Number of Initiation Points:	300
Number of Surfaces From Each Point:	100
Left Initiation Point:	11.00 ft
Right Initiation Point:	16.00 ft
Left Termination Point:	17.80 ft
Right Termination Point:	26.00 ft
Minimum Elevation:	0.00 ft
Segment Length:	1.00 ft
Positive Angle Limit:	45.00 deg
Negative Angle Limit:	-50.00 deg

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****
***** RESULTS *****
****

Critical Surfaces

No.	Safety Factor	Center X (ft)	Center Y (ft)	Circle Radius (ft)
1	1.729	14.23	11.20	5.32
2	1.729	14.07	11.63	5.70
3	1.730	14.08	11.56	5.60
4	1.731	14.33	11.10	5.20
5	1.731	14.24	11.06	5.19
6	1.731	14.33	11.25	5.33
7	1.731	14.12	11.72	5.75
8	1.731	14.05	11.58	5.61
9	1.731	14.15	11.58	5.70
10	1.731	14.16	11.59	5.61

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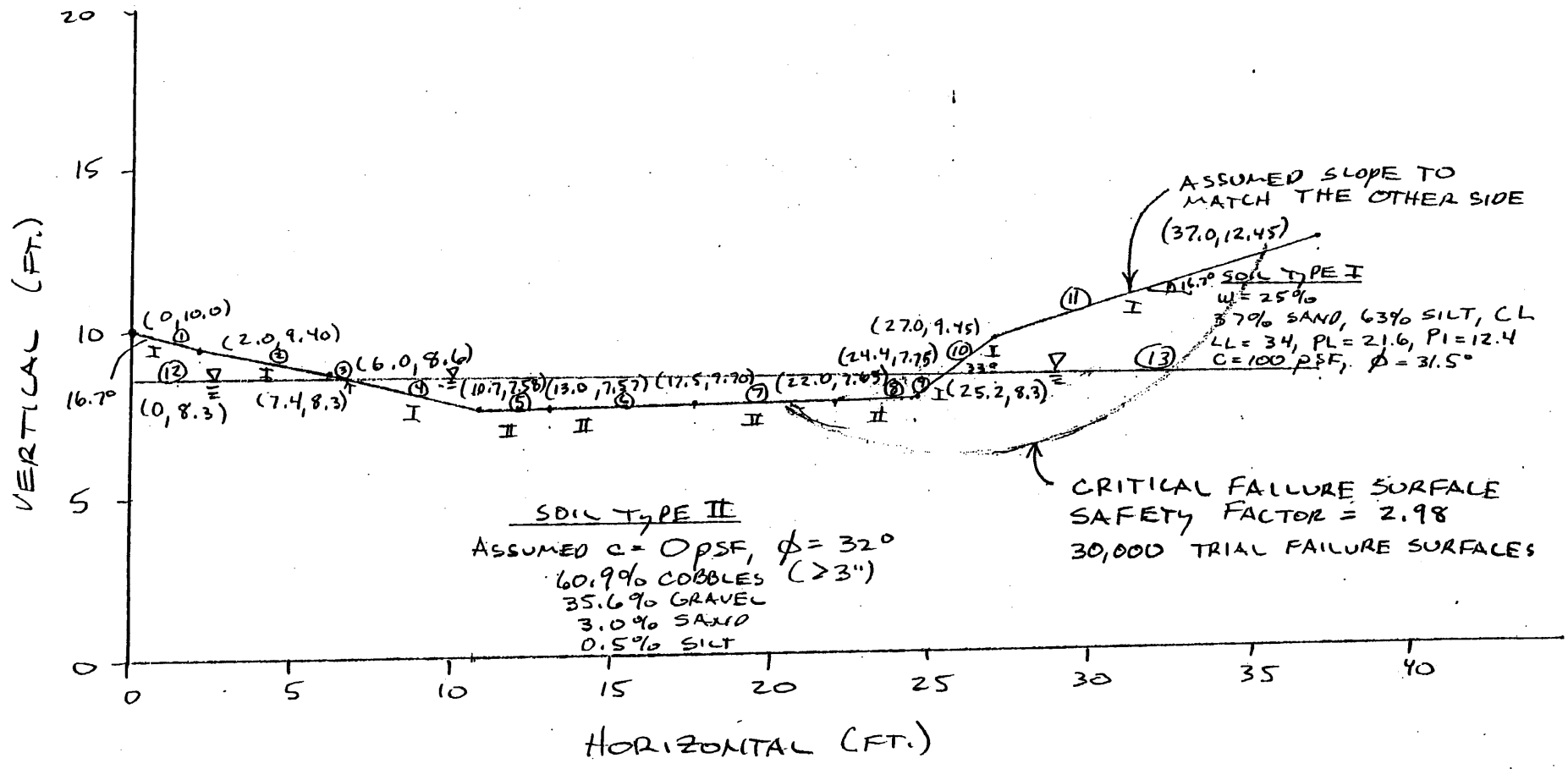
SKYLINE MINE DISCHARGE STUDY
SECTION MC-2



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TITLE
SKYLINE MINES DISCHARGE STUDY
MUD CREEK CROSS SECTION MC-2
MEASURED WATER LEVEL; MC2.DAT
PROFIL
13 11
0 10 2 9.4 1
2 9.4 6 8.6 1
6 8.6 7.4 8.3 1
7.4 8.3 10.7 7.58 1
10.7 7.58 13 7.57 2
13 7.57 17.5 7.7 2
17.5 7.7 22 7.65 2
22 7.65 24.4 7.75 2
24.4 7.75 25.2 8.3 1
25.2 8.3 27 9.45 1
27 9.45 37 12.45 1
0 8.3 7.4 8.3 1
25.2 8.3 37 8.3 1
SOIL
2
150 150 100 31.5 0 0 1
150 150 0 32 0 0 1
WATER
1 62.4
4
0 8.3
7.4 8.3
25.2 8.3
37 8.3
CIRCL2
300 100 18 25.5 26.5 35 0 1 33.-50
END
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Problem Title: SKYLINE MINES DISCHARGE STUDY
Description: MUD CREEK CROSS SECTION MC-2
Remarks: MEASURED WATER LEVEL; MC2.DAT

INPUT DATA

Profile Boundaries

Number of Boundaries: 13
Number of Top Boundaries: 11

Boundary No.	X-Left (ft)	Y-Left (ft)	X-Right (ft)	Y-Right (ft)	Soil Type Below Bnd
1	0.00	10.00	2.00	9.40	1
2	2.00	9.40	6.00	8.60	1
3	6.00	8.60	7.40	8.30	1
4	7.40	8.30	10.70	7.58	1
5	10.70	7.58	13.00	7.57	2
6	13.00	7.57	17.50	7.70	2
7	17.50	7.70	22.00	7.65	2
8	22.00	7.65	24.40	7.75	2
9	24.40	7.75	25.20	8.30	1
10	25.20	8.30	27.00	9.45	1
11	27.00	9.45	37.00	12.45	1
12	0.00	8.30	7.40	8.30	1
13	25.20	8.30	37.00	8.30	1

Soil Parameters

Number of Soil Types: 2

Soil Type No.	Total Unit Wt. (pcf)	Saturated Unit Wt. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Param.	Pressure Constant (psf)	Piez. Surface No.
1	150.0	150.0	100.0	31.5	0.00	0.0	1
2	150.0	150.0	0.0	32.0	0.00	0.0	1

DIV OF OIL GAS & MINING

Piezometric Surfaces

Number of Surfaces: 1
Unit Weight of Water: 62.40 pcf

Piezometric Surface No.: 1
Number of Coordinate Points: 4

Point No.	X-Water (ft)	Y-Water (ft)
1	0.00	8.30
2	7.40	8.30
3	25.20	8.30
4	37.00	8.30

****
***** TRIAL SURFACE GENERATION *****
****

Data for Generating Circular Surfaces

Number of Initiation Points:	300
Number of Surfaces From Each Point:	100
Left Initiation Point:	18.00 ft
Right Initiation Point:	25.50 ft
Left Termination Point:	26.50 ft
Right Termination Point:	35.00 ft
Minimum Elevation:	0.00 ft
Segment Length:	1.00 ft
Positive Angle Limit:	33.00 deg
Negative Angle Limit:	-50.00 deg

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****
***** RESULTS *****
****

Critical Surfaces

No.	Safety Factor	Center X (ft)	Center Y (ft)	Circle Radius (ft)
1	2.982	25.56	16.89	10.68
2	2.982	25.55	17.00	10.75
3	2.983	25.67	16.87	10.59
4	2.983	25.74	16.28	10.26
5	2.983	25.73	16.61	10.38
6	2.983	25.59	17.00	10.72
7	2.983	25.74	16.77	10.48
8	2.984	25.76	16.54	10.32
9	2.984	25.80	16.20	10.17
10	2.984	25.57	16.61	10.48

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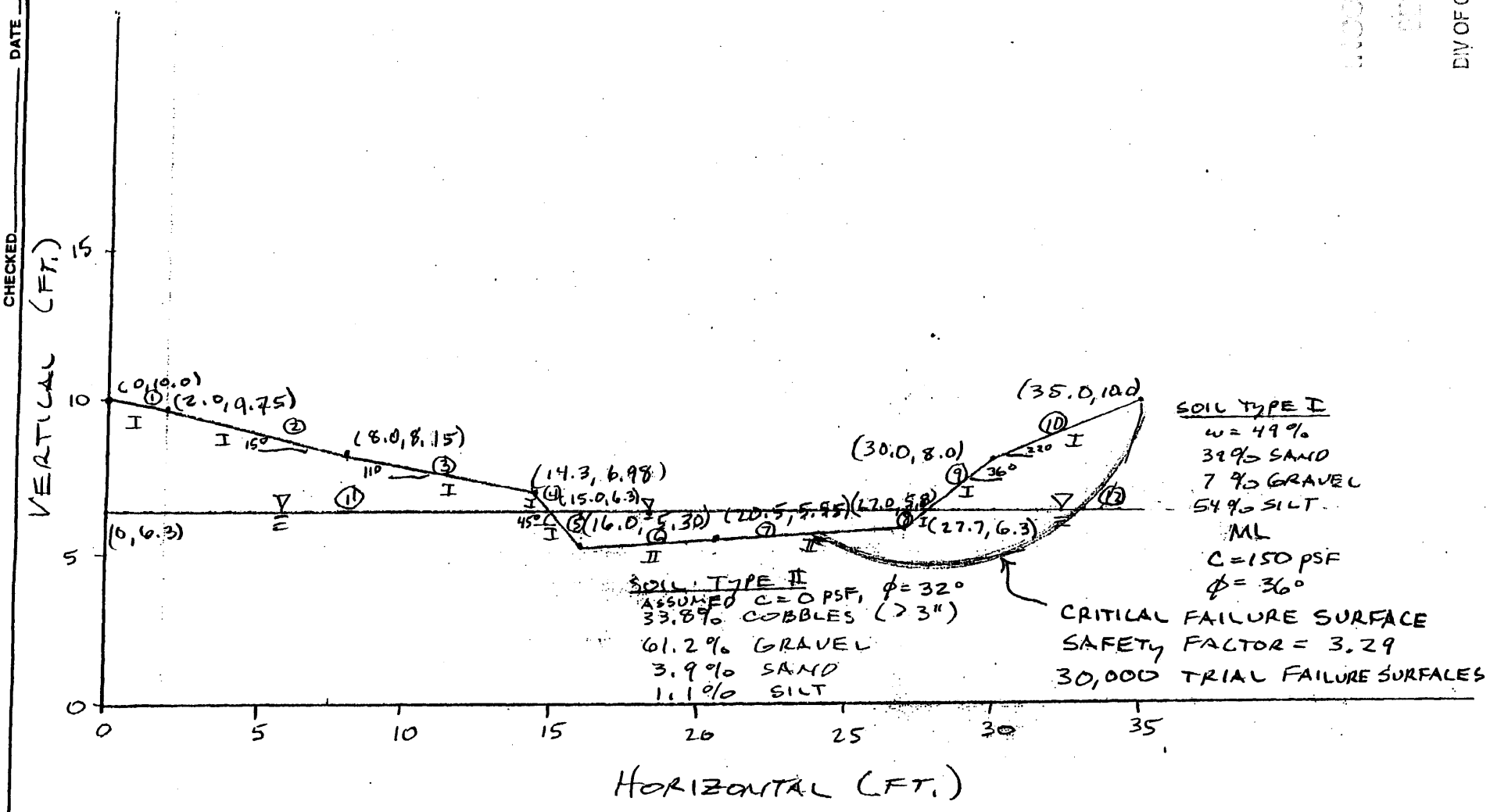
SKYLINE MINE DISCHARGE STUDY

SECTION MC-3 EAST



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TITLE
SKYLINE MINES DISCHARGE STUDY
MUD CREEK CROSS SECTION MC-3 EAST
MEASURED WATER LEVEL; MC3EAST.DAT
PROFIL
12 10
0 10 2 9.75 1
2 9.75 8 8.15 1
8 8.15 14.3 6.98 1
14.3 6.98 15 6.3 1
15 6.3 16 5.3 1
16 5.3 20.5 5.55 2
20.5 5.55 27 5.8 2
27 5.8 27.7 6.3 1
27.7 6.3 30 8 1
30 8 35 10 1
0 6.3 15 6.3 1
27.7 6.3 35 6.3 1
SOIL
2
150 150 150 36 0 0 1
150 150 0 32 0 0 1
WATER
1 62.4
4
0 6.3
15 6.3
27.7 6.3
35 6.3
CIRCL2
300 100 24 28.5 30 35 0 1 36 -50
END
```

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GeoSlope
Version 5.00

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Problem Title: SKYLINE MINES DISCHARGE STUDY
Description: MED CREEK CROSS SECTION MC-3 EAST
Remarks: MEASURED WATER LEVEL; MC3EAST.DAT

INPUT DATA

Profile Boundaries

Number of Boundaries: 12
Number of Top Boundaries: 10

Boundary No.	X-Left (ft)	Y-Left (ft)	X-Right (ft)	Y-Right (ft)	Soil Type Below Bnd
1	0.00	10.00	2.00	9.75	1
2	2.00	9.75	8.00	8.15	1
3	8.00	8.15	14.30	6.98	1
4	14.30	6.98	15.00	6.30	1
5	15.00	6.30	16.00	5.30	1
6	16.00	5.30	20.50	5.55	2
7	20.50	5.55	27.00	5.80	2
8	27.00	5.80	27.70	6.30	1
9	27.70	6.30	30.00	8.00	1
10	30.00	8.00	35.00	10.00	1
11	0.00	6.30	15.00	6.30	1
12	27.70	6.30	35.00	6.30	1

Soil Parameters

Number of Soil Types: 2

Soil Type No.	Total Unit Wt. (pcf)	Saturated Unit Wt. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Param.	Pressure Constant (psf)	Piez. Surface No.
1	150.0	150.0	150.0	36.0	0.00	0.0	1
2	150.0	150.0	0.0	32.0	0.00	0.0	1

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Piezometric Surfaces

Number of Surfaces: 1
Unit Weight of Water: 62.40 pcf

Piezometric Surface No.: 1
Number of Coordinate Points: 4

Point No.	X-Water (ft)	Y-Water (ft)
1	0.00	6.30
2	15.00	6.30
3	27.70	6.30
4	35.00	6.30

****
***** TRIAL SURFACE GENERATION *****
****

Data for Generating Circular Surfaces

Number of Initiation Points:	300
Number of Surfaces From Each Point:	100
Left Initiation Point:	24.00 ft
Right Initiation Point:	28.50 ft
Left Termination Point:	30.00 ft
Right Termination Point:	35.00 ft
Minimum Elevation:	0.00 ft
Segment Length:	1.00 ft
Positive Angle Limit:	36.00 deg
Negative Angle Limit:	-50.00 deg

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****
***** RESULTS *****
****

Critical Surfaces

No.	Safety Factor	Center X (ft)	Center Y (ft)	Circle Radius (ft)
1	3.285	27.83	12.12	7.48
2	3.286	27.89	11.97	7.37
3	3.289	27.93	11.85	7.28
4	3.290	27.79	12.20	7.51
5	3.291	27.94	11.89	7.30
6	3.292	27.96	11.88	7.28
7	3.292	27.89	11.81	7.25
8	3.293	27.98	11.86	7.26
9	3.294	27.98	11.82	7.23
10	3.295	27.99	11.77	7.20

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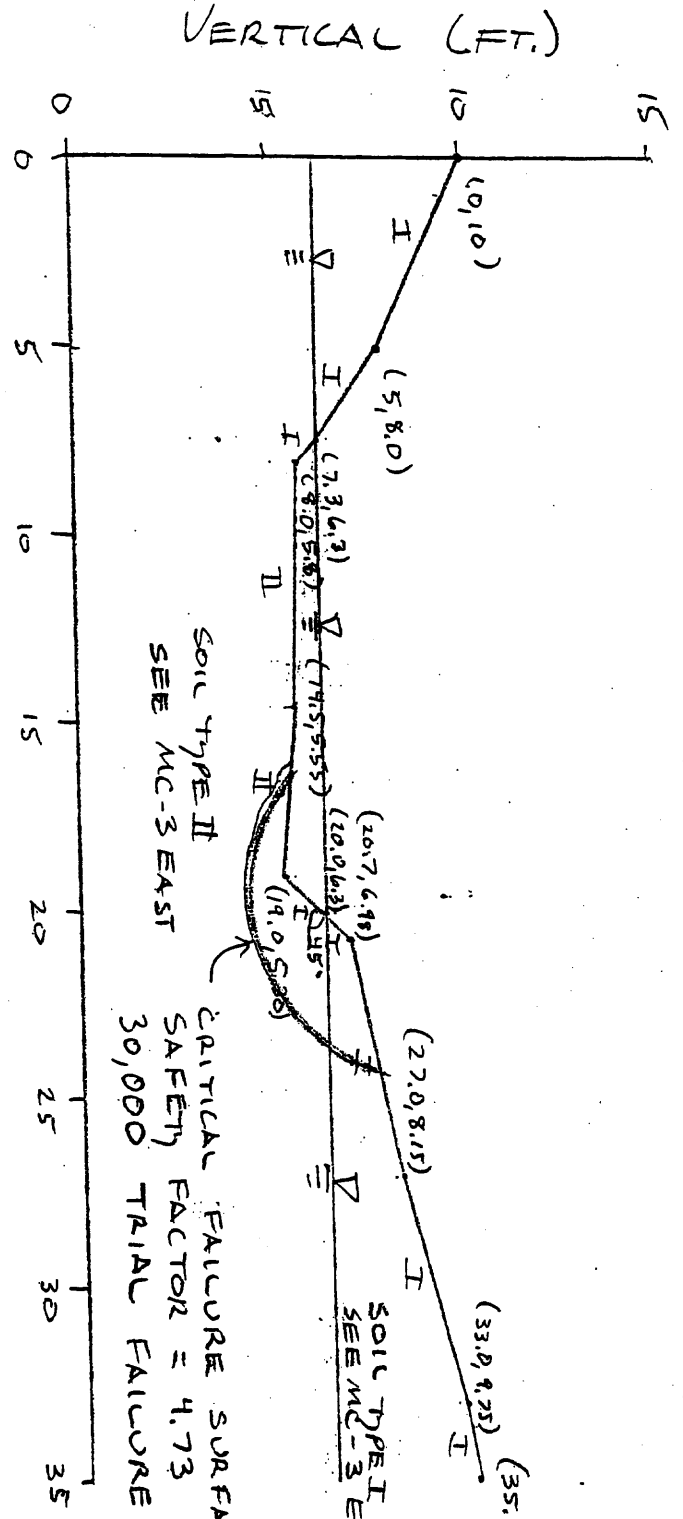
ENGINEERS / SCIENTISTS

PROJECT UC794.02 PAGE ____ OF ____
COMPUTED RKB DATE 12/16/01
CHECKED ____ DATE ____



SKYLINE MINE DISCHARGE STUDY
SECTION MC-3 WEST

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TITLE
SKYLINE MINES DISCHARGE STUDY
MUD CREEK CROSS SECTION MC-3 WEST
MEASURED WATER LEVEL; MC3WEST.DAT
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5 8 7.3 6.3 1
7.3 6.3 8 5.8 1
8 5.8 14.5 5.55 2
14.5 5.55 19 5.3 2
19 5.3 20 6.3 1
20 6.3 20.7 6.98 1
20.7 6.98 27 8.15 1
27 8.15 33 9.75 1
33 9.75 35 10 1
0 6.3 7.3 6.3 1
20 6.3 35 6.3 1
SOIL
2
150 150 150 36 0 0 1
150 150 0 32 0 0 1
WATER
1 62.4
4
0 6.3
7.3 6.3
20 6.3
35 6.3
CIRCL2
300 100 15 20 20.7 30 0 1 45 -50
END
```

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****
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***** *****
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****

Problem Title: SKYLINE MINES DISCHARGE STUDY
Description: MUD CREEK CROSS SECTION MC-3 WEST
Remarks: MEASURED WATER LEVEL; MC3WEST.DAT

****
***** INPUT DATA *****
****

Profile Boundaries

Number of Boundaries: 12
Number of Top Boundaries: 10

Boundary No.	X-Left (ft)	Y-Left (ft)	X-Right (ft)	Y-Right (ft)	Soil Type Below Bnd
1	0.00	10.00	5.00	8.00	1
2	5.00	8.00	7.30	6.30	1
3	7.30	6.30	8.00	5.80	1
4	8.00	5.80	14.50	5.55	2
5	14.50	5.55	19.00	5.30	2
6	19.00	5.30	20.00	6.30	1
7	20.00	6.30	20.70	6.98	1
8	20.70	6.98	27.00	8.15	1
9	27.00	8.15	33.00	9.75	1
10	33.00	9.75	35.00	10.00	1
11	0.00	6.30	7.30	6.30	1
12	20.00	6.30	35.00	6.30	1

Soil Parameters

Number of Soil Types: 2

Soil Type No.	Total Unit Wt. (pcf)	Saturated Unit Wt. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Param.	Pressure Constant (psf)	Piez. Surface No.
1	150.0	150.0	150.0	36.0	0.00	0.0	1
2	150.0	150.0	0.0	32.0	0.00	0.0	1

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Piezometric Surfaces

Number of Surfaces: 1
Unit Weight of Water: 62.40 pcf

Piezometric Surface No.: 1
Number of Coordinate Points: 4

Point No.	X-Water (ft)	Y-Water (ft)
1	0.00	6.30
2	7.30	6.30
3	20.00	6.30
4	35.00	6.30

****
***** TRIAL SURFACE GENERATION *****
****

Data for Generating Circular Surfaces

Number of Initiation Points:	300
Number of Surfaces From Each Point:	100
Left Initiation Point:	15.00 ft
Right Initiation Point:	20.00 ft
Left Termination Point:	20.70 ft
Right Termination Point:	30.00 ft
Minimum Elevation:	0.00 ft
Segment Length:	1.00 ft
Positive Angle Limit:	45.00 deg
Negative Angle Limit:	-50.00 deg

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****
***** RESULTS *****
****

Critical Surfaces

No.	Safety Factor	Center X (ft)	Center Y (ft)	Circle Radius (ft)
1	4.731	19.46	9.40	5.04
2	4.731	19.33	9.82	5.33
3	4.731	19.42	9.43	5.09
4	4.732	19.48	9.43	5.08
5	4.733	19.34	9.26	4.92
6	4.734	19.34	9.30	4.97
7	4.734	19.31	9.16	4.63
8	4.735	19.25	9.28	4.77
9	4.735	19.23	8.99	4.48
10	4.736	19.31	9.32	4.81

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APPENDIX D

Results of Channel Erosional Stability Evaluations

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EROSIONAL STABILITY OF ECCLES CREEK AND MUD CREEK

- Determine allowable velocity according to US Soil Conservation Service (1977) for channel bed and Haan et al. (1994) for channel banks and floodplains
- Evaluate stability under both sediment-laden and sediment-free conditions at flows varying from 5,000 to 30,000 gpm (11.1 to 66.9 cfs)
- Evaluate stability of the stream bank and bed at each sample location (see map on pg 2 of this calculation)

Calculate rating tables and curves for each cross section using FlowMaster PE (Haestad Methods, 1998). For flows within the channel banks, use Manning's "n" calculated based on field measurements:

Station	Q (cfs)	A (ft^2)	Avg. V (ft/s)	WP (ft)	R (ft)	S (ft/ft)	n
EC-1	22.84	8.0	2.9	9.8	0.82	0.078	0.127
EC-2	25.15	5.9	4.3	8.1	0.73	0.048	0.062
EC-3	21.49	6.3	3.4	7.2	0.88	0.036	0.076
MC-1	18.28	5.4	3.4	13.9	0.39	0.015	0.029
MC-2	21.05	7.4	2.8	18.1	0.41	0.013	0.033
MC-3	24.44	9.6	2.5	13.3	0.72	0.008	0.042

For flows outside of the channel banks, use a Manning's "n" of 0.060 (typical of vegetated flood plains).

Rating tables and curves for each of the three Eccles Creek cross sections and three Mud Creek cross sections are provided on pages 3-11 of this calculation. Cross sections are shown on pages 12-17. Allowable velocities were determined for flows within the channel banks and on the floodplains at discharge rates of 5,000 gpm (11.1 cfs), 10,000 gpm (22.3 cfs), 20,000 gpm (44.6 cfs), and 30,000 gpm (66.9 cfs).

Channel bed results - see pp 18-19 of this calculation. The D_{75} at EC-2 was assumed to be the average of values at EC-1 and EC-3. All velocities at the design discharge rates are less than the allowable velocities. Hence, the channels will be erosionally stable.

Channel bank results - see pg 23 of this calculation. All velocities at the design discharge rates are less than the allowable velocities. Hence, the channel banks will be erosionally stable during the design discharges.

Floodplain results - see pg 23 of this calculation. All velocities at the design discharge rates are less than the allowable velocities. Hence, the floodplain will be erosionally stable during the design discharges.

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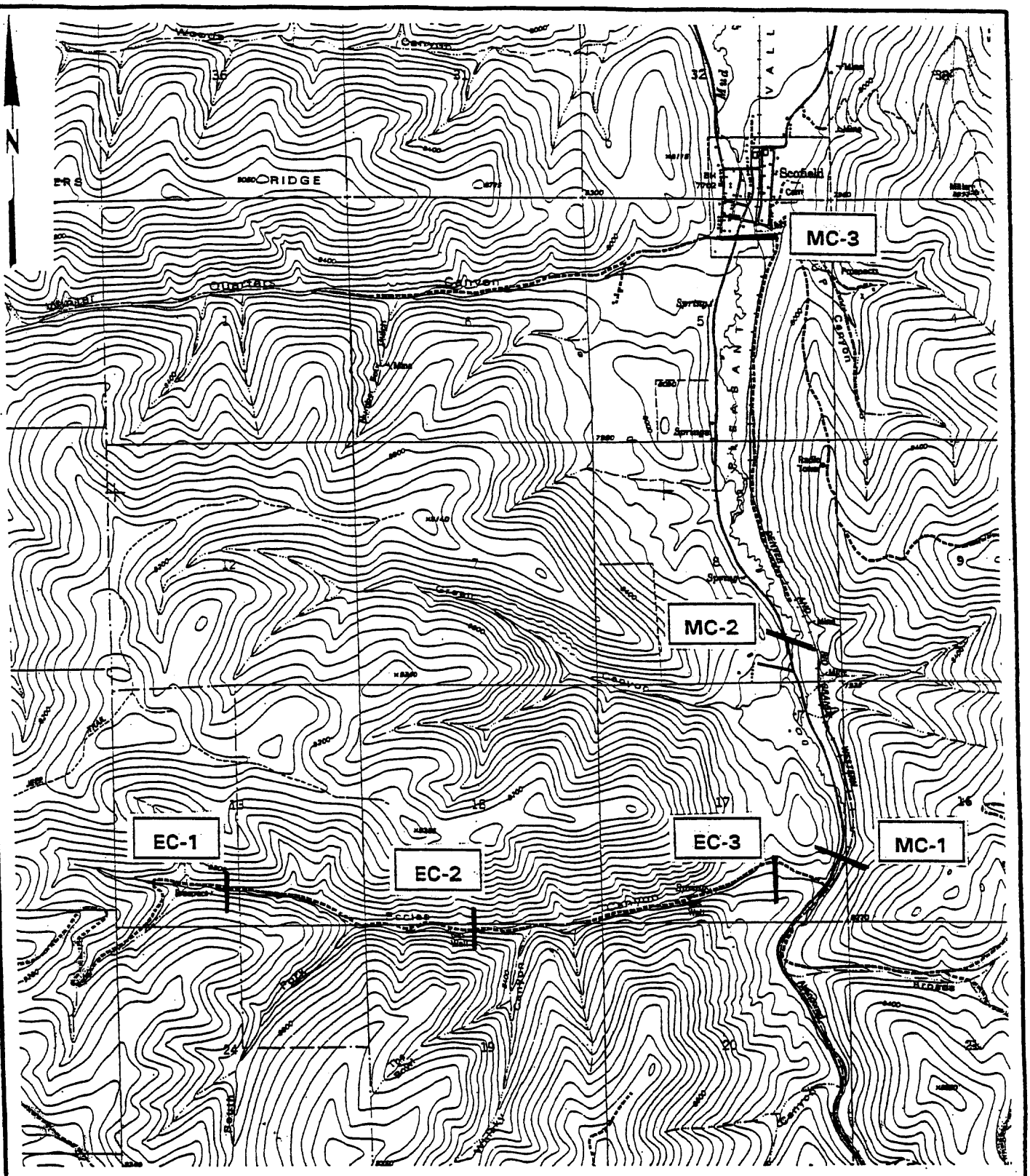

BASE MAP: SCOFIELD, UTAH 7½ MIN
USGS QUADRANGLE (1979)

SCALE: 1" = 3,000'

LOCATION OF CHANNEL CROSS SECTIONS

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EarthFax

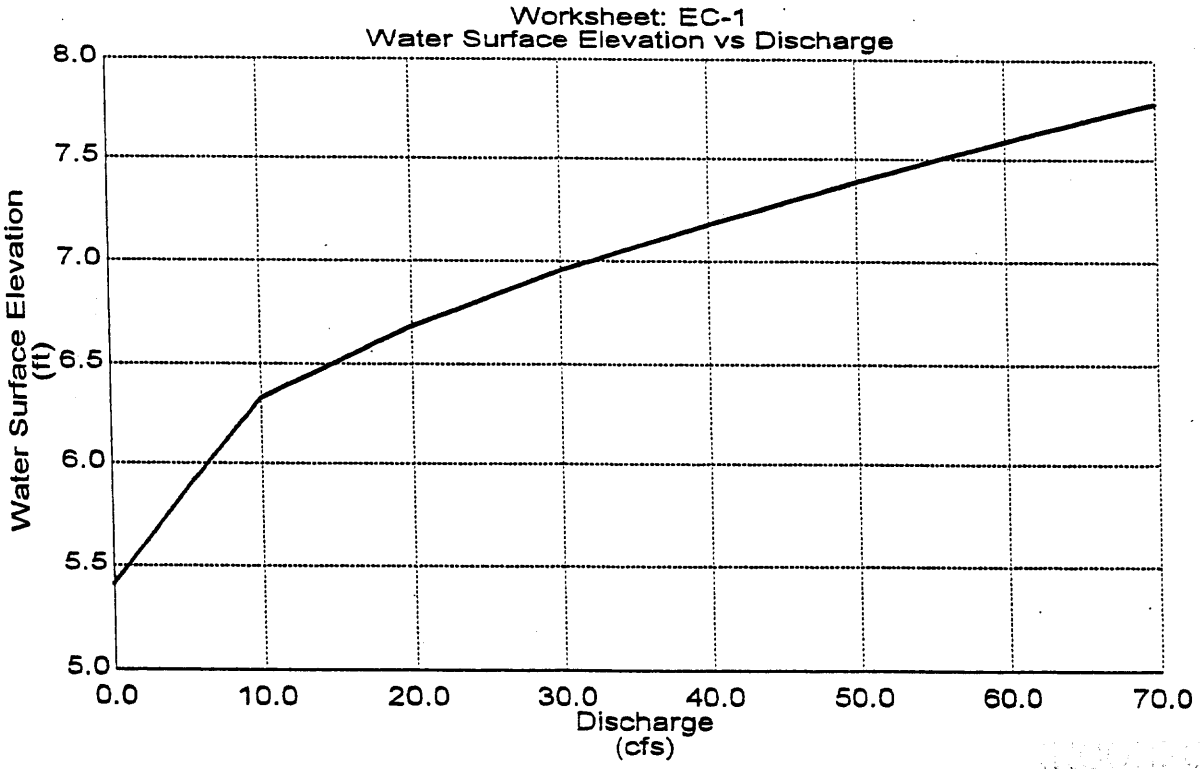
Rating Table and Discharge Curve for EC-1

Project Description	
Worksheet	EC-1
Flow Element	Irregular Channel
Method	Manning's Formula
Solve For	Channel Depth

Input slope = 0.078 ft/ft

Options	
Current Roughness Method	Improved Lotter's Method
Open Channel Weighting Method	Improved Lotter's Method
Closed Channel Weighting Method	Horton's Method

Discharge (cfs)	Water Surface Elevation (ft)	Velocity (ft/s)	Flow Area (ft^2)	Wetted Perimeter (ft)	Top Width (ft)
10.00	6.32	2.26	4.4	7.74	7.20
20.00	6.68	2.79	7.2	9.08	8.16
30.00	6.95	3.17	9.5	9.94	8.68
40.00	7.18	3.49	11.5	10.41	8.79
50.00	7.39	3.75	13.3	10.84	8.89
60.00	7.59	3.97	15.1	11.25	8.99
70.00	7.77	4.17	16.8	11.64	9.08



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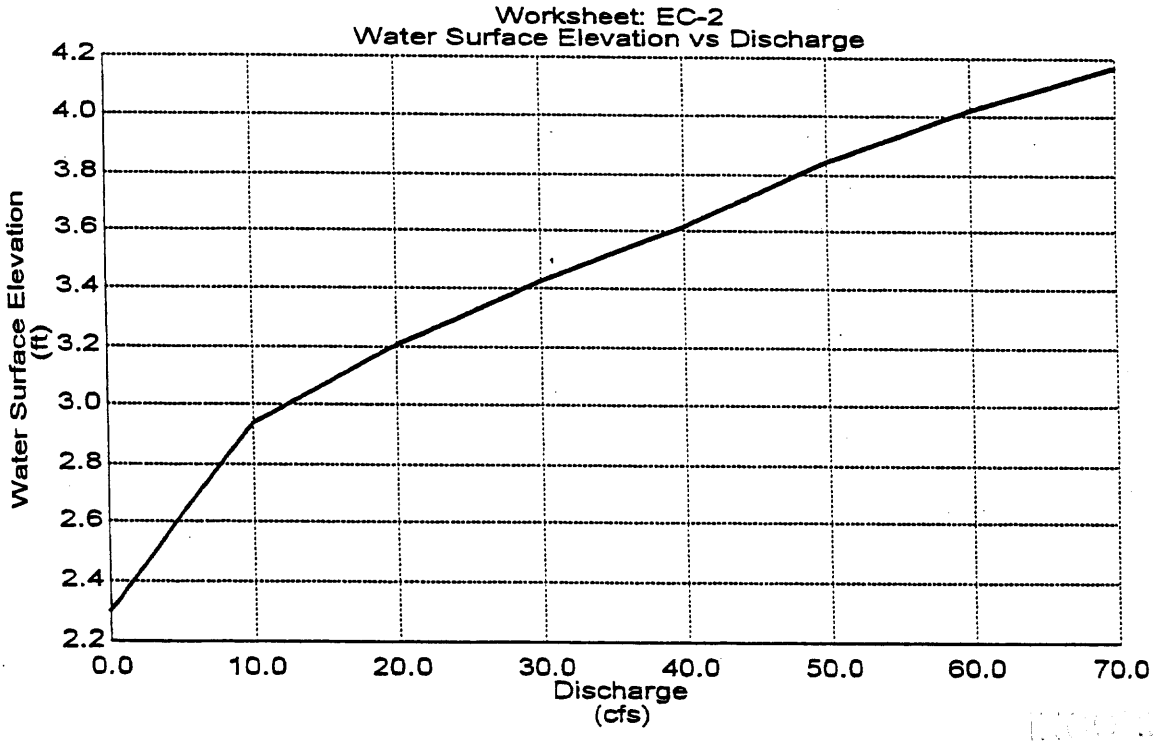
Rating Table and Discharge Curve for EC-2

Project Description	
Worksheet	EC-2
Flow Element	Irregular Channel
Method	Manning's Formula
Solve For	Channel Depth

Input slope = 0.048 ft/ft

Options	
Current Roughness Method	Improved Lotter's Method
Open Channel Weighting Method	Improved Lotter's Method
Closed Channel Weighting Method	Horton's Method

Discharge (cfs)	Water Surface Elevation (ft)	Velocity (ft/s)	Flow Area (ft^2)	Wetted Perimeter (ft)	Top Width (ft)
0.00	2.30	0.00	0.0	0.00	0.00
10.00	2.94	3.04	3.3	7.49	6.85
20.00	3.21	3.89	5.1	8.08	7.08
30.00	3.42	4.47	6.7	8.56	7.28
40.00	3.62	4.92	8.1	9.06	7.54
50.00	3.84	5.01	10.0	10.77	9.09
60.00	4.02	5.10	11.8	12.48	10.75
70.00	4.17	5.20	13.4	13.85	12.09



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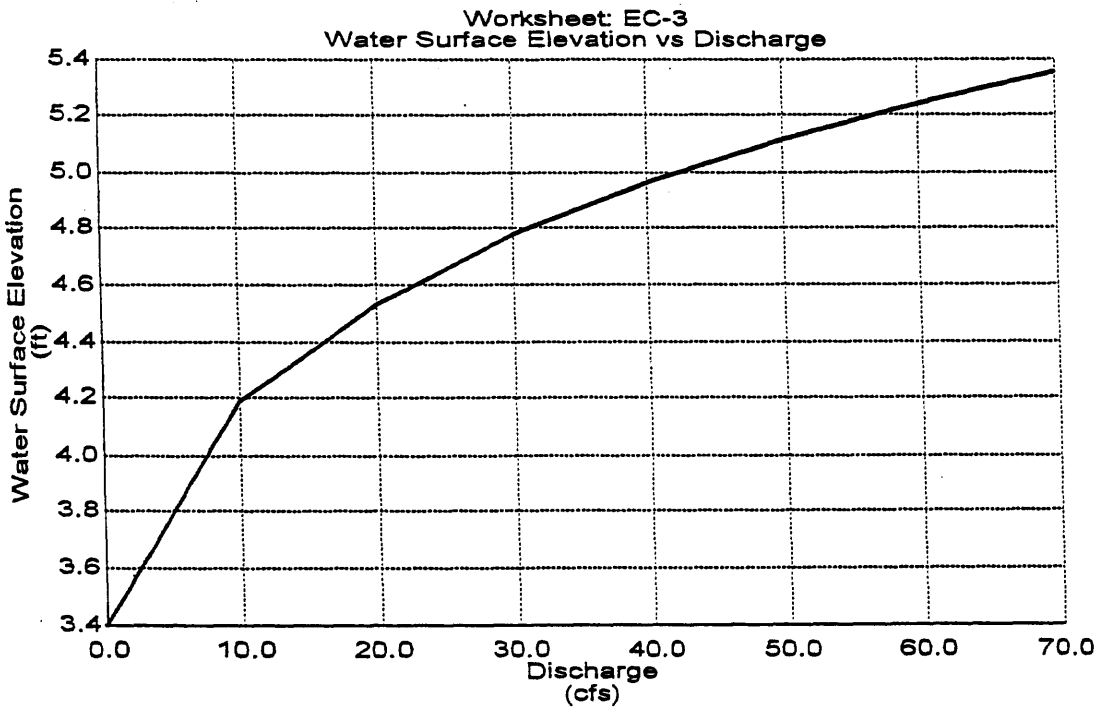
Rating Table and Discharge Curve for EC-3

Project Description	
Worksheet	EC-3
Flow Element	Irregular Channel
Method	Manning's Formula
Solve For	Channel Depth

Input slope = 0.036 ft/ft

Options	
Current Roughness Method	Improved Lotter's Method
Open Channel Weighting Method	Improved Lotter's Method
Closed Channel Weighting Method	Horton's Method

Discharge (cfs)	Water Surface Elevation (ft)	Velocity (ft/s)	Flow Area (ft^2)	Wetted Perimeter (ft)	Top Width (ft)
0.00	3.40	0.00	0.0	0.00	0.00
10.00	4.19	2.53	3.9	6.99	6.56
20.00	4.53	3.13	6.4	9.13	8.45
30.00	4.78	3.36	8.9	13.06	12.15
40.00	4.96	3.51	11.4	16.01	14.92
50.00	5.11	3.62	13.8	18.46	17.24
60.00	5.24	3.72	16.1	20.55	19.22
70.00	5.35	3.80	18.4	22.51	21.09



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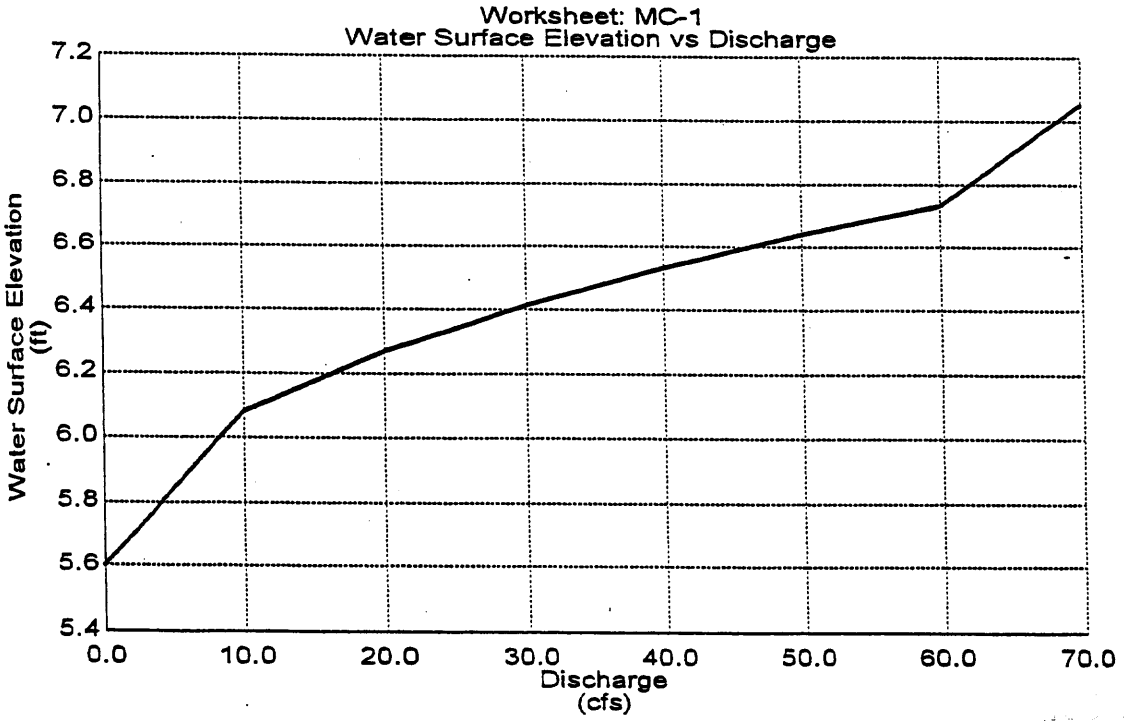
Rating Table and Discharge Curve for MC-1

Project Description	
Worksheet	MC-1
Flow Element	Irregular Channel
Method	Manning's Formula
Solve For	Channel Depth

Input slope = 0.015 ft/ft

Options	
Current Roughness Method	Improved Lotter's Method
Open Channel Weighting Method	Improved Lotter's Method
Closed Channel Weighting Method	Horton's Method

Discharge (cfs)	Water Surface Elevation (ft)	Velocity (ft/s)	Flow Area (ft^2)	Wetted Perimeter (ft)	Top Width (ft)
0.00	5.60	0.00	0.0	0.00	0.00
10.00	6.08	3.00	3.3	10.11	10.01
20.00	6.27	3.71	5.4	11.84	11.68
30.00	6.41	4.22	7.1	12.90	12.71
40.00	6.53	4.61	8.7	13.80	13.58
50.00	6.64	4.93	10.2	14.60	14.34
60.00	6.73	5.20	11.5	15.31	15.03
70.00	7.05	4.08	17.2	22.22	21.78



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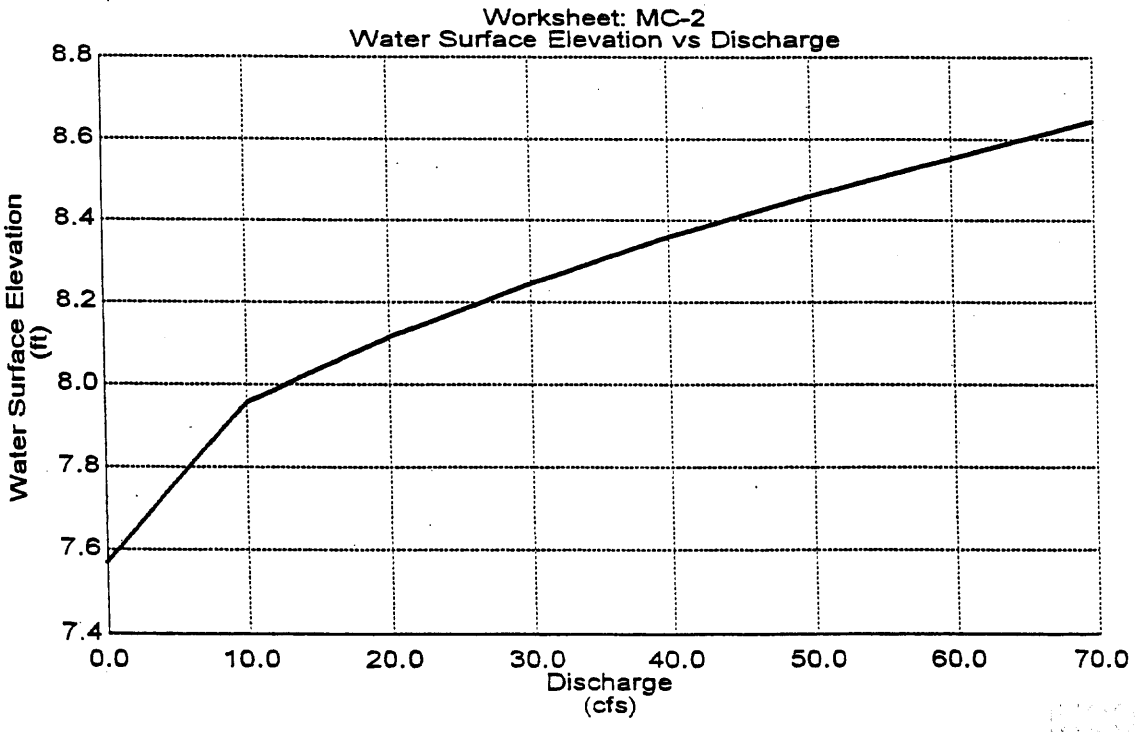
Rating Table and Discharge Curve for MC-2

Project Description	
Worksheet	MC-2
Flow Element	Irregular Channel
Method	Manning's Formula
Solve For	Channel Depth

Input slope = 0.013 ft/ft

Options	
Current Roughness Method	Improved Lotter's Method
Open Channel Weighting Method	Improved Lotter's Method
Closed Channel Weighting Method	Horton's Method

Discharge (cfs)	Water Surface Elevation (ft)	Velocity (ft/s)	Flow Area (ft^2)	Wetted Perimeter (ft)	Top Width (ft)
0.00	7.57	0.00	0.0	0.00	0.00
10.00	7.96	2.19	4.6	15.86	15.75
20.00	8.12	2.79	7.2	16.90	16.73
30.00	8.25	3.20	9.4	17.75	17.53
40.00	8.36	3.51	11.4	18.48	18.21
50.00	8.46	3.77	13.2	19.14	18.83
60.00	8.55	4.00	15.0	19.75	19.40
70.00	8.64	4.16	16.8	20.36	19.98



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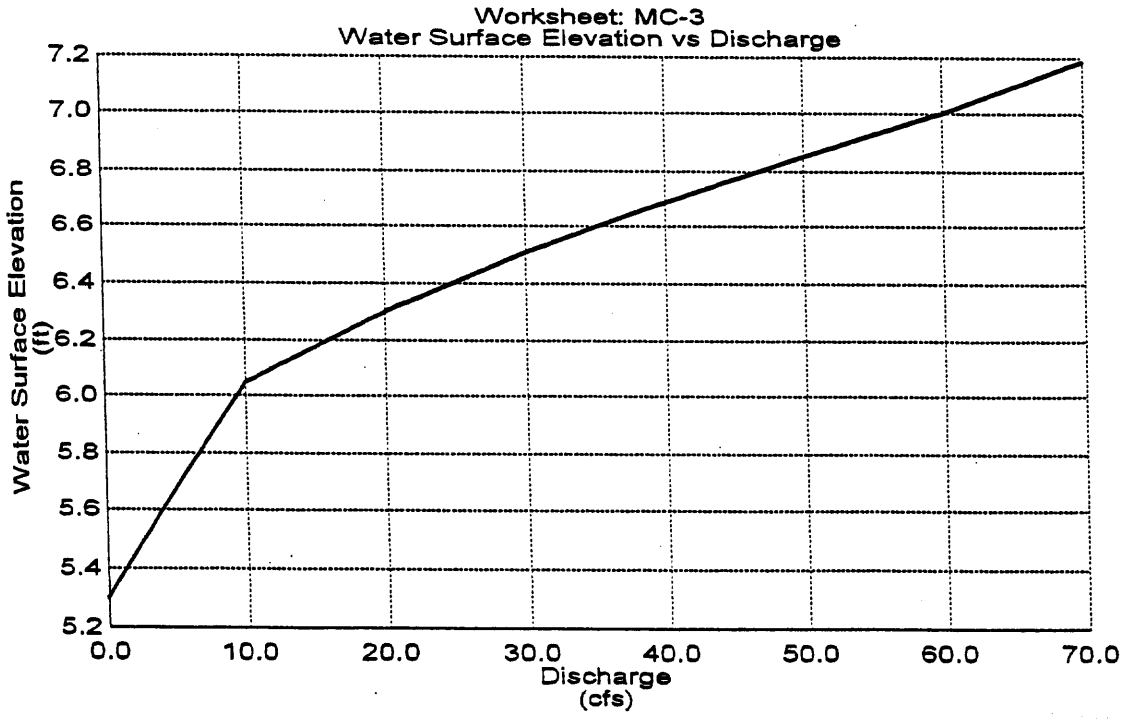
Rating Table and Discharge Curve for MC-3

Project Description	
Worksheet	MC-3
Flow Element	Irregular Channel
Method	Manning's Formula
Solve For	Channel Depth

Input slope = 0.008 ft/ft

Options	
Current Roughness Method	Improved Lotter's Method
Open Channel Weighting Method	Improved Lotter's Method
Closed Channel Weighting Method	Horton's Method

Discharge (cfs)	Water Surface Elevation (ft)	Velocity (ft/s)	Flow Area (ft^2)	Wetted Perimeter (ft)	Top Width (ft)
0.00	5.30	0.00	0.0	0.00	0.00
10.00	6.05	1.81	5.5	12.49	12.09
20.00	6.30	2.31	8.7	13.27	12.69
30.00	6.50	2.65	11.3	13.92	13.18
40.00	6.68	2.91	13.7	14.48	13.61
50.00	6.85	3.13	16.0	14.98	13.99
60.00	7.00	3.30	18.2	15.56	14.47
70.00	7.19	3.34	21.0	16.88	15.71



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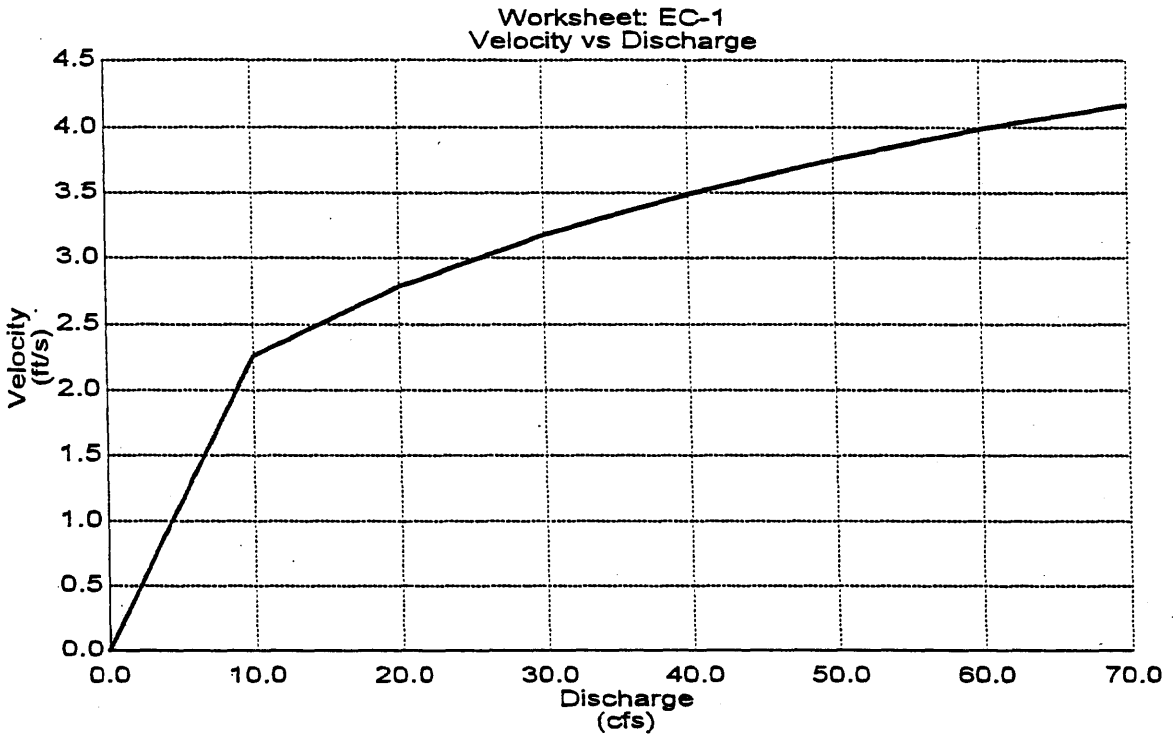

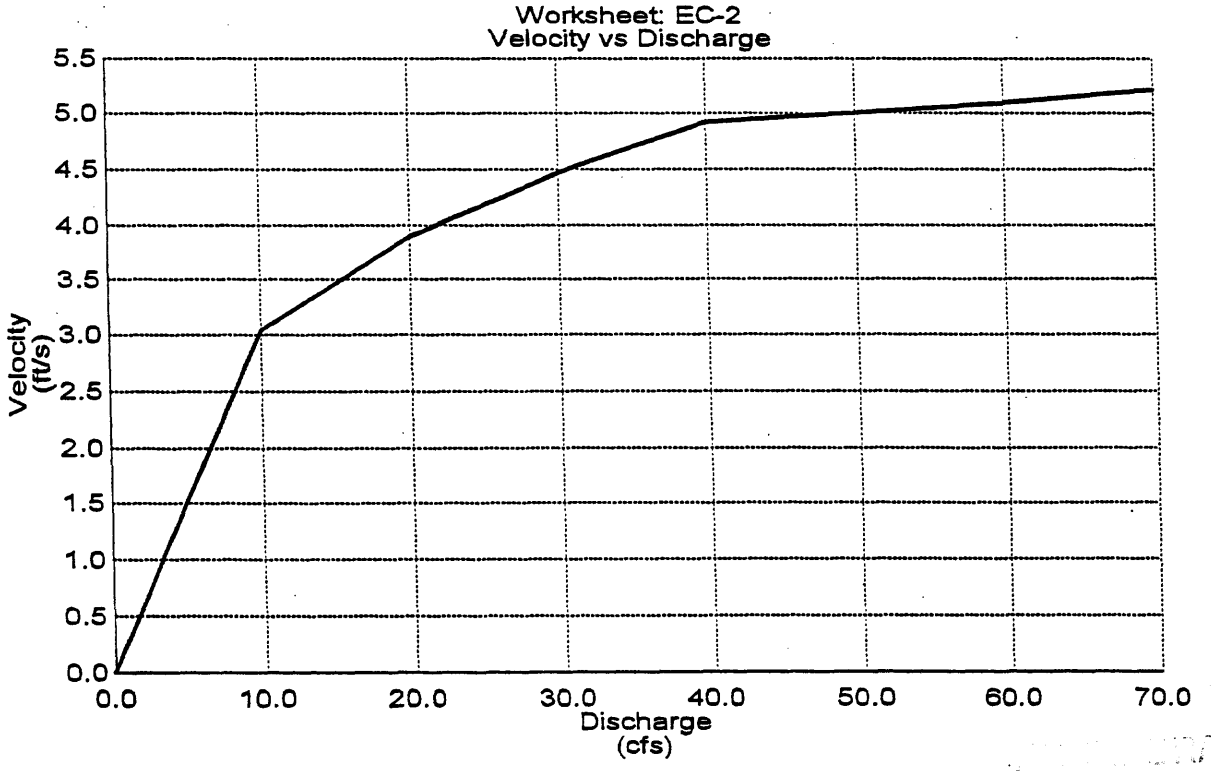

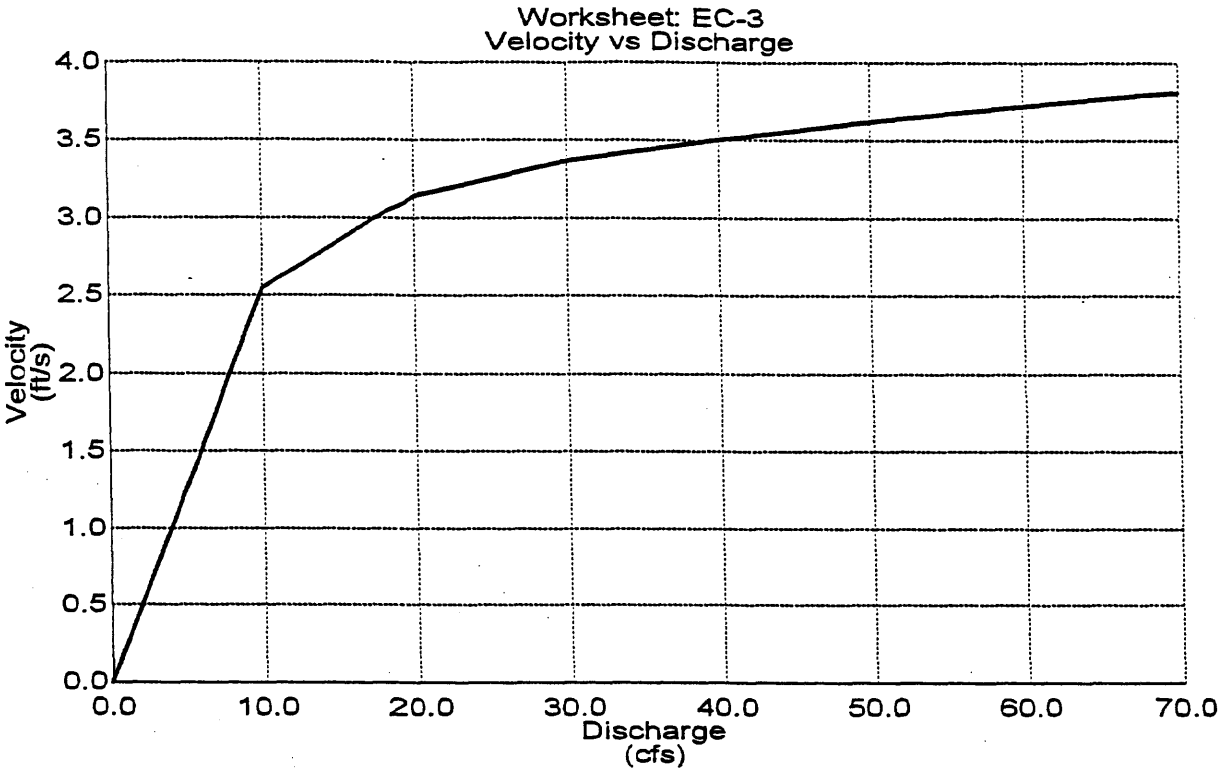

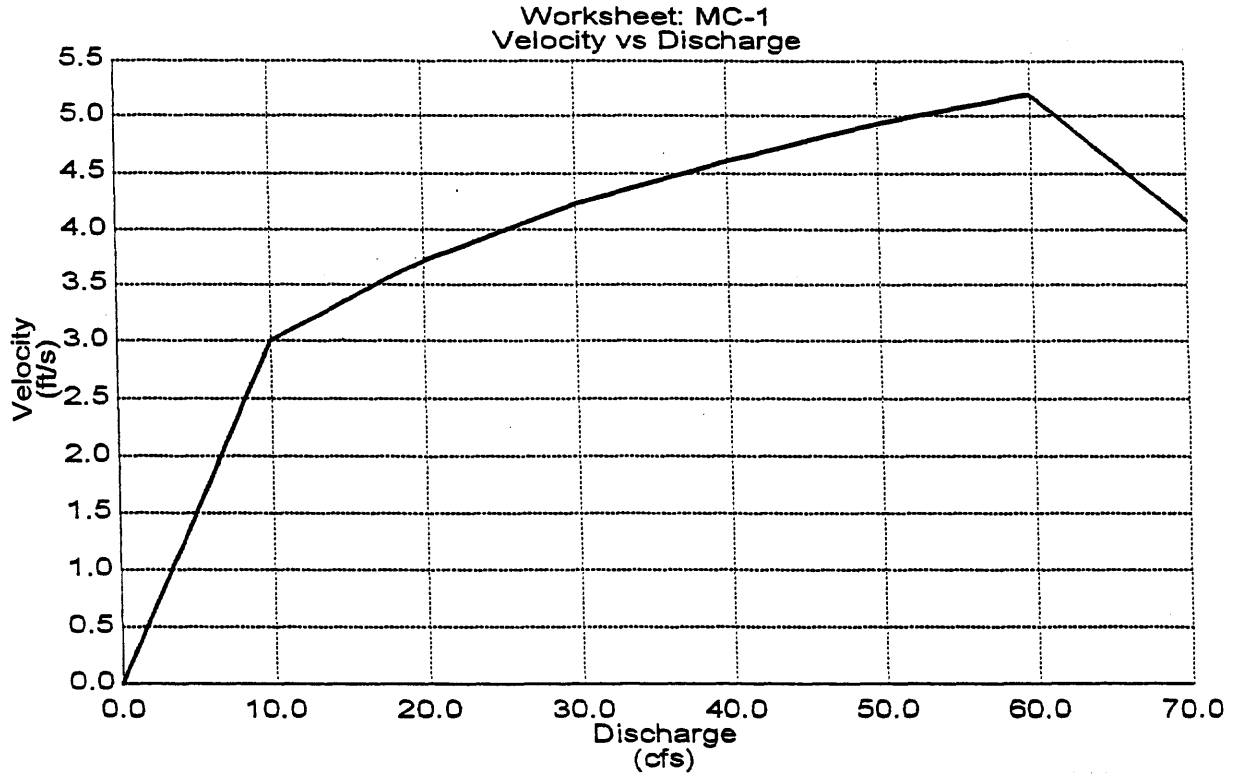

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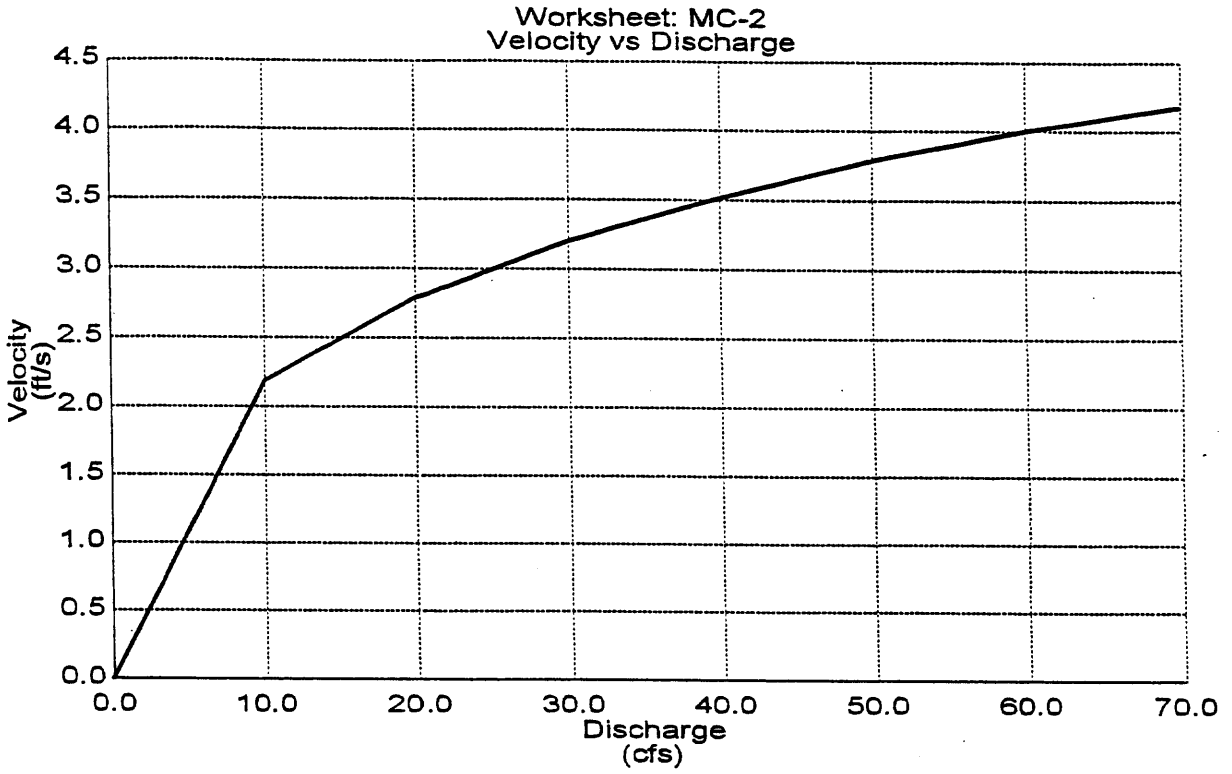

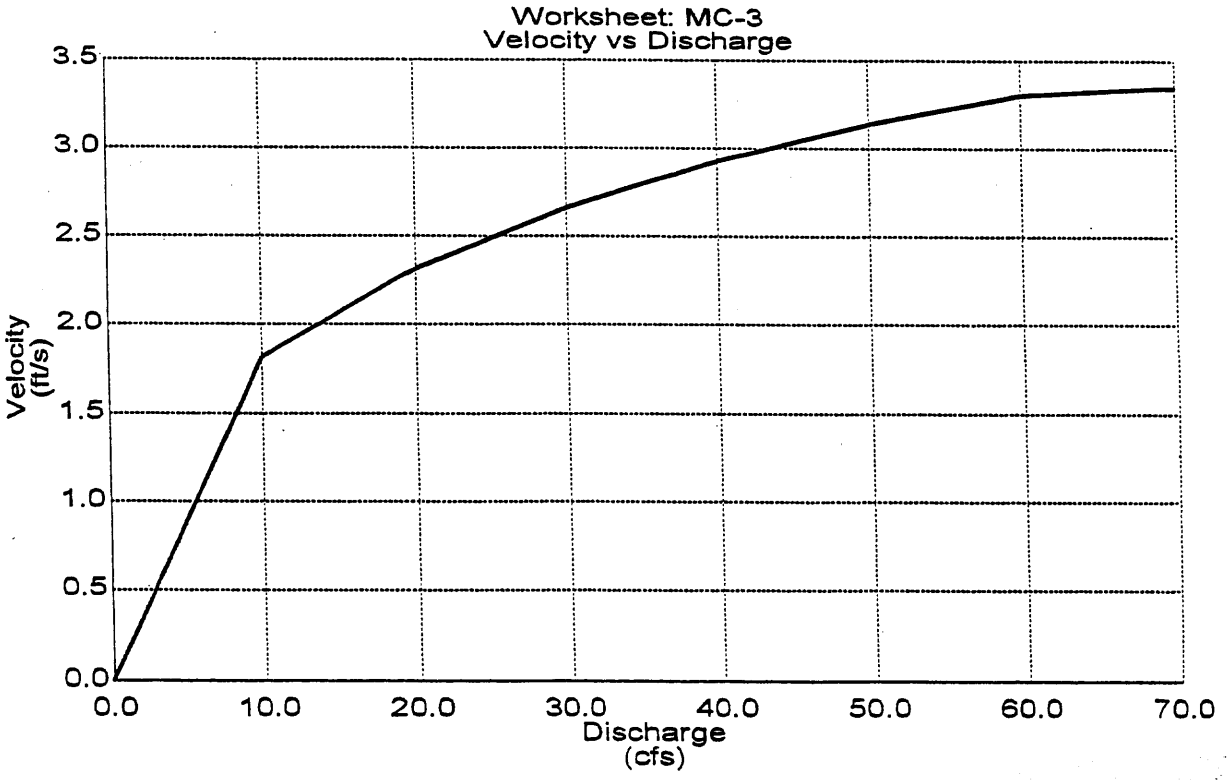

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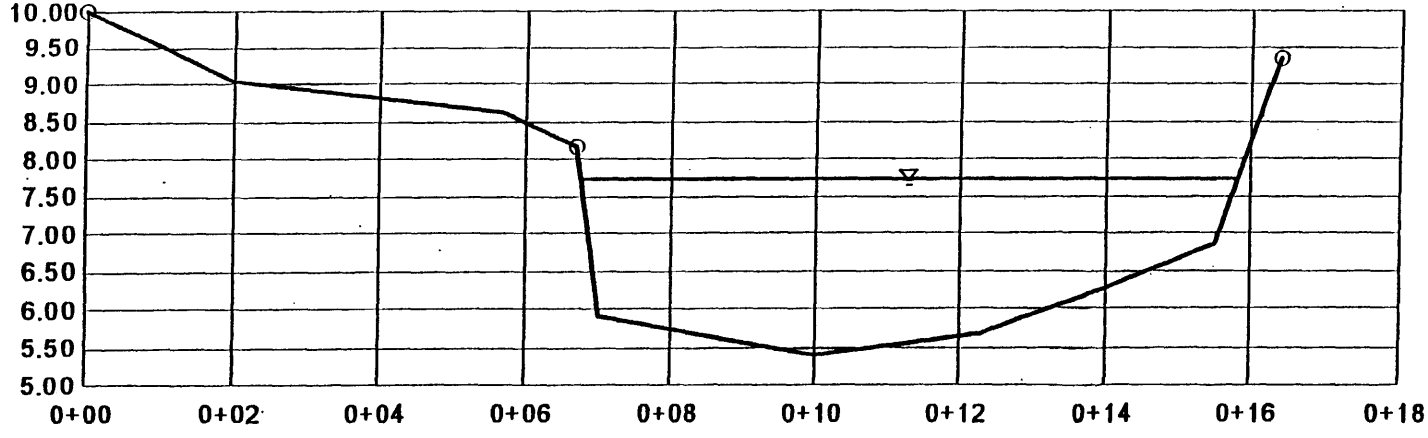
Cross Section
Cross Section for Irregular Channel

Project Description	
Worksheet	EC-1
Flow Element	Irregular Channel
Method	Manning's Formula
Solve For	Channel Depth

Section Data	
Mannings Coefficient	0.127
Slope	0.078000 ft/ft
Water Surface Elevation	7.72 ft
Elevation Range	5.40 to 10.00
Discharge	66.90 cfs



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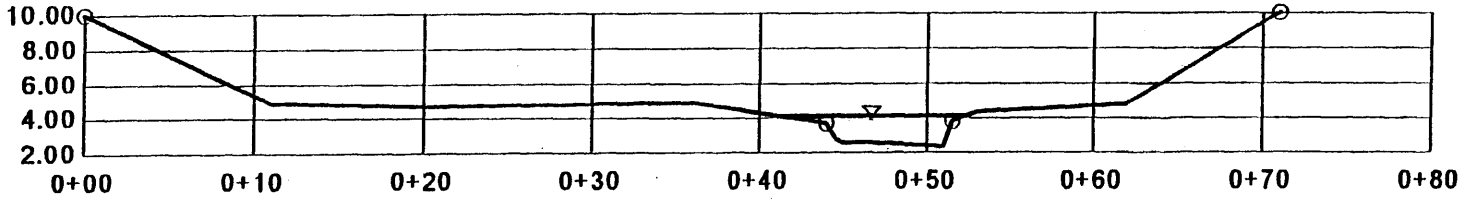
Cross Section
Cross Section for Irregular Channel

Project Description	
Worksheet	EC-2
Flow Element	Irregular Channel
Method	Manning's Formula
Solve For	Channel Depth

Section Data	
Mannings Coefficient	0.061
Slope	0.048000 ft/ft
Water Surface Elevation	4.12 ft
Elevation Range	2.30 to 10.00
Discharge	66.90 cfs

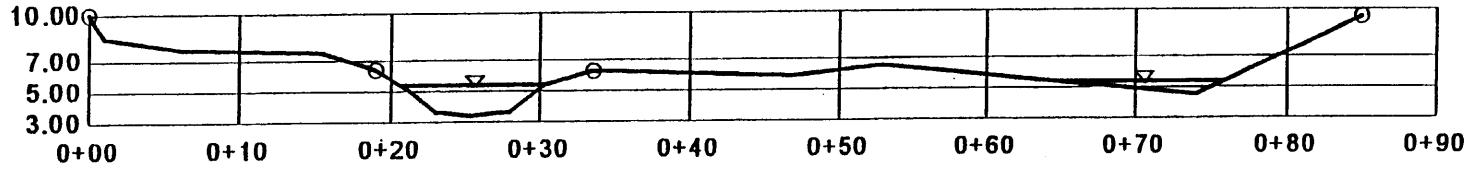


V:1
H:1
NTS

Cross Section
Cross Section for Irregular Channel

Project Description	
Worksheet	EC-3
Flow Element	Irregular Channel
Method	Manning's Formula
Solve For	Channel Depth

Section Data	
Mannings Coefficient	0.065
Slope	0.036000 ft/ft
Water Surface Elevation	5.32 ft
Elevation Range	3.40 to 10.00
Discharge	66.90 cfs



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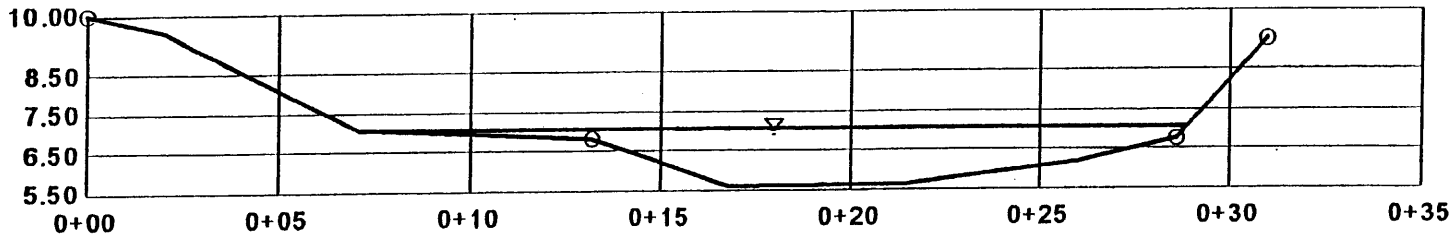
Cross Section
Cross Section for Irregular Channel

Project Description	
Worksheet	MC-1
Flow Element	Irregular Channel
Method	Manning's Formula
Solve For	Channel Depth

Section Data	
Mannings Coefficient	0.039
Slope	0.015000 ft/ft
Water Surface Elevation	7.05 ft
Elevation Range	5.60 to 10.00
Discharge	66.90 cfs



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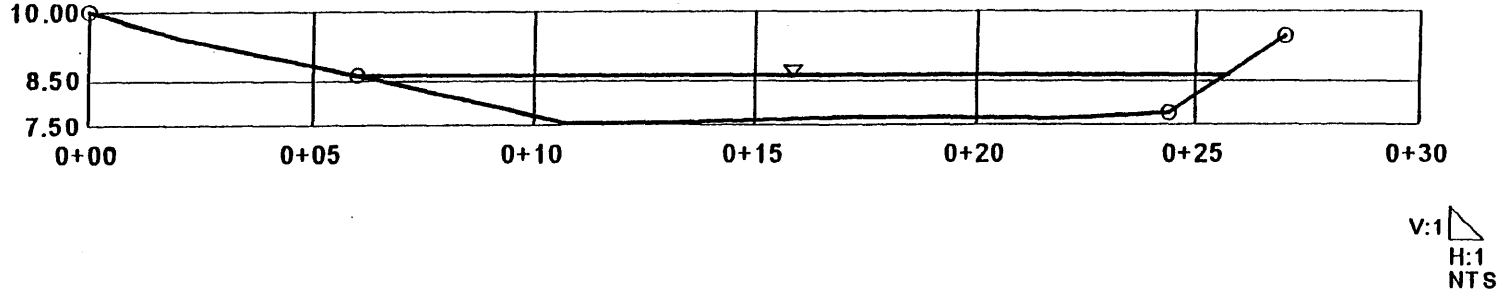
Cross Section
Cross Section for Irregular Channel

Project Description	
Worksheet	MC-2
Flow Element	Irregular Channel
Method	Manning's Formula
Solve For	Channel Depth

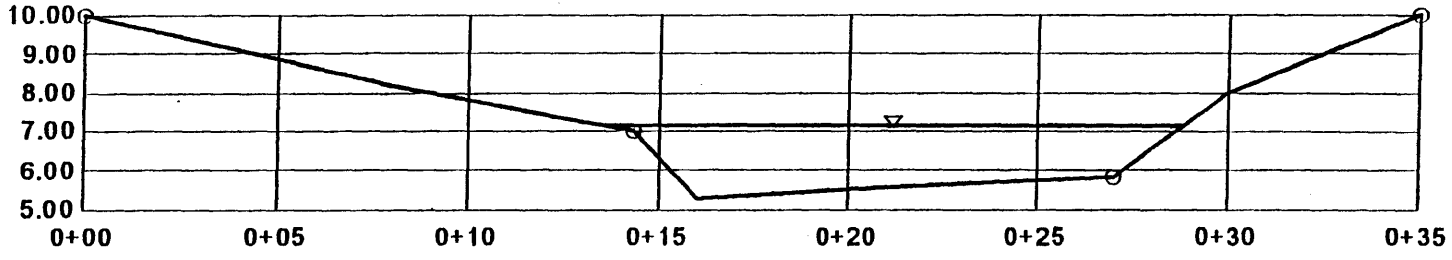
Section Data	
Mannings Coefficient	0.036
Slope	0.013000 ft/ft
Water Surface Elevation	8.61 ft
Elevation Range	7.57 to 10.00
Discharge	66.90 cfs



Cross Section
Cross Section for Irregular Channel

Project Description	
Worksheet	MC-3
Flow Element	Irregular Channel
Method	Manning's Formula
Solve For	Channel Depth

Section Data	
Mannings Coefficient	0.046
Slope	0.008000 ft/ft
Water Surface Elevation	7.13 ft
Elevation Range	5.30 to 10.00
Discharge	66.90 cfs



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Allowable velocities on the channel bottom (i.e., no bank slope correction factor needed):

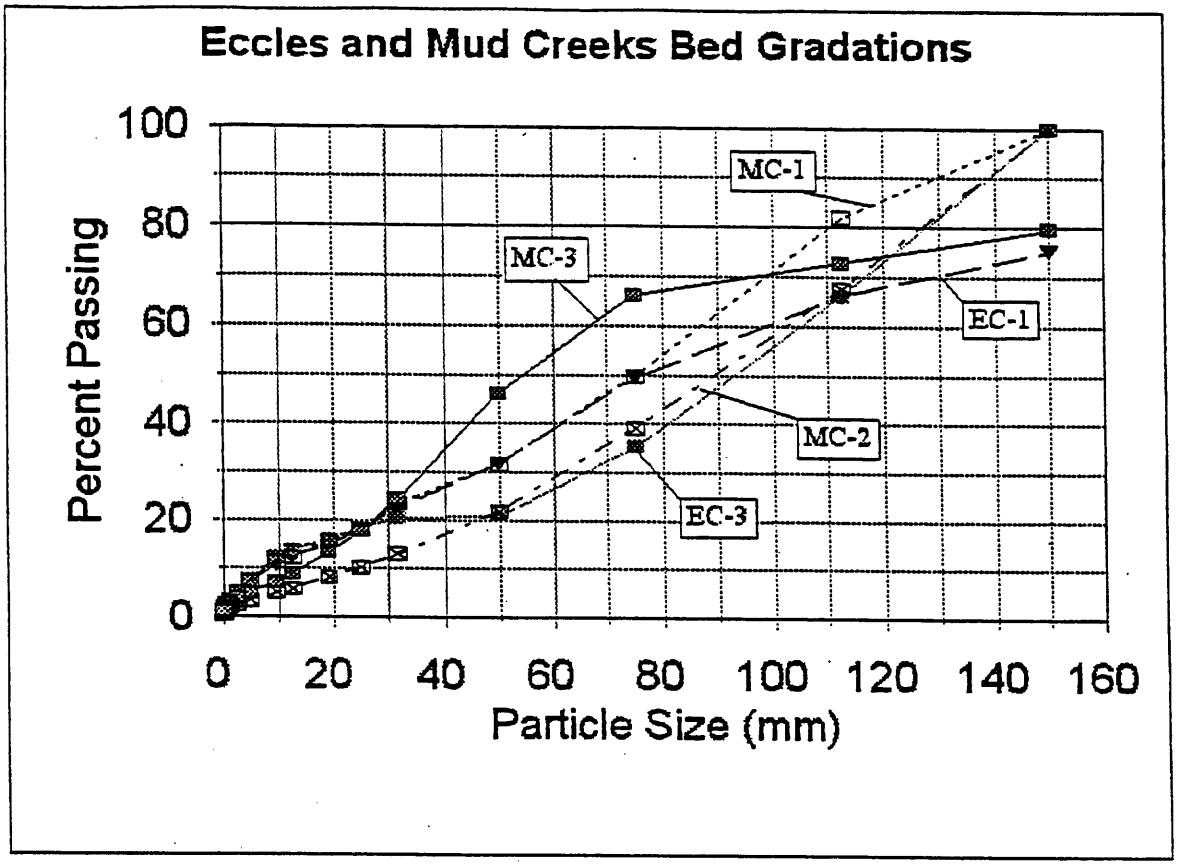
Stream Station	D_{75} (mm)[a]	Sediment-Laden Conditions[b]				Sediment-Free Conditions[b]				Actual Velocity (ft/s)[c]	Comments
		Basic Vel. (ft/s)	Depth Factor	Alignment Factor	Allowable Vel. (ft/s)	Basic Vel. (ft/s)	Depth Factor	Alignment Factor	Allowable Vel. (ft/s)		
Discharge Rate = 5,000 gpm (11.1 cfs)											
EC-1	150	12.5	0.9	1.0	11.3	10.5	0.9	1.0	9.5	2.4	OK
EC-2	136	12.0	0.9	1.0	10.8	10.0	0.9	1.0	9.0	3.1	OK
EC-3	122	11.3	0.9	1.0	10.2	9.3	0.9	1.0	8.4	2.6	OK
MC-1	104	11.0	0.9	1.0	9.9	8.8	0.9	1.0	7.9	3.1	OK
MC-2	120	11.3	0.9	0.8	8.1	9.3	0.9	0.8	6.7	2.3	OK
MC-3	105	11.0	0.9	1.0	9.9	8.8	0.9	1.0	7.9	1.9	OK
Discharge Rate = 10,000 gpm (22.3 cfs)											
EC-1	150	12.5	0.9	1.0	11.3	10.5	0.9	1.0	9.5	2.9	OK
EC-2	136	12.0	0.9	1.0	10.8	10.0	0.9	1.0	9.0	4.0	OK
EC-3	122	11.3	0.9	1.0	10.2	9.3	0.9	1.0	8.4	3.2	OK
MC-1	104	11.0	0.9	1.0	9.9	8.8	0.9	1.0	7.9	3.8	OK
MC-2	120	11.3	0.9	0.8	8.1	9.3	0.9	0.8	6.7	2.9	OK
MC-3	105	11.0	0.9	1.0	9.9	8.8	0.9	1.0	7.9	2.4	OK

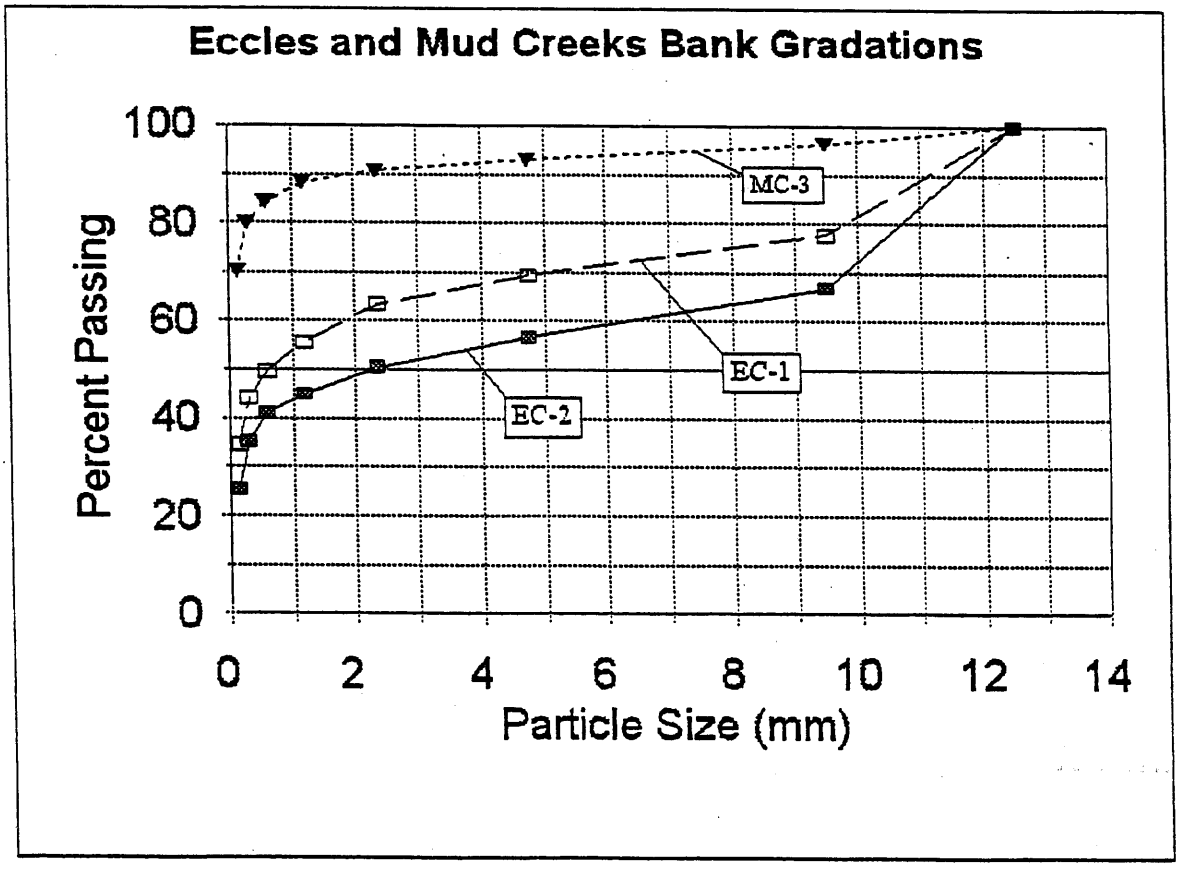
[a] See gradation results (pp. 20-21 of this calculation)
[b] See graphs on pg. 22 of this calculation
[c] See velocity rating curves (pp. 9-11 of this calculation)

Allowable velocities on the channel bottom (continued):

Stream Station	D_{75} (mm)[a]	Sediment-Laden Conditions[b]				Sediment-Free Conditions[b]				Actual Velocity (ft/s)[c]	Comments
		Basic Vel. (ft/s)	Depth Factor	Alignment Factor	Allowable Vel. (ft/s)	Basic Vel. (ft/s)	Depth Factor	Alignment Factor	Allowable Vel. (ft/s)		
Discharge Rate = 20,000 gpm (44.6 cfs)											
EC-1	150	12.5	0.9	1.0	11.3	10.5	0.9	1.0	9.5	3.6	OK
EC-2	136	12.0	0.9	1.0	10.8	10.0	0.9	1.0	9.0	5.0	OK
EC-3	122	11.3	0.9	1.0	10.2	9.3	0.9	1.0	8.4	3.6	OK
MC-1	104	11.0	0.9	1.0	9.9	8.8	0.9	1.0	7.9	4.7	OK
MC-2	120	11.3	0.9	0.8	8.1	9.3	0.9	0.8	6.7	3.6	OK
MC-3	105	11.0	0.9	1.0	9.9	8.8	0.9	1.0	7.9	3.1	OK
Discharge Rate = 30,000 gpm (66.9 cfs)											
EC-1	150	12.5	0.95	1.0	11.9	10.5	0.95	1.0	10.0	4.1	OK
EC-2	136	12.0	0.9	1.0	10.8	10.0	0.9	1.0	9.0	5.2	OK
EC-3	122	11.3	0.9	1.0	10.2	9.3	0.9	1.0	8.4	3.7	OK
MC-1	104	11.0	0.9	1.0	9.9	8.8	0.9	1.0	7.9	5.5	OK
MC-2	120	11.3	0.9	0.8	8.1	9.3	0.9	0.8	6.7	4.1	OK
MC-3	105	11.0	0.9	1.0	9.9	8.8	0.9	1.0	7.9	3.3	OK

(a) See gradation results (pp. 20-21 of this calculation)
(b) See graphs on pg. 22 of this calculation
(c) See velocity rating curves (pp. 9-11 of this calculation)





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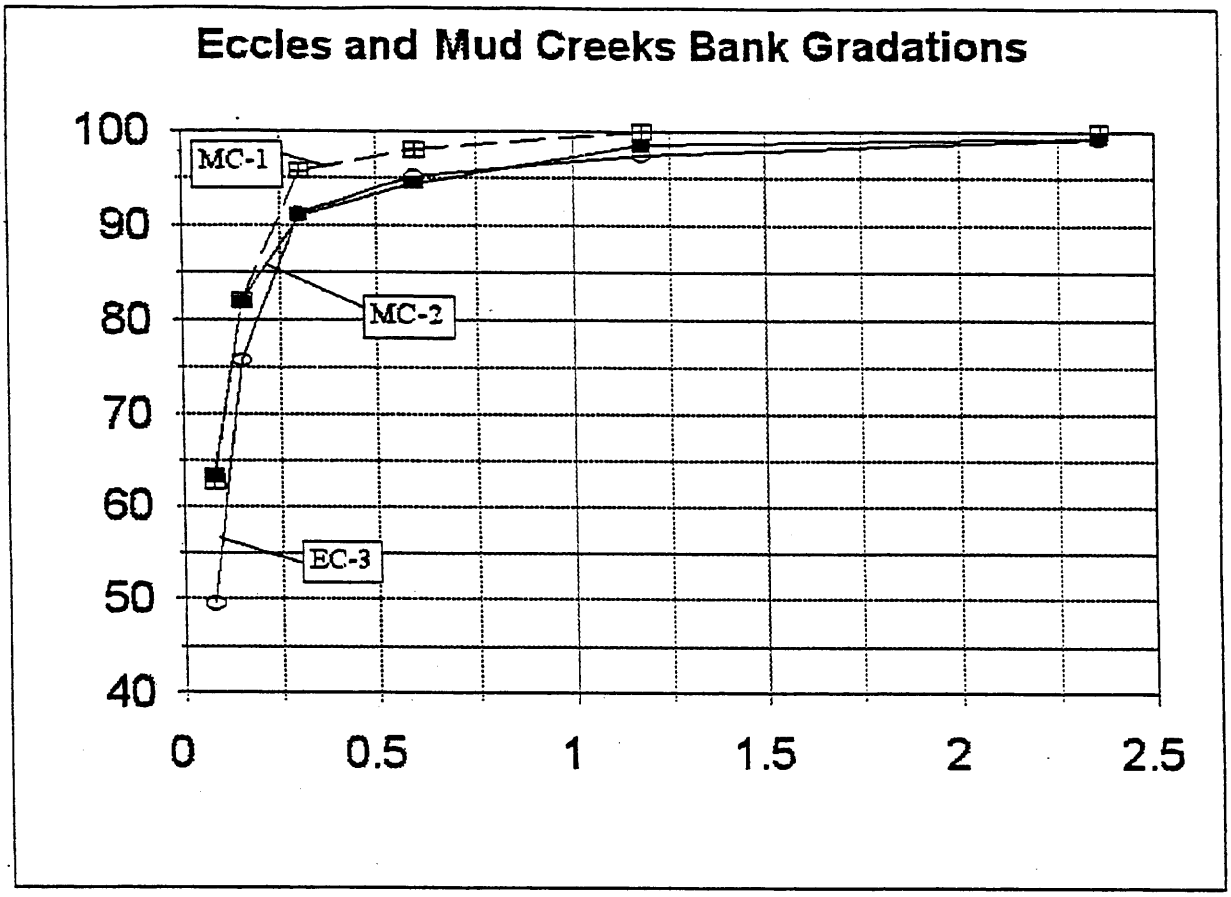

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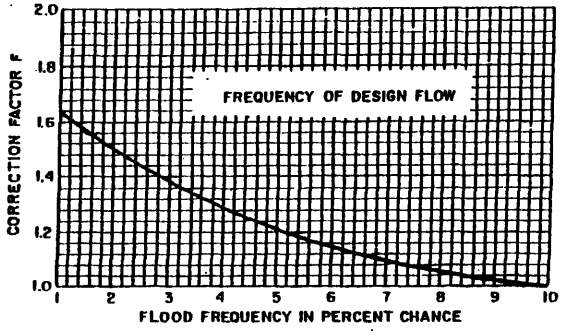
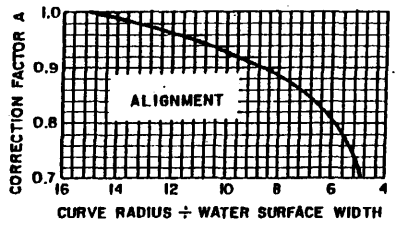
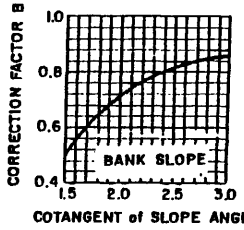
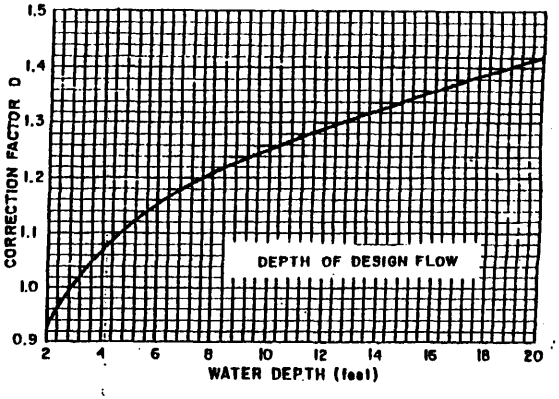
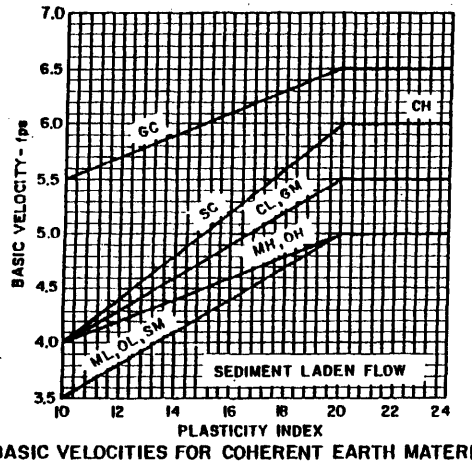


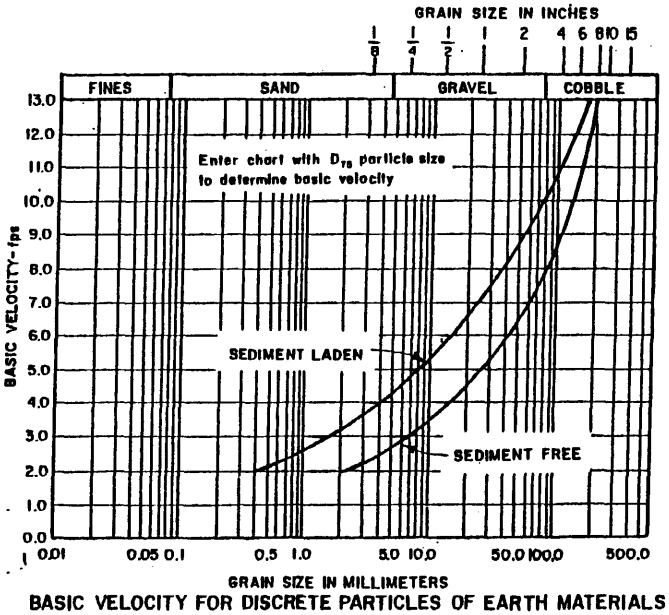




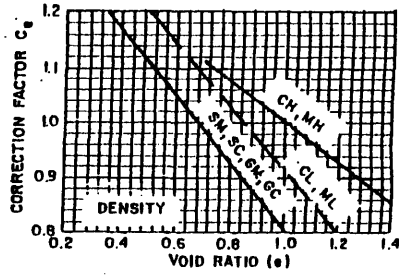




BASIC VELOCITIES FOR COHERENT EARTH MATERIALS (v_b)

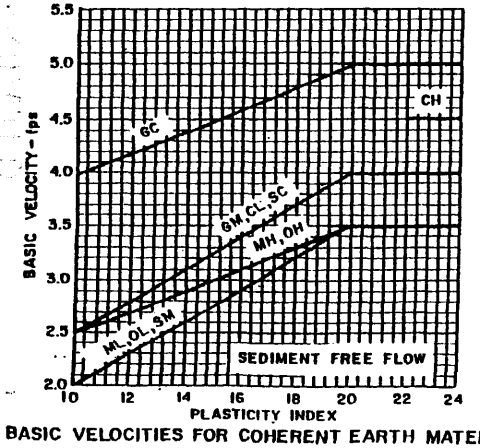


BASIC VELOCITY FOR DISCRETE PARTICLES OF EARTH MATERIALS (v_b)



NOTES:

1. In no case should the allowable velocity be exceeded when the 10% chance discharge occurs, regardless of the design flow frequency.



BASIC VELOCITIES FOR COHERENT EARTH MATERIALS (v_b)

ALLOWABLE VELOCITIES FOR UNPROTECTED EARTH CHANNELS	
CHANNEL BOUNDARY MATERIALS	ALLOWABLE VELOCITY
DISCRETE PARTICLES	
Sediment Laden Flow	
$D_{75} > 0.4$ mm	Basic velocity chart value x D x A x B
$D_{75} < 0.4$ mm	2.0 fps
Sediment Free Flow	
$D_{75} > 2.0$ mm	Basic velocity chart value x D x A x B
$D_{75} < 2.0$ mm	2.0 fps
COHERENT EARTH MATERIALS	
PI > 10	Basic velocity chart value x D x A x F x C_e
PI < 10	2.0 fps

Source: US SCS (1977)

ALLOWABLE VELOCITIES FOR UNPROTECTED EARTH CHANNELS

Revised –

Calculate allowable velocities on channel banks. Channel banks below the grass line are comprised of material typical of the bed materials. Therefore, base the analysis on the vegetated portion of the channel banks (i.e., fine-grained soil). The vegetation consists of a good stand of native grasses, approx 12" tall. Evaluate each cross section at its maximum velocity. Assume the average cross section velocity is representative of the velocity against the bank. Soils are erosion resistant:

Stream Station	Bank Soil Type[a]	Channel Slope (%)	Allowable Vel. (ft/s)[b]	Max. Actual Vel. (ft/s)[c]	Comments
EC-1	SM (silty sand)	7.8	6	4.1	OK
EC-2	SM (silty sand)	4.8	7	5.2	OK
EC-3	SM-ML (silty clayey sand)	3.6	7	3.8	OK
MC-1	ML (clayey silt)	1.5	7	5.2	OK
MC-2	CL (silty clay)	1.3	7	4.1	OK
MC-3	ML-SM (sandy clayey silt	0.8	7	3.3	OK

(a) See gradation results (pp. 20-21 of this calculation)
(b) See table on pg 24 of this calculation
(c) Maximum velocity of flow ≤ 30,000 gpm from velocity rating curves (pp. 9-11 of this calc.)

Calculate allowable velocities on the floodplain. Evaluate only those channels where the flow exceeds the channel capacity and impacts the floodplain (EC-2, MC-1, and MC-3). Analysis based on good stand of native grasses, approx 12" tall and on erosion-resistant soils (i.e., relatively high silt and clay content). Floodplain only impacted at highest evaluated discharge rate (30,000 gpm):

Stream Station	Floodplain Soil Type[a]	Floodplain Slope (%)	Allowable Vel. (ft/s)[b]	Actual Vel. (ft/s)[c]	Comments
Discharge Rate = 30,000 cfs (66.9 gpm)					
EC-2	SM (silty sand)	4.8	7	5.2	OK
MC-1	ML (clayey silt)	1.5	7	4.5	OK
MC-3	ML-SM (sandy clayey silt	0.8	7	3.4	OK

(a) See gradation results (pp. 20-21 of this calculation)
(b) See table on pg 24 of this calculation
(c) Average cross section velocity from velocity rating curves (pp. 9-11 of this calculation)

Allowable Velocities for Vegetated Channels
(From Haan et al., 1994)

	Allowable Velocity (ft/s)					
	Erosion-Resistant Soils (% Slope)			Easily Eroded Soils (% Slope)		
	0-5	5-10	>10	0-5	5-10	>10
Bermuda grass	8	7	6	6	5	4
Buffalo grass Kentucky bluegrass Smooth brome Blue gramma Tall fescue	7	6	5	5	4	3
Lespedeza sericea Weeping lovegrass Kudzu Alfalfa Crabgrass	3.5	NR[a]	NR	2.5	NR	NR
Grass mixture	5	4	NR	4	3	NR
Annuals for temporary protection	3.5	NR	NR	2.5	NR	NR

[a] Not recommended

Note: Shaded row considered representative of natural grasses along Eccles and Mud Creeks.

References Cited

Haan, C.T., B.J. Barfield, and J.C. Hayes. 1994. Design Hydrology and Sedimentology for Small Catchments. Academic Press. San Diego, CA.

Haestad Methods, Inc. 1998. FlowMaster Professional Edition for Windows, Version 6.0. Waterbury, CT.

U.S. Soil Conservation Service. 1977. Design of Open Channels. Technical Release No. 25. U.S. Department of Agriculture. Washington, D.C.

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EarthFax

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Engineering Inc.
Engineers/Scientists
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Midvale, Utah 84047
Telephone 801-561-1555
Fax 801-561-1861

December 17, 2001

Mr. Chris Hansen
Canyon Fuel Company
Skyline Mine
HC 35, Box 380
Helper, Utah 84526

Re: Addendum to Skyline Mine Discharge Evaluation

Dear Chris:

At your request, EarthFax Engineering, Inc. ("EarthFax") has modified the addendum to the discharge evaluation for the Skyline Mine. The scope for this additional evaluation is based on concerns raised by the Manti-LaSal National Forest regarding incorporating phosphorus data into the flow-weighted linear mixing water quality model.

According to Hem (1985), phosphorous in natural waters occurs in several forms. Analyses for phosphorous measure either orthophosphate or total phosphorous. Orthophosphate is the most common stable dissolved form of phosphorous. Total phosphorous includes both the dissolved form and the phosphorous contained in particulate matter in the sample, such as sediment or organic matter. There is no way to convert between the dissolved and total results, due to the inclusion of un-dissolved phosphorous from the sediment and organic matter in the total analysis results.

NorWest (2000a) prepared an Addendum to the Technical Report-Surface-water and Groundwater Resources in the Flat Canyon Area that addressed impacts to the receiving water quality by comparing the beneficial use standards against the historic data. Exceedances were identified for total phosphorous.

Historic data for several sampling points for phosphorous and orthophosphate are presented in Attachment A. The mean and maximum values of these parameters are summarized in Table 1. For those samples with parameter results that were less than detection limits, the data were adjusted to one-half the detection limit. The upstream historic mean values of total phosphate are 2 to 3 times the beneficial use standard of 0.05 mg/l. Using the mean historic values as input, the linear flow weighted mixing model results in an accurate projection of water quality downstream of the mine (see Table 2). The historic projection is within 2 percent of the measured average value.

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At the time of our October 22, 2001 water quality evaluation, no data had been received from samples collected on emergency discharges for either orthophosphate or total phosphorus. Subsequently, orthophosphate and total phosphorous sample results were received for samples collected in September, October, and November 2001. In September and October 2001 samples were taken at the normal monitoring points. On November 20th, one stream sample above the mine and a composite mine water sample (Mine 1, Mine 3, and sediment pond) were collected. On November 26th and 30th, composite mine water samples were collected. On November 28th, one stream sample below the mine and a composite mine water sample were collected.

In the November 20th samples, total phosphorous was identified in the composite mine water (0.110 mg/l) and the sample above the mine (0.231 mg/l). For all other samples during this period total phosphorus was not detected. The orthophosphate sample results were all non-detects.

The November 20th sampling had occurred at the end of an extended period of rainfall/runoff in the area of the mine. In these samples, orthophosphate was not detected. Because orthophosphate analyses are run on field-filtered samples, it is likely that the phosphorus that was detected in the total phosphorous results came from sediment or organic matter contained in the un-filtered total phosphorous samples. Subsequent sampling has not detected any additional total phosphorus. Therefore, it is likely that the phosphorous in the samples were naturally occurring.

All expansion water discharged from the mine is to be treated by sand filtering. Therefore, as evidenced by the lack of detectable total phosphorus in the mine discharge, this filtering appears to be adequate for the removal of phosphorus from the mine water. Hence, based on the data to date, the likely discharges from Mine 1 will be in the range of the September through November results (0.025 mg/l). Based on these assumptions, Tables 3, 4, and 5 present the model predictions of water quality in Eccles Creek under the three discharge scenario conditions.

As can be seen, the mine discharges are not likely to result in any adverse impacts to surface waters with respect to elevated concentrations of orthophosphate or total phosphorus. As indicated in the original report, the increased flow from the mines will result in an improvement to the water quality flowing in Eccles Creek below the mine. The total phosphorous concentration predictions will be less than the beneficial use standards.

For the projection of discharges to the Huntington Creek drainage, the historic data for Upper Huntington Creek were used with the anticipated discharges from Mine 1. Tables 6, 7, and 8 present the model predictions of water quality to Electric Lake under the three discharge scenario conditions.

The projected total phosphorous concentrations to Electric Lake will be less than the historic values for all three scenarios. However, they will be at or above the beneficial use standard.

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Given the high level of the historic total phosphorous in the lake, the additional discharge would improve the lake water quality.

I hope this description of the potential impacts provides you with the information that you need. If you have any questions, please give me a call.

Sincerely,

Thomas J. Suchoski
Hydrologist

Table 1

Summary of Total and Orthophosphate Data

Site Name	Site Description	Total Phosphorous Average (mg/l)	Total Phosphorous Maximum (mg/l)	Ortho Phosphorous Average (mg/l)	Ortho Phosphorous Maximum (mg/l)
CS-3	Upper middle Fk of Eccles Ck	0.12	1.15	0.03	0.04
CS-4	Upper L Fork of Eccles Ck	0.14	1.52	0.03	0.05
CS-9	R Fk of Eccles Ck AB mine	0.17	3.50	0.03	0.05
CS-11	L Fork of Eccles Ck immediately AB mine	0.10	0.66	0.04	0.05
CS-12	#3 Mine Q	0.05	0.21	0.03	0.04
CS-14	#1 Mine Q	0.14	0.99	0.03	0.07

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TABLE 2

ECCLES CREEK-Historic Conditions

Monitoring Point:	Flows (gpm)
CS-4 - Upper Eccles	190
CS-14 - Mine 1 Discharge	153
CS-12 - Mine 3 Discharge	242

	INPUT						OUTPUT			
Parameter	X_{cs4} Upstream Concentration (mg/l)	Q_{cs4} Upstream Discharge (gpm)	X_{cs14} Mine Concentration (mg/l)	Q_{cs14} Mine Discharge (gpm)	X_{cs12} Mine Concentration (mg/l)	Q_{cs12} Mine Discharge (gpm)	X_{ds} Downstream Concentration (mg/l)	Q_{ds} Downstream Discharge (gpm)	Historic Downstream Concentration (mg/l)	Percentage of Historic %
Alkalinity, Bicarbonate	266	190	310	153	280	242	283.30	585	321	-11.74
Calcium	74	190	141	153	74.9	242	91.90	585	88	4.43
Chloride	12	190	14.8	153	11	242	12.32	585	14	-12.01
Magnesium	14	190	85.3	153	49.7	242	47.42	585	35	35.47
Phenol	0	190	0	153	0	242	0.00	585	0	0.00
Potassium	1	190	13.1	153	7.5	242	6.85	585	6.1	12.35
Phosphorous	0.136	190	0.144	153	0.053	242	0.10	585	0.105	-1.18
Sodium	6	190	62.9	153	52.5	242	40.12	585	52	-22.85
TDS	269	190	1104	153	797	242	705.81	585	554	27.40
TOC	1.65	190	0.36	153	0.7	242	0.92	585	0.7	31.37
TSS	0	190	26	153	6	242	9.28	585	27	-65.62
Sulfate	15	190	525	153	361	242	291.52	585	193	51.04

TABLE 8

ELECTRIC LAKE - Expansion Conditions

Monitoring Point:	Flow (gpm)
UPL-10 - Upper Huntington Creek @ Lake Inflo	3857
Mine 1	12000
Mine 1 Adjustment	8.1

Parameter	UPL-10 Average Concentration (mg/l)	UPL-10 Flow Rate (gpm)	Mine 1 Average Concentration (mg/l)	Mine 1 Adjusted Concentration (mg/l)	Mine 1 Flow Rate (gpm)	Estimated Concentration (mg/l)	Total Discharge (gpm)	Historic Concentration (mg/l)	Precentage of Historic %
Alkalinity, Bicarbonate	183	3857	226	244.306	12000	229.39	15857.00	183	25.35
Calcium	53	3857	45.03	48.67743	12000	49.73	15857.00	53	-6.17
Chloride	6.5	3857	3.9	4.2159	12000	4.77	15857.00	6.5	-26.59
Magnesium	9.9	3857	17.21	18.60401	12000	16.49	15857.00	9.9	66.53
Phosphorous	0.101	3857	0.025	0.027025	12000	0.05	15857.00	0.146	-69.17
Potassium	1	3857	2.56	2.76736	12000	2.34	15857.00	1	133.75
Sodium	3.7	3857	3.54	3.82674	12000	3.80	15857.00	3.7	2.59
TDS	182	3857	185	199.985	12000	195.61	15857.00	182	7.48
Sulfate	15.2	3857	7.89	8.52909	12000	10.15	15857.00	15.2	-33.21

STATE OF COLORADO
DIVISION OF WATER RESOURCES

PHC ADDENDUM

APPENDIX E
SCOFIELD RESERVOIR STUDIES

NONPOINT SOURCE POLLUTION AND FISHERIES IN SCOFIELD RESERVOIR, CARBON COUNTY, UTAH
January, 1991

Kevin D. Christopherson
Utah Division of Wildlife Resources

Harry Judd
Utah Bureau of Water Pollution Control

DIV OF OIL GAS & MINING

NONPOINT SOURCE POLLUTION AND FISHERIES IN SCOFIELD RESERVOIR, CARBON COUNTY, UTAH
January, 1991

Kevin D. Christopherson
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Harry Judd
Utah Bureau of Water Pollution Control

INTRODUCTION

The fishery at Scofield Reservoir has experienced a dramatic decline over the past decade. Two major variables also changed during this period. Fishing regulations were changed to allow year round fishing, and the reservoir experienced a decline in water quality. Controversy and confusion has marked the debate over this decline. This report will summarize the data collected over the past ten years, and make recommendations on how to best solve the problems.

Scofield has traditionally been one of Utah's top fisheries. Besides producing desirable size and quantities of trout, it is unique in that it is an outstanding shore fishery. It is located in the northwest corner of Carbon County in southeastern Utah. The dam impounds much of the drainage to the Price River. At maximum capacity the reservoir is 49 feet deep, stores 65,780 useable acre-feet of water and is 2,908 surface acres.

Beyond the obvious recreational, culinary, and quality of life benefits, this reservoir also provides a great deal of economic benefit to the state's tourism industry. Based on a 1986 angler survey the reservoir provided 81,200 angler days of fishing use. The U.S. Fish and Wildlife Service, 1985 National Hunting and Fishing Survey, estimated the economic value of an angler day to be $30.20. That projects the economic value of fishing at Scofield Reservoir to be 2,452,240 dollars per year. Eleven percent of the anglers originated from Carbon County, making the value to the local economy at least 269,746 dollars annually. This value does not include the money that was spent in Carbon County by anglers from outside the county. It clearly is an important resource.

The fishery in Scofield Reservoir has been managed under a basic yield concept where 600,000 fingerling trout (3 inches) were stocked every year, allowed to grow naturally in the reservoir and then harvested by anglers when they reach an acceptable size (put-grow-take). These fish were usually harvested the following year after they had grown to ten or more inches. This management has failed several of the past years,

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and adjustments must be made.

Declining water quality is a nationwide problem. Many large and important reservoirs have lost their usefulness due to poor water quality, or siltation. Water pollution that originates from the watershed is called non point source (NPS) pollution. This has been well documented in reservoirs in the Tennessee Valley and throughout the country. Cascade Reservoir in central Idaho has experienced a similar decline. Non point source (NPS) pollution was identified as the cause, and to date considerable effort has been made to correct the problem (Agricultural Pollution Abatement Plan, Cascade Reservoir Watershed, Valley County, Idaho 1990). This is becoming an important issue in Utah, and perhaps will be even more acute in this arid region, where water is such a precious resource.

In the mid-1970s the Southeastern Utah Association of Local Governments (SEUALG) initiated the development of the Waste Water Quality Management-208 Plan (June 1977). This document identified water quality problems within the Scofield Reservoir watershed. The problems were caused by a nutrient rich state (eutrophic), and was manifested by blue-green algal blooms and anoxic hypolimnion during summer stratification.

Additional study and reports by the Utah Bureau of Water Pollution Control have made recommendations to include a waste water treatment plant for the town of Scofield, stabilizing stream banks, install year-round public rest rooms, the creation of wetlands, and improved watershed management on private and public lands.

All of these options have merit; most are expensive. Some of these recommendations have been implemented, but it has not been enough. Scofield Reservoir is too important a fishery resource to lose. Trout need good water quality to survive, and poor water quality is a key factor in the decline of the fishery.

STATUS OF THE FISHERY

To monitor fish growth, condition, and survival the Utah Division of Wildlife Resources (DWR) conducts annual gill net surveys. The nets are traditionally set in the spring and fall, and provide a base line of data to compare the current year with past years.

Scofield Reservoir has been stocked annually with at least 600,000 fingerling (3 inch) trout for the past ten years. Stocked trout are most vulnerable in their first year of life. For a successful fishery, they must survive their first year in order to grow to a harvestable size (ten or more inches). Monitoring these young fish is the primary objective of the gill net sampling.

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Three inch trout have been used because they are less costly. The cost of hatchery raised trout is approximately three dollars per pound. Six hundred thousand three inch fish weigh 6667 pounds, costing $20,000. The same number of five inch fish weigh 30,000 pounds and cost approximately $90,000. Clearly if the three inch fish survive, they are more cost effective.

The number of fingerling trout caught in the nets each spring has declined dramatically since 1981, indicating low survival from the previous year (figure 1). Even more alarming are the low numbers caught in the fall nets. Spring stocked fish are absent by fall, indicating that they have not even survived the summer (figure 2).

Major fish kills have been reported in the years 1960, 1961, 1972, 1976, 1977, and 1981. Beyond major observable fish kills, gill netting indicated poor survival of stocked fingerling in, 1981, 1982, 1985, 1987, and 1989, a discouraging trend.

WATER QUALITY

History

Water quality is not a new issue for Scofield reservoir and its watershed. The declining fishery, blue-green algal blooms, and severe oxygen depletion has again raised concerns over water quality. A number of government agencies have documented the declining water quality in Scofield Reservoir.

In the mid-1970s the Southeastern Utah Association of Local Governments (SEUALG) initiated the development of the Waste Water Quality Management-208 Plan (June 1977). This document identified water quality problems within the Scofield Reservoir watershed. The problems were caused by a nutrient rich (eutrophic) condition, and was manifested by blue-green algae blooms and anoxic hypolimnion during summer stratification.

An outgrowth of the 208 Plan was a study of the reservoir conducted by the Utah Bureau of Water Pollution Control in 1979-1980. Over fertility resulting from excessive inputs of nitrate and phosphate was identified as a major problem. Two recommendations were made to limit pollution. First a more adequate sewage facility for the area, and second, better control of livestock related nutrients in the watershed.

A 1981 study, Water Quality in Pleasant Valley, Utah, (Clyde et al, 1981) found peaks in nutrient levels during spring run-off in Mud Creek. This was suggested to be a major part of the problem, and fecal coliform ratios (0.3:1.0) indicated the major portion was from livestock.

The Bureau of Water Pollution Control (Denton 1983) completed a Phase I Clean Lakes Study at Scofield Reservoir in 1983. The study suggested four options as the most feasible and beneficial for solving the pollution problems. They were; 1)

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creation of a south shore wetland to trap nutrients before they can enter the reservoir; 2) increase public awareness and generate support for reduced human impacts; 3) alter the outlet to allow more hypolimnetic discharge; 4) Continue to monitor projects through SEUALG (Pleasant Valley Committee).

Water quality and fishing

It has been suggested that ice fishing has contributed to the declining water quality, due to litter and human waste left by the anglers. In 1989-90 a twelve month study was conducted by the Price River Water Improvement District (PRWID) to monitor coliform bacteria in the reservoir and the drainage. At the same time the Utah Bureau of Water Pollution Control sampled nutrient levels at similar stations. Coliform bacteria are an indicator species used to identify the amount of all bacteria in the water. Coliform bacteria live naturally in the stomachs of warm blooded animals, and their presence in water is an indication of human or other mammalian waste.

Theses studies indicated that the source for most of the nutrients and bacteria were from the tributaries (figure 3). The levels of coliform bacteria also varied seasonally with the peaks occurring June through September (figure 4). This time period correlated with the presence of livestock in the drainage, and the study concluded livestock are the most likely source of the coliform bacteria entering the reservoir.

Anglers are not a significant source of pollution, and in fact the fish that are harvested are a removal of phosphorus from the reservoir (estimated at 2,200 pounds of phosphorus, Donaldson 1986). Fishing, and the resulting removal of these nutrients is actually helping the water quality.

Erosion is the major source of pollution in Scofield Reservoir. Sediment related nutrients are the primary reason for the deteriorating water quality in the reservoir.

Sources of the pollution

The Utah Bureau of Water Pollution Control completed a Phase I - 314 Clean Lake Study at Scofield Reservoir (Denton et al., 1983). This study identified the sources of pollution. Phosphate and nitrate were responsible for the nutrification, and phosphate was identified as the limiting nutrient. For this reason phosphate was made the focal point for nutrient reduction efforts.

The blue-green algae blooms were linked to internal and external phosphate loading. Internal loading of phosphorus involves chemical interactions within the reservoir. Beginning with the reservoir impoundment in 1946, sediments have been deposited in the reservoir. These sediments contain phosphorus that has been stored in different chemical forms. The phosphorus

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is bound to other elements (iron and calcium) to form phosphate salts. In summer and winter the lake thermally stratifies so that the hypolimnion (bottom) can not mix with the surface. As the organic molecules decompose the free oxygen in the water is consumed and, eventually, the hypolimnion becomes anoxic. Under these conditions phosphate salts dissolve and the phosphorus is released into the water (Figure 5). These nutrients become biologically available, leading to the blue-green algal bloom observed in the summer, which produces large amounts of organic material that sinks to the bottom.

Fish species like carp (Cyprinus carpio) may add to the problem of internal loading by stirring up the sediments, and releasing nutrients into the water.

If external loading could be eliminated water passing through the reservoir would eventually flush out the internally loaded phosphates.

External loading consists of phosphorus, bound to sediments, entering the reservoir from the watershed. Approximately 77% of all external loading comes from Upper Fish Creek and Mud Creek. The remaining tributaries contribute approximately 18%, and only 5% comes from shoreline erosion.

The external sources of phosphorus include sediment, culinary and livestock waste. Much has been done since 1983 to reduce culinary waste. A more adequate sewage system has been installed in the Scofield area. Erosion and livestock continue to be the major problem.

Erosion in the watershed leads directly to sediment release, and the external loading of phosphorus and nitrates into the reservoir. Intensive livestock grazing in the watershed increases the natural erosion in the area. Combined this with road construction, recreational home construction and mining activities, the damage to the watershed is considerable.

The Manti LaSal National Forest has completed a Water Resource Inventory for the Price River watershed (G. Dennis Kelly, Manti-LaSal National Forest). Computer models (SEDROUT) were used to predict sedimentation. The data were compiled on 72,359 acres in and around the National Forest. Sediment yields were estimated and water shed improvement needs were identified.

Of the land surveyed, 7257 acres or 10.1 percent of the Price watershed was classified as having high to extreme erosion potential. Water quality based on suspended sediments was, estimated to range up to 276 mg/l in Mud Creek. Anything above 100 mg/l is considered high, or very poor water quality.

Current Study

In an effort to determine eutrophication trends occurring in the reservoir, the Utah Bureau of Water Pollution Control has utilized Carlson's (1977) trophic state index (TSI) values. These index values may be estimated from summer values of Secchi Disk (SD) depth readings in meters, total phosphorus (TP)

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concentrations in mg/m^3 or a weighted combination of these components. Carlson assigned TSI values on a scale of 0-100 for these variables.

These TSI values are related to trophic condition through a [illegible] greater than 50, with hyper eutrophic lakes greater than 60. A mesotrophic, or moderately productive reservoir, is preferred for fish production and recreation.

Data does not exist for all of the above parameters for the period of study (1981-1989). Bases on the data available, there is a general trend towards eutrophication for all of the parameters measured (figure 6). An average TSI plot of all factors substantiates the trend towards eutrophication.

Secchi depth and chlorophyll-a indicate an overall increase in algal productivity as evidenced by the decrease in transparency and increase in chlorophyll-a production. It is this increased algal productivity that results in a loss of recreational uses, and leads to an increase in internal phosphorus loading. In addition to nuisance algal blooms which are linked to noxious tastes and odors, the high algal productivity leads to a reduction of dissolved oxygen (DO) within the reservoir.

In an effort to document DO depletion, an instrument (datasonde) was deployed in the water column at a deep site of the reservoir. This instrument is manufactured by Hydrolab Corporation and is capable of monitoring DO concentrations for a specified time interval over an extended period of time. The instrument was deployed at a depth of 2.5 meters while the maximum water depth was approximately 7.0 meters. The depth was selected after an initial profile identified it as a depth where aerobic conditions would likely exist throughout the study period. The instrument was programmed to take a DO reading every 2 hours. A plot of daily DO averages, in the hypolimnion, over the study period (January 10 through April 23, 1990) is graphically represented in Figure 5.

On January 10, when the datasonde was initially deployed, the DO profile depicted a gradual decline from 8.3 mg/l at the surface to 5.0 mg/l at the bottom. A review of Figure 6 reveals a consistent decline in DO concentrations. On April 4, 1990 the last DO profile was conducted. The profile showed a DO concentration of 4.1 mg/l at the surface with anoxic condition below 5 meters. In addition, the DO concentration at 2.5 meters was 1.5 mg/l. Overall, the DO depletion incurred during the study period was severe. There was an approximate loss of 0.005 mg/l of DO per day at the study depth. If ice coverage had extended an additional three weeks, a maximum concentration at the surface would have been 3.0 mg/l, a critical level of dissolved oxygen for fish survival.

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DISCUSSION

Reasons for poor trout survival

Declining numbers of trout in the reservoir under a put-grow-take management scheme can be explained by one or both of two situations. Either the stocked fish are not surviving to a harvestable size, or the harvest is too great.

If the harvest is too great for the population then either the numbers of stocked fish must be increased to match the harvest or the harvest must be reduced. It should be noted that stocking more fish is not always an option. Every ecosystem has a maximum carrying capacity that cannot be exceeded. The carrying capacity is established by the resources available to the population. These resources include food, oxygen, temperature or other habitat parameters. In a given system one or more of these factors will be limiting. Excess numbers of fish will simply not survive when they are placed into a system that is already at its maximum capacity.

In 1986 the DWR changed it's state wide regulations to allow year-round fishing. The increased number of fishing days would likely increase total harvest and could adversely affect the fish population. This was of concern to DWR fisheries biologists. To assess the impacts of year-round fishing, creel surveys were conducted at many of Utah's major fishing waters, including Scofield Reservoir. An intensive twelve month survey of numbers of anglers the harvested trout was conducted in 1986. The fishing pressure and trout harvest can be compared to a similar survey conducted prior to year-round fishing in 1984 (Donaldson 1986).

The 1986 harvest was estimated at 252,200 trout, an increase of 13% over 1984. Of the 1986 harvested trout, 119,800 (48%) were from shore, 87,800 (35%) were from boats, and 44,500 (18%) were through the ice. The 13% increase observed in 1986 may not be significant because of a high statistical variability in the 1984 survey. Even if the 13% increase in harvest is real, it is doubtful that an increase of this size would have a dramatic effect on the fishery. As these larger fish are harvested it leaves more room (ecologically) for smaller fish. Excess fish have been stocked into the reservoir in 1988, and 1989, but fishing has not improved.

There are several reasons why fingerling trout may not survive including, poor water quality, predation, low food availability, disease, and poor fish condition at time of stocking. A good place to start is to identify what is different now as compared to fifteen years ago when the fingerling trout were surviving. As was demonstrated earlier section, the water quality has degraded continually during this period.

If the reduced trout numbers was a result of over harvest, the largest fish would be missing from the population. This is a

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result of the selectivity of anglers and fishing tackle for larger fish. In Scofield Reservoir the opposite is observed. Many larger fish are collected in the samples but very few fingerling trout. Often fish die off in large numbers in a short amount of time. Even when this happens there may be no visual evidence of dead fish. Depending on conditions they may sink to the bottom or be removed by scavengers. These massive die offs can occur any time of the year depending on the cause. This happens when the environmental conditions become so extreme that a threshold of tolerance is crossed. The fish are able to barely exist, but a point is reached that they can no longer tolerate, and they die.

During the summer and winter seasons, lakes can stratify to form temperature layers. As a result the water no longer mixes and the bottom layer (hypolimnion) becomes enriched with nutrients as solid particles settle to the bottom. As these nutrients and organic materials break down (oxidize) they consume the oxygen in the hypolimnion, further contributing to the problem. As the season progresses this anoxic layer becomes larger, forcing the fish into the upper layers of the reservoir. The fish can actually be "squeezed" into such a small layer that food or other resources are limited. This stratification and oxygen loss was documented in the winter of 1990 (figure 5). In the summer the fish can be forced to choose between top layer (epilimnion) where the water is too warm, or bottom layers where the oxygen is poor (see Coutant 1987).

This was documented in the summer of 1961, when oxygen levels dropped below critical levels and there was a large die off of trout and kokanee salmon. Kokanee require even more oxygen than trout. This has also occurred during drought cycles when the reservoir was drawn down to very low levels. Water quality was becoming a problem almost thirty years ago.

Major fish kills have been reported in six different years from 1960 to 1983. Most were associated with low water discharge from the tributaries or decreased reservoir storage (Stephens 1985). It has been reported (Waddell et al 1983, and Denton et al. 1983) that fish kills occur 80 percent of the time when the annual flushing rate (total inflow divided by Price River outflow) is less than 0.85. No fish kills have been observed during years when the flushing rate was greater than 1.1. During wetter years the extra water has a beneficial diluting effect on the poor water quality. This trend, reported in 1983, has continued (figure 6).

Flushing rates for Scofield Reservoir in the years 1980-1989 reveal that 1983-1986 were the only years that more water passed through the reservoir than was stored (figure 7). The best years for trout survival, were 1983-1987 (figure 1), compelling evidence that poor water quality is negatively effecting trout survival. Depth of water and flushing rates are key to trout survival.

Prior to the 1980s, spring stocking of three inch fish into Scofield Reservoir was successful. Good fingerling survival led

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to good fishing in the years that followed. The 1982, 1984, and 1986 year class of fish had good survival (figure 1). There was almost no survival of the fish stocked in 1980, 1981, 1987, 1988, and 1989. This correlates well with the climatic wet cycle, flushing rates, and reservoir volume.

As the reservoir ages if water quality continues to deteriorate, wetter cycles will become necessary for good trout survival, and major fish kills will become more common. The fishery is getting by on the fish that survive the good years. Fingerling mortality is the problem, and the problem started prior to the implementation of year-round fishing. If fingerling trout do not survive to reach a harvestable size, the fishery will fail. Evaluation of the size of fish stocked into the reservoir, and gill net trends indicate that larger fish may survive better (figure 8). This may provide some management options for the immediate future. However, this will only be a partial solution.

Scofield reservoir also has blue-green algae blooms in the summer. Blue-green algae is present and growing in all natural water systems, but under low phosphate limiting conditions they do not compete well with other phytoplankton. Abundant blue-green algae growth is a result of nutrient rich (eutrophic) conditions. Blue-green algae is a prokaryote and therefore able to fix free nitrogen, giving them a competitive edge in phosphate rich systems. The algae blooms reduce the phytoplankton and zooplankton communities, an important part of the food chain for trout.

Natural reproduction and recruitment could also help Scofield Reservoir. If the streams were in better condition the trout would be able to more successfully spawn, and wild fish would recruit to the reservoir and contribute to the fishery. In the late 1970s as much as thirty percent of the fish caught were cutthroat trout, many naturally produced in the tributaries. These streams are currently closed to fishing in the spring to protect spawning fish. If these streams could be returned to a more natural state, many more wild or naturally recruited fish could be produced.

In their current condition, the streams lack cover which shades the stream protecting the fish and keeping the water cool. Sediment is also a problem because it can cover trout eggs, suffocating them. In spawning areas, if the percent of fine sediments exceed 25%-30% trout eggs will not survive (Wesche et al. 1989). The current degraded condition of the streams is more conducive to spawning and survival of nongame fish species which compete with the trout when they enter the reservoir. This was documented in the Strawberry Reservoir drainage where well over 90 percent of the naturally produced fish were non-game species.

In a well managed watershed, sedges, grasses and willows hold the soil in place, and the turf is able to absorb water and allow it to slowly drain into the streams. The riparian vegetation acts as a filter, trapping sediments that are carried toward the stream. The roots from this vegetation stabilize the

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stream bank, preventing the soil from being washed down stream. Road construction needs to be limited, mining, grazing, and other activities should be conducted in a way that minimizes impacts.

Better watershed and riparian management would help the fishery in two ways. First it would reduce external loading of nutrients, and secondly it would also enhance natural reproduction of trout.

Other Considerations

The reservoir is filling up with sediments, resulting in a loss of storage. As storage capacity is lost there will be less and less water available from Scofield Reservoir. The recreational value will be lost for all water activities. Blue-green algae can make the water unpleasant with strong odors, and can even cause skin irritation. Scofield Reservoir is a culinary water source and the cost of treating this water will continue to rise as the water quality degrades.

SUMMARY

The effects of the sediment loading and eutrophication can be summarized as follows.

Problems of poor water quality

1) Major algae blooms lead to loss of the zooplankton, food for trout.
2) Oxygen depletion threatens fish populations.
3) Excessive sedimentation, difficult to purify for culinary use.

Effects on Reservoir

1) Visual impacts and offensive odors.
2) Boater and swimmer safety.
3) Low fish survival.
4) Water more costly to treat for culinary use.
5) Loss of water storage.

Sources of Sedimentation

1) Grazing and resulting loss of vegetation leading to eroding stream banks.
2) Road and vacation home construction.
3) Mining activities.
4) Poor pasture management.
5) Damaged riparian areas.

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Effects on the Drainage

1) Threaten cold water fish in streams.
2) Enhance production of non-game fish.
3) Reduce or inhibit trout spawning.
4) Reduced wildlife habitat.
5) Visual impacts.
6) Loss of top soil.
7) Erosion damage to roads.

RECOMMENDATIONS

1) The Price River/Scofield Reservoir watershed is vital to the area, and the Manti LaSal National Forest should evaluate managing the drainage specifically for watershed protection.

2) Stream bank stabilization and riparian enhancement should continue at an accelerated pace.

3) Wetlands should be created to trap sediments before they enter the reservoir.

4) A project to chemically remove the carp should be undertaken.

5) New fisheries management techniques need to be developed and evaluated. A study should be conducted to evaluate the survival of different sizes of stocked rainbow trout. Other species such as cutthroat trout should be evaluated to determine their survival and potential for natural recruitment.

6) Efforts should continue to inform the public about the importance of our watersheds and how to protect them.

7) Sources of funding must be located. These might include:
   a) Special Agriculture Conservation Program (ACP)
   b) National Forest Service
   c) Wallop-Breau fisheries enhancement
   d) Water Quality Act, Section 319 (Riparian)
   e) Water Quality Act, Section 314 (Clean Lakes)
   f) Bureau of Reclamation
   g) Flat Water Fisheries Enhancement.
   h) Watershed Protection and Flood Prevention Act PL-83-566 USDA SCS

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i) Special Appropriation from Utah State Legislature.

A great deal of effort and resources will be necessary to reverse the trend at Scofield Reservoir. Because of the many agencies involved, the Southeastern Utah Association of Local Governments Water Quality Committee should function to organize this effort. A subcommittee should be formed to focus specifically on Scofield Reservoir.

Clear and attainable goals need to be set with regard to water quality. These goals should include a measurable level of water quality in the reservoir such as chlorophyll a, or TSI. Goals should also be set for the sediment load in the tributaries.

A master plan needs to be developed with treatment areas and responsible agencies identified. This plan should identify alternatives, their relative costs, and benefits.

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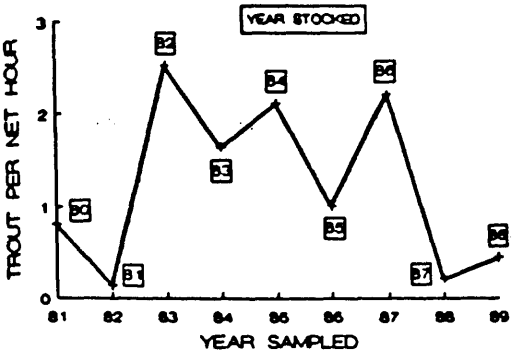

Figure 1. Gill net results for spring netting, representing age one fish. The numbers in the boxes reflect the year stocked.

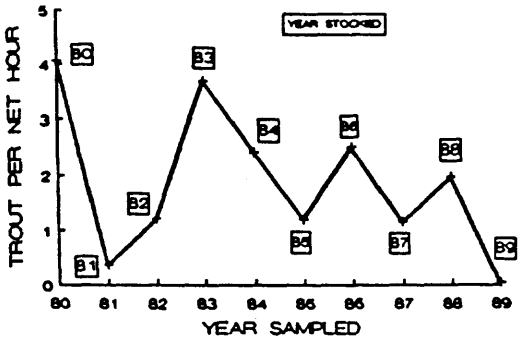

Figure 2.Fall gill net results, values represent age 0 fish stocked the previous spring.

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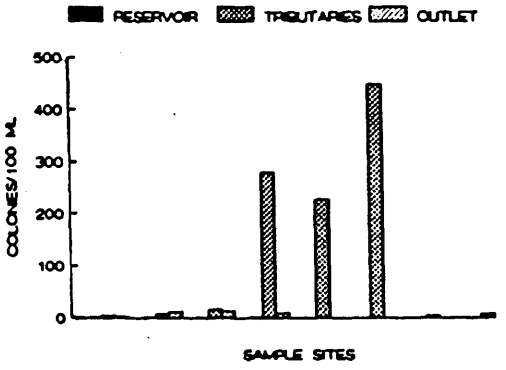

Figure 3. Mean coliform bactera counts for Scofield Reservoir and its tributaries. T = total and C = coliform bacteria. T1 and C1 for Mud Creek, T2 and C2 for Fish Creek, T3 and C3 for reservoir samples, and T4 and C4 for Price River below the reservoir.

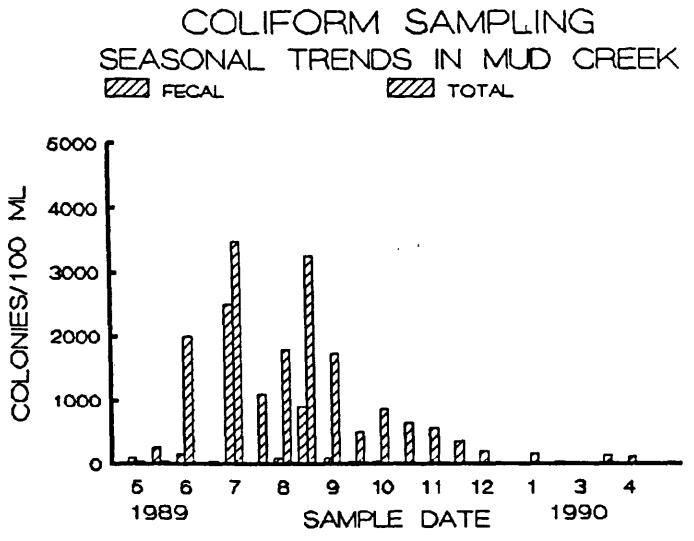

Figure 4. Seasonal cycle of coliform bacteria in Mud Creek. High numbers of bacteria are related to summer activities in the watershed.

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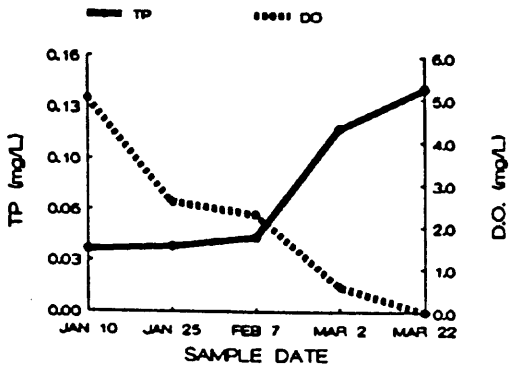

Figure 5. Relationship between total phosphate (TP) and dissolved oxygen (DO) in Scofield Reservoir. The drop in DO results in the release of phosphate form the sediments (internal loading).

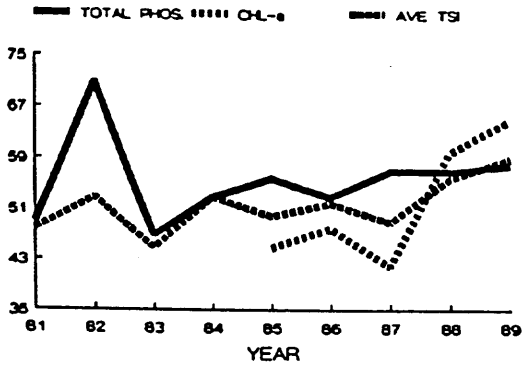

Figure 6. Water quality trends for Scofield Reservoir, for chloriphil-a (CHL-a), total phosphates (TP), and trophic state index (TSI). A eutorphic lake is defined as a lake with TSI values greater than 50.

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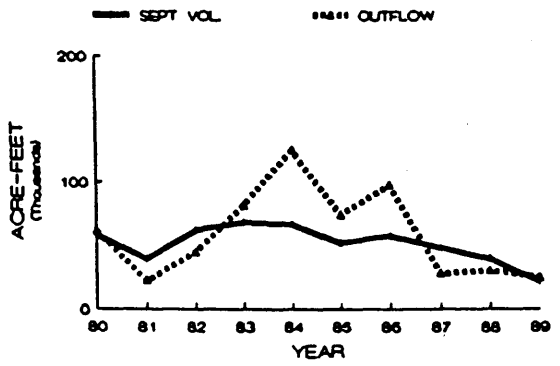


Figure 7. Flushing rate of Scofield Reservoir comparing September volume verses total out flow. Years 1983-1986 the total water passing through the reservoir exceded September volumn.

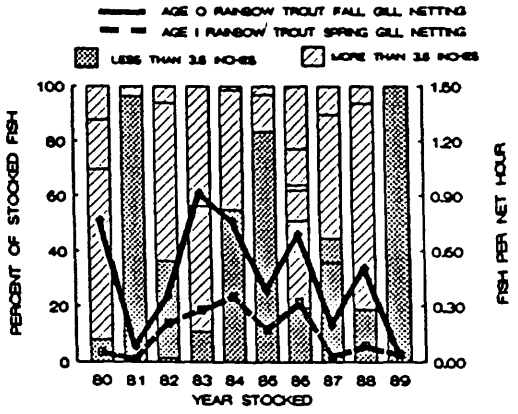
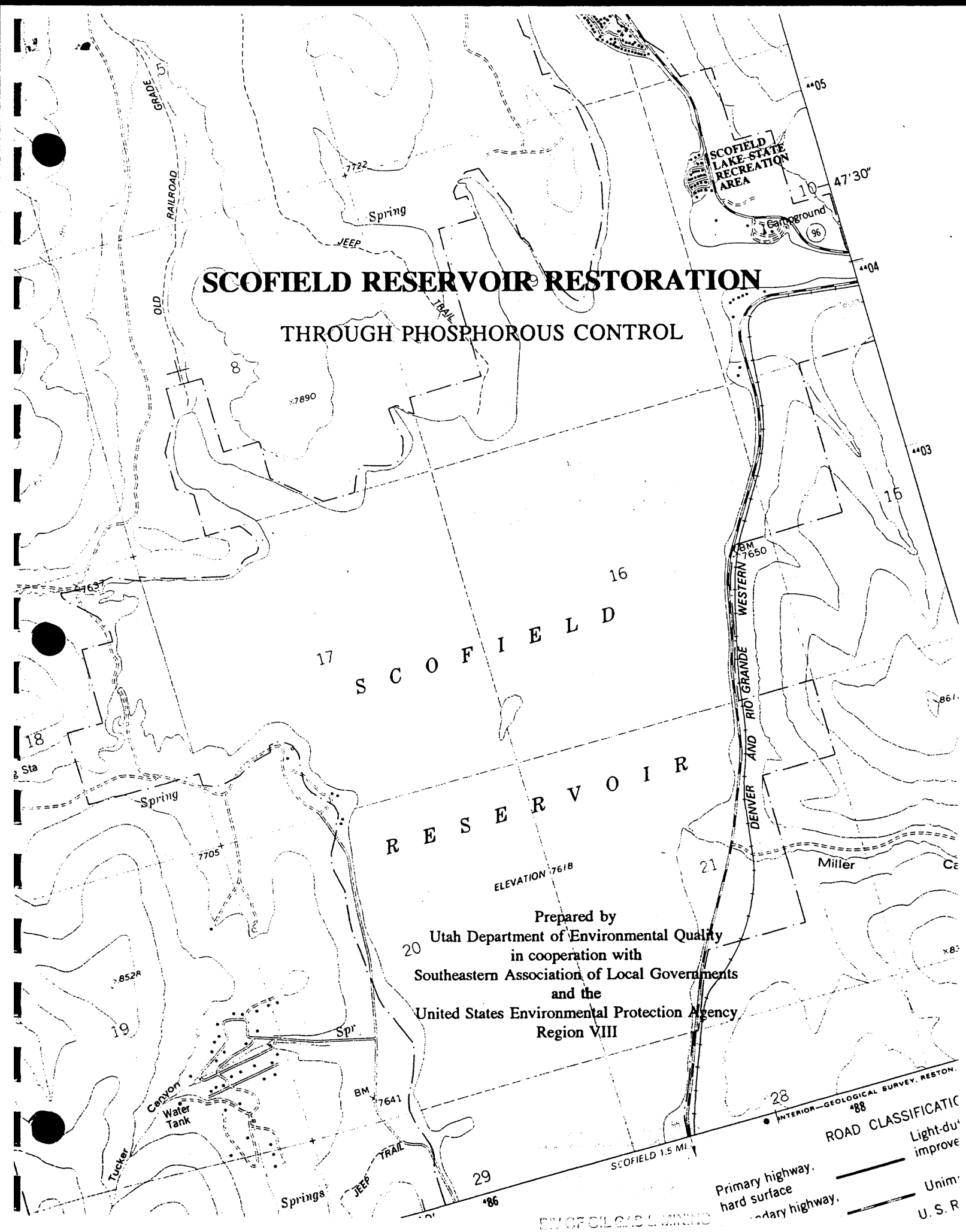


Figure 8. Gill net catch rate for spring (age 1), and fall (age 0) trout, plotted against average length of trout stocked. The netting results have been shifted in time to reflect the year they were stocked (i.e. age 1 fish stocked in '80 were actually sampled in '81).


SCOFIELD RESERVOIR RESTORATION
THROUGH PHOSPHOROUS CONTROL
SCOFIELD
RESERVOIR
ELEVATION 7618
Prepared by
Utah Department of Environmental Quality
in cooperation with
Southeastern Association of Local Governments
and the
United States Environmental Protection Agency
Region VIII
SCOFIELD LAKE STATE RECREATION AREA
Campground
GRADE
RAILROAD
OLD
JEEP
TRAIL
Spring
WESTERN
DENVER AND RIO GRANDE
Miller
Water Tank
Canyon
Springs
SCOFIELD 1.5 MI
47'30"
ROAD CLASSIFICATIO
Primary highway, hard surface
U. S. R

SCOFIELD RESERVOIR RESTORATION

THROUGH PHOSPHORUS CONTROL

by

Harry Lewis Judd
Division of Water Quality
Department of Environmental Quality
Salt Lake City, Utah 84114

Grant #S008417-01-2

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This study was conducted in cooperation with United States
Environmental Protection Agency, Region VIII.

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EXECUTIVE SUMMARY

Scofield Reservoir has been adversely affected by nutrient loadings in recent years. Nutrient enrichment to the reservoir has resulted in excessive algal and macrophyte growth with extensive late summer blue-green algal blooms. This high level of eutrophication has led to hypolimnetic oxygen deficiencies, recreation and fishery decline, aesthetic quality loss and concern for culinary treatment downstream.

In 1984 the Utah Department of Environmental Quality received a Clean Reservoir Phase II grant pursuant to Section 314 of the Clean Water Act to rehabilitate the reservoir through a program to reduce total phosphorus loading to the reservoir. Supplemental monies were awarded to the project in 1985 and 1986. The restoration project consisted of installing stream revetments and checkdams, revegetating denuded streambanks, replacing water diversion systems for irrigation, providing a fish cleaning station, and developing a public awareness and education program to alert people of the pollution problem and solicit their support in reducing phosphorus loads to the reservoir. Streambank rehabilitation activities occurred primarily on segments of Mud Creek, a major tributaries contributing approximately 29 per cent of the phosphorus load to the reservoir. However, late in the project some rehabilitation work was accomplished on Fish Creek the major tributary to the reservoir. The overall streambank work was designed to reduce stream sediments and erosion through streambank stabilization and revegetation of denuded soils in highly eroded areas.

The project has been effective. Streambank stabilization and revegetation has occurred in the project area. Visual observations indicate that sediments are being removed from the streams and that the vegetation in the riparian area is returning. Although, there is insufficient empirical data to conclusively support the effects of implementation efforts the data when compared to "typical" instream phosphorus concentrations does indicate a decline in total phosphorus concentrations.

In-lake observations substantiate the fact that the eutrophication process in continuing to increase. A comparison of overall Trophic State Index (TSI) values from 1983 to 1991 reveal a rising trend during recent years with a significant increase of 33 per cent from 1983 to 1991 (49.72 to 66.32). This increase is probably due in some part to an increase in internal phosphorus loadings within the reservoir and a decline in annual flows into the reservoir.

This report was submitted in fulfillment of grant number S008417-01-2 by the Utah Department of Environmental Quality under the partial sponsorship of the U.S. Environmental Protection Agency. This report covers a period from June, 1984 until June, 1992 and work was completed as of September, 1990.

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ACKNOWLEDGEMENTS

The Scofield Reservoir Restoration Project conducted by the Division of Water Quality through cooperative management efforts with Southeastern Utah Association of local Governments is a product of technical assistance and support of a large number of people not all of whom are mentioned or listed below.

Kevin Christopherson	Utah Division of Wildlife Resources
Walt Donaldson	Utah Division of Wildlife Resources
Larry Dalton	Utah Division of Wildlife Resources
George Cook	Soil Conservation Service
Gary Moreau	Soil Conservation Service
Craig Funk	Utah Division of Parks and Recreation
Nolan Hansen	Utah Division of Parks and Recreation
Mike Jackson	Utah Division of Parks and Recreation
Chad Gourley	Utah Division of Water Rights
Glen Beagle	Division of State Lands and Forestry
Tracy Dunford	Division of State Lands and Forestry
Dennis Kelly	U.S. Forest Service
Ira Hatch	U.S. Forest Service

We extend our appreciation to Richard Denton of the Division of Water Quality for his early efforts in securing the grant and establishing the implementation program with the assistance of other interested parties. He served as the project officer until February, 1988.

Special thanks is extended to Fred Jensen, Duane Frandsen and Pete Frandsen for their concern for the environment and their willingness to not only permit but support the implementation of the stream restoration project on their property. This type of cooperation was greatly appreciated.

A special recognition is given to the Pleasant Valley Committee under the chairmanship of Garth Frandsen. Countless hours were spent on their part to assist in the implementation of selected alternatives. Their local support and encouragement enhanced the spirit of cooperation needed to proceed with this project.

We appreciated the financial support received for the project. Donated monies and inkind contributions provided the required match for this project. Extra credit must be given to Walt Wright, Valley Camp, for providing all the minebolts used in the revetments, additional match late in the project and a place for work crews to camp while working on site.

In addition, we must recognize the importance of support from property owners, citizens and political groups such as the Carbon County Planning Commission working on zoning regulations, and the Carbon County Commissioners; specifically Lee Semken, Floyd Mar, and Guido Rachiele

who have lent support to the implementation of the project.

A special tribute to the members of Troop 739 (Bountiful), Troop 285 (Price), and Varsity Team 6861 (Price) affiliated with the Boy Scouts of America for service rendered during the [illegible] period. We thank the Utah National Guard for extensive hours of labor and the Fish [illegible] a specialized workforce from the Utah State Prison under the direction of Glenn Pea[illegible] and Tracy Dunford.

We recognize and appreciate the interest and support of Mr. Thomas Braidech and Mr. [illegible] Rathke (Project Officers for EPA, Region VIII) and other EPA and Division of Water Quality staff for their guidance, field assistance, and general support of projects aimed at improving the quality of water within Scofield Reservoir, a critical water resource in Central Utah.

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INTRODUCTION

Scofield Reservoir a 2,815 acre body of water, is located in Carbon County in Central Utah (Figure 1.1). The reservoir was originally impounded in 1926 and enlarged in 1946. Uses of Scofield Reservoir and its watershed include coal mining, agriculture, residential, fishing, hunting, snowmobiling, camping, and a variety of other types of summer and winter recreations.

Use designation for the waters of Scofield Reservoir have been established as: 1C, protected for domestic purposes with prior treatment by standard complete treatment processes as required by the Utah Department of Environmental Quality; Class 2B, protected for boating, water skiing, and similar uses, excluding recreational bathing (swimming); Class 3A, protected for cold water species of game fish and other cold water aquatic life, including the necessary aquatic organisms in their food chain; and Class 4--protected for agricultural uses including irrigation of crops and stock watering.

In 1980 a Clean Lakes 314 Phase I water quality study was jointly funded by the Environmental Protection Agency and the Utah Department of Health. A summary of the findings of that study (Scofield Reservoir Phase I Clean Lakes, 1983) indicate that the lake has good water quality as measured by most parameters. The lake is moderately high in alkalinity (55 mg/L) and hardness (170 mg/L). Secchi depth readings for the study period during the summer months range from 2 to 5 meters which is typical for mesotropic systems. Nutrient levels in the epilimnion are relatively high but drop during the summer as nutrients are depleted by phytoplankton growth. Total phosphorous levels were commonly reported at 0.01 to 0.05 mg/L and inorganic nitrogen (NH_4-N, NO_3-N, NO_2-N) at 0.10 to 0.30 mg/L. As expected, dissolved oxygen (DO) was low in the hypolimnion with temperature and DO profiles typical when compared to other mesotrophic to slightly eutrophic lakes in Utah. However, oxygen depletions were found near the lake bottom during late summer and again during the winter. During late summer anoxic conditions are present.

Scofield Reservoir was determined to be eutrophic in both 1981 and 1982 based on overall trophic state indexes (TSI) following Carlson's (1977) TSI guidelines. Overall TSI values for those years were respectfully near 49 and 53. As part of the Phase I study phytoplankton samples from the reservoir were analyzed. These studies substantiated the trophic state determinations. It was concluded that Scofield Reservoir is a mesotrophic/eutrophic system. Although algal diversity was found to be moderately high, high numbers of Anabaena and Aphanizomenon were present in late summer blooms. Summer and fall Diatoms, Melosira granulata var. angutissima and Asterionella formosa which are indicative of eutrophic systems were identified. In addition the centric diatom, Stephanodiscus minuta, an indicator species of eutrophic conditions reached high numbers in the phytoplankton community.

Sediment chemistry studies suggest that the reservoir sediment could support moderate rates of phosphorus release under anaerobic conditions (Messer, et.al, 1983). Further

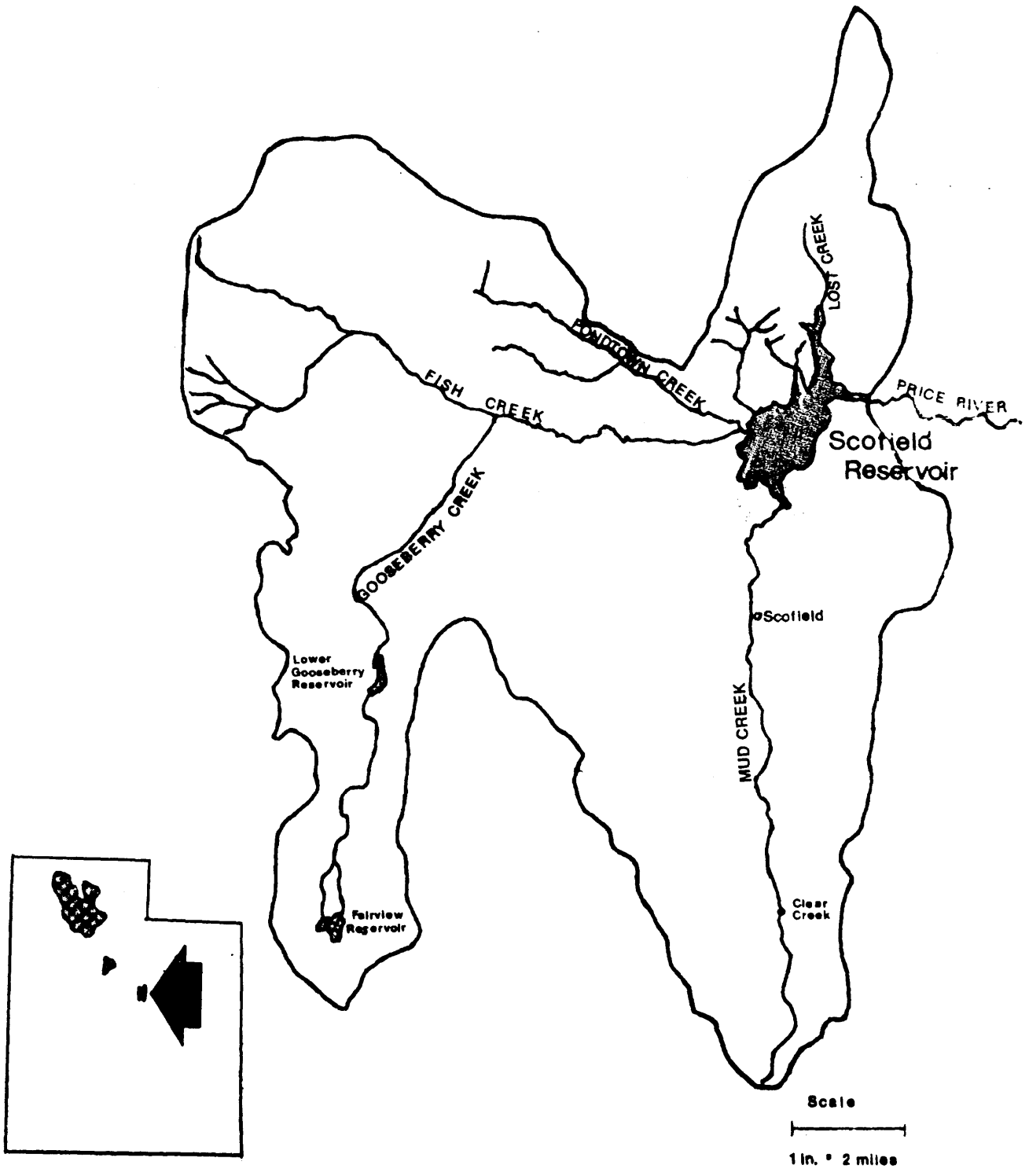

Figure 1.1 Location map of Scofield Reservoir

investigations reveal that organic phosphorus in the sediments was relatively low, however, total phosphorus concentration was the highest of any value measured in the western reservoirs.

Nutrient loading models suggest that phosphorus controls primary productivity. The model of Schinder, et.al. (1971) based on Vollenweider's model determined current nitrogen loadings are 2.17 g/m2/yr in the mesoeutropic range. However, the phosphorus loading of 0.59 g/m2/yr supports eutrophic algal growth. Although total phosphorus loadings to the reservoir are very large, findings indicate an unusually large fraction is in chemically-bound forms rendering it unavailable to algae growth in the reservoir (Denton et.al. 1983). Phase I findings concluded that current loadings of "available" phosphorus were low enough to expect a decline in the eutrophication of the reservoir through the control of phosphorus.

Due to a lack of feasible restoration techniques available to address the Fish Creek drainage problems, which represents 52% (3,508 kg/yr) of phosphorus loading to the reservoir, the Mud Creek drainage representing 29% (1,943 Kg/yr) of the phosphorus load was selected for treatment. [The Clean Lake study indicated that 31 per cent of the phosphorus is naturally-occurring phosphorus-laden soils in the watershed.] The riparian vegetation within the Mud Creek drainage is of poor to fair quality. [The Phase II project area is on private property and is severely eroded due to overgrazing coupled with high flows during the runoff season.] Phosphorus levels in Scofield Reservoir can be directly attributed to the transport of upper watershed soils by erosion during spring runoff. Therefore, an implementation program designed to reduce phosphorus loadings by reducing stream sediments through erosion control was vital to the overall restoration of Scofield Reservoir. Erosion control measures identified as part of the implementation program include checkdams, fences, juniper revetments, streambank rehabilitation and revegetation of denuded soil surfaces. In addition, other effective means to limit phosphorus input to the lake were identified and were part of the implementation project. These include installation of a fish cleaning station and a public awareness and educational program.

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SECTION 2

METHODOLOGY

GENERAL PHOSPHORUS CONTROL

As reported in the Clean Lakes Phase I report, the most pragmatic and effective means to control the further eutrophication of Scofield Reservoir, or possibly to effect a moderate reversal of the eutrophication process, appears to be a reduction of the phosphorus load to the lake.

Of the numerous restoration elements developed during the feasibility analysis, the implementation program focused on three major elements. The plan included the following:

1. Implementation of the Mud Creek and Fish Creek stream restoration and streambank stabilization projects.

2. Construction of a public fish cleaning station.

3. Development of a public education and awareness campaign.

In support of this phosphorus reduction plan, several other concepts were developed outside of the scope of this plan for the control of pollution in the Scofield Reservoir watershed. They included developing and implementing livestock grazing management plans, planning of recreational development, providing an improved sewer disposal system, and the controlling of surface disturbance activities and solid waste disposal.

Mud Creek Project

Phosphorus loading and the nutrient budget indicates approximate 29% (1,950 ky/yr) of the total loading to the reservoir enters from the Mud Creek drainage (Denton, et.al., 1983, p69). Although this drainage was not the major contributor of phosphorus to the reservoir, it was determined to be the most feasible area for treatment with a potential to effect reservoir eutrophication. Early field observations (1981-82) indicated extensive bank erosion (Figure 2.1) had occurred due to a loss of riparian habitat from overgrazing. Prior to implementation additional damage was imposed upon the streambanks in this drainage due to excessive high runoff in the early 1980's.

It was estimated in the Clean Lake Phase I Study (1983) that implementation of the proposed project would reduce total phosphorus loads by 24.4% (500 Kg/yr). The project consisted of the following components:

1. Gabion check dam installations.

   Flow control structures attached to retention structures (Figure 2.2) were used to create gabion checkdams (2). Checkdams were installed at two specific sites to provide bank stability, decrease water velocity, raise groundwater and create a point of diversion for irrigation, and allow for the settling of sediments. Construction of these structures were oriented to create a pool on the upstream

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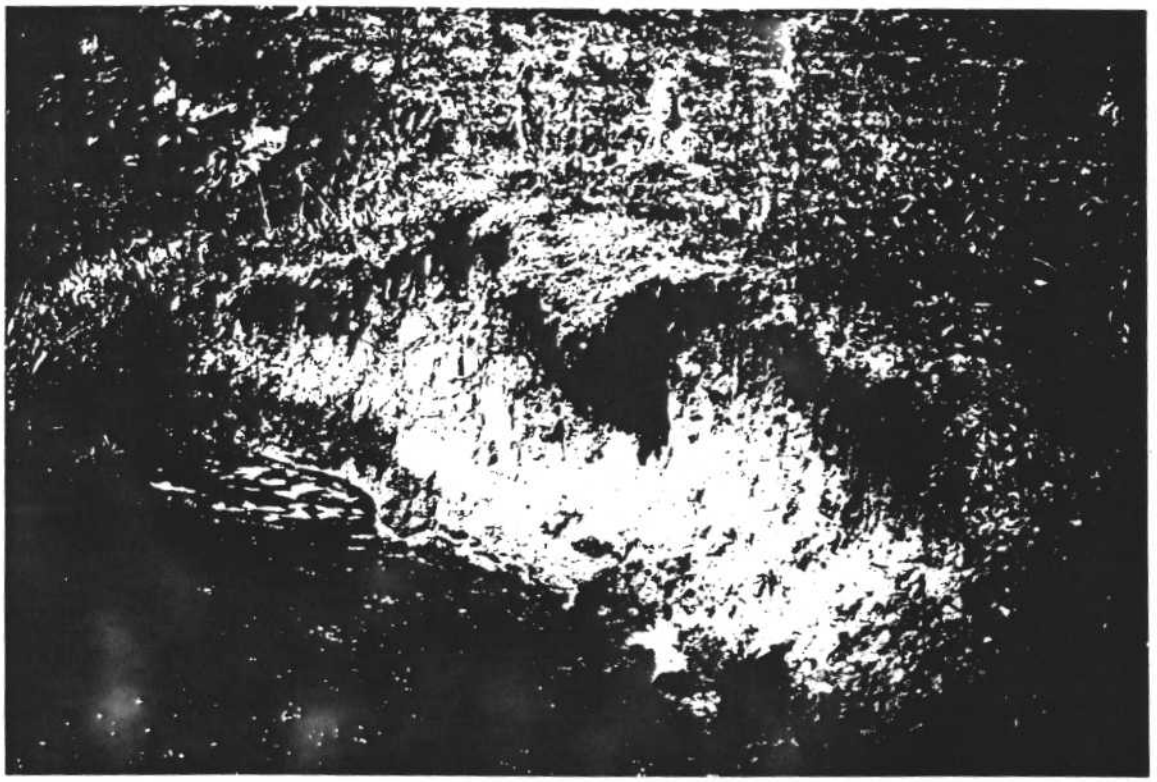

Figure 2.1 Streambank damage due to erosion

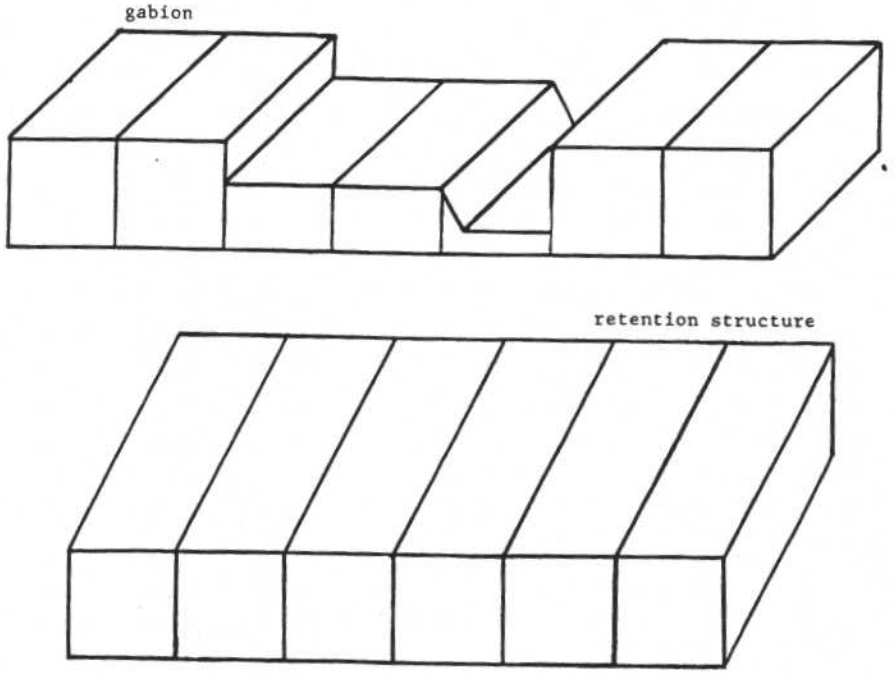

Figure 2.2 Drawing of a gabion and a retention structure

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side and a rock lined splash basin on the downstream side for erosion control. Streambank riprap was placed in conjunction with these structures to assure bank stability (Figure 2.3). In conjunction with checkdams fish ladder structures (Figure 2.4) were placed downstream as required to facilitate the movement of fish during the spawning season.

Rock size and type used to fill gabions and for riprap conformed to Soil Conservation Service (SCS) specifications. These structures were placed during low flow conditions to reduce the effects from soil disruption during construction. Since installation no repair has been required.

2. Bank stabilization.

Banks were stabilized by adding juniper revetments at the point of contact with the stream where needed. The use of the juniper technique (Figure 2.5) involved the creation of an overlapping type armor along the banks to reduce stream velocities, collect sediments (Figure 2.6) and provide fishery habitat. Tree placement began at the foot of the streambank at the downstream end of the bank with installation of additional trees proceeding upstream. Trees were oriented with the top of the tree pointing downstream, overlapping the trunk end of the previous tree. The trees were secured by six-foot long mine bolts placed through a drilled hole in the trunk end and driven into the stream bank. The overlapping ends were wired together. The core of the tree was aligned with the normal high water mark for the stream. Finally, the upstream end of the revetment was protected utilizing the edge of the streambank or riprap. Trees judged to be ideal for placement were considered to be very bushy and approximately 6-10 feet in length. Approximately 14,000 feet of streambank revetments were placed during the project

3. Revegetation and establishment of riverine riparian zone.

Denuded banks from recent erosion or from resloping were reseeded with Carex sp. (sedgegrass) and a variety of forbes. In addition approximately 8,000 willow shoots were placed above juniper revetments (Figure 2.7) and at other strategically located sites along the stream corridor. Revegetation was required to protect the banks from erosion by developing essential vegetation to enhance bank stability. By increasing bank stability, erosion was reduced and water quality was protected.

4. Enclosure of project area by fencing.

To prevent further streambank damage and provide protection for new vegetative growth it was critical to remove grazing activity from the lower pasture area. This was accomplished by fencing (Figure 2.8). Prior to treatment of streambanks and eroded areas, the lower project area was enclosed with an electric fence system. Later, it became evident that the electric fence was not only inadequate for keeping animals out of the project area but it was also in constant need of maintenance for operation. In 1988 the electric fence was replaced with a four strand barbed wire fence built

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Figure 2.3 Typical checkdam installation with riprap

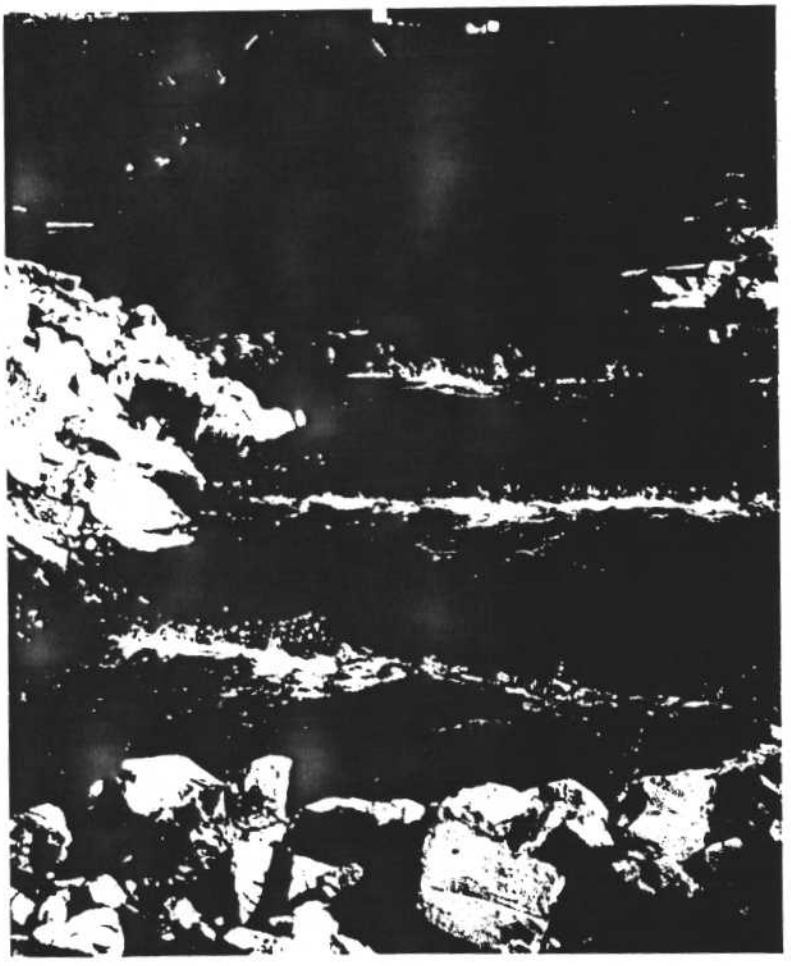

Figure 2.4 Fish ladder structures below a checkdam diversion point

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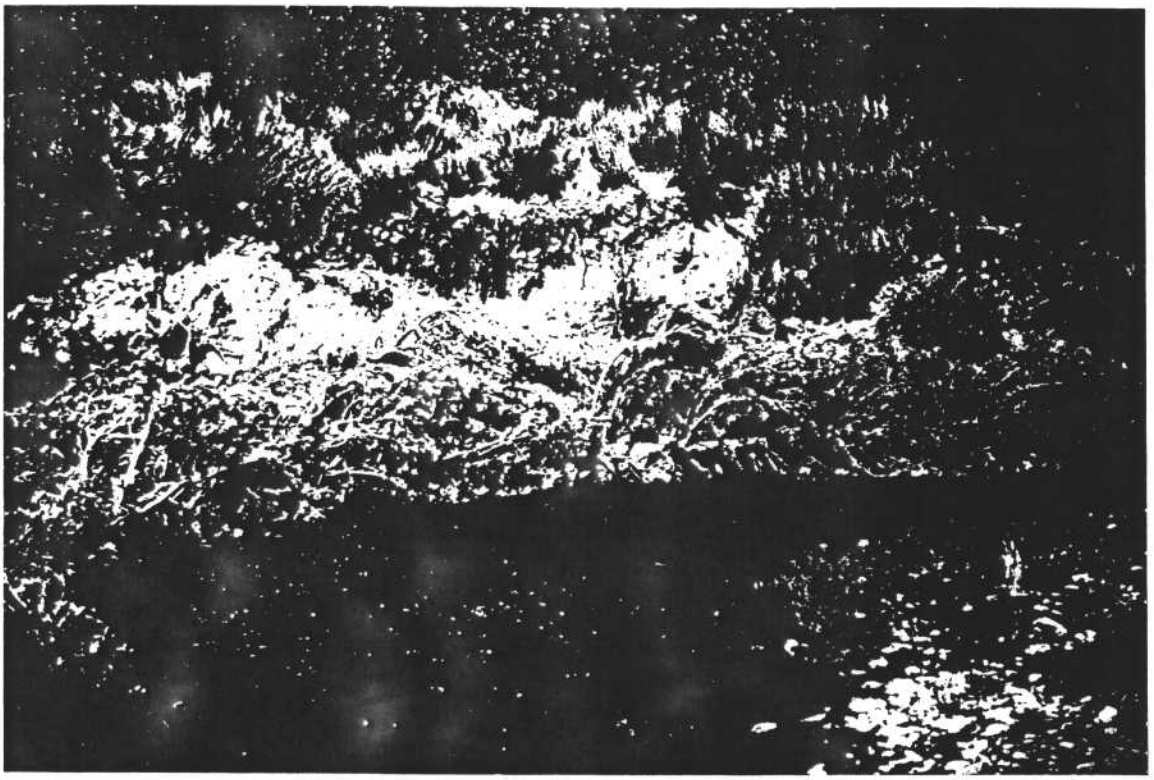

Figure 2.5 Properly constructed juniper revetment

Figure 2.6 Juniper revetments trap sediments

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Figure 2.7 Juniper revetments provide stability for revegetation

Figure 2.8 Fencing to protect area during revegetation period

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according to Bureau of Land Management (BLM) fence standards for livestock and wildlife. It was later modified and a fifth wire was added to the bottom to prohibit calves from getting into the project area.

Fish Creek Project

Although this drainage which contributes approximately 53% of the phosphorus loading to the reservoir, it was not selected as the area of primary rehabilitation. Due to the lack of local cooperation in the Mud Creek drainage, funds were diverted to accomplish restoration in the Fish Creek drainage where property owners were eager to participate. Treatment focused on private lands from the U.S. Forest boundary downstream to the beginning of Bureau of Reclamation property.

The following restoration techniques were incorporated in the rehabilitation.

1. Approximately 3,300 feet of mesh fence was installed to protect the project area from not only livestock but vehicular access. Both of these agents were responsible for the loss of riparian habitat and the creation of erodible conditions.

2. Eroded areas, both overland gullies and streambanks were treated. Land areas in need of attention were filled, sloped and reseeded for stabilization. Rehabilitation of eroding streambanks included realignment of meanders; placement of riprap and tree defector structures; bank reshaping and revegetation with willow clumps and rooted shoots.

Fish Cleaning Station

During the summer of 1987 a fish cleaning station was constructed. A long term agreement was secured for the operation and maintenance of the station with Utah Division of Parks and Recreation. Efforts were made to solicit the support and use of the station. Visual observation of the stations shows that people are aware of the pollution problem and they are using the station as planned.

Public Education Campaign

By informing the public about the problems associated with Scofield Reservoir and providing them information on how they could help resolve problems, it was determined that a reduction of pollution to the reservoir could occur. Therefore, a public awareness and education program was planned as part of the project. This program included the following activities:

1. A sign placement program in highway approaches to Scofield Reservoir and in major automobile parking areas was conducted by Utah Division of Wildlife Resources and the Pleasant Valley Committee. These signs drew attention to pollution of the lake and the need for public support to control potential problems.

2. A media campaign was developed focusing on various aspects of pollution

and tracked the completion of specific project plans. Efforts were directed towards keeping the concept of lake water quality protection before the general public. Tours of the project area have been and continue to be conducted for interested groups.

3. A program to encourage the use of trash receptacles has been promoted.

4. A county ordinance making it illegal to dispose of fish entrails into the reservoir was adopted. This ordinance is implemented by the Utah Division of Wildlife Resources and is mentioned in their Wildlife Fishing Proclamation.

SECTION 3

RESULTS AND DISCUSSION

INTRODUCTION

The issue of water quality is not new for Scofield Reservoir and its associated watershed. Fish kills in the reservoir, late summer blue-green algal blooms and severe oxygen depletions have raised concerns over water quality. A number of agencies have initiated and completed studies assessing water quality within the Scofield Reservoir watershed.

In June, 1977 the Southeastern Utah Association of Local Governments (SEUALG) documented in its Waste Water Quality Management - 208 Plan water quality problems within this watershed and noted the enriched state (eutrophic) of the reservoir was leading to blue-green algal blooms and an anoxic hypolimnion during summer stratification. Sources of nutrients identified were livestock grazing, human sewage, coal mine effluents and wastes from recreational users (human waste, litter, boat motor fluids, fish entrails).

In 1979-80 the Utah Division of Water Quality studied the reservoir as part of a statewide lake assessment program. Their results were presented in the Utah Clean Lakes Inventory and Classification, Vol.2, April, 1982. Although, the overall condition of the reservoir was classified as mesotropic, phosphorus concentrations yielded a Carlson TSI value of 53.3 which is indicative of a eutrophic system. The reservoir was still considered a fairly rich system. This study identified the pollution sources as sewage disposal, recreational use on private lands and livestock grazing.

Clyde, et al (1981) evaluated shallow groundwater and surface water along Mud Creek, a tributary to Scofield Reservoir. Peaks in nitrate and phosphate levels were noted during spring run-off. The study suggested this high loading during run-off may contribute to a nutrient rich reservoir. Later, the Division of Water Quality completed a Phase I Clean Lakes Study in December, 1983. The study ranked the reservoir as early eutrophic and targeted phosphorus as the nutrient needing control within the watershed. External phosphorus loadings were attributed to sediment producing activities (overgrazing, coal mining, and summer home development), inadequate sewage facilities, livestock, and recreational users. In addition, an internal phosphorus load was occurring when anoxic conditions existed at the sediment/water interface during stratification (July-August). Under anoxic conditions phosphate salts, particularly those bonded with iron, are released back into the water column.

The aforementioned studies have all identified the most critical water quality problem within the reservoir and its watershed. This problem is the continual nutrient enrichment of Scofield Reservoir through both external and internal phosphorus loading.

Numerous agencies have planned and initiated programs since 1976 to improve water quality within the Scofield Reservoir watershed. A variety of programs have been

implemented toward accomplishing this task. From a written communication with Walter K. Donaldson of the Utah Division of Wildlife Resources (DWR) these efforts have been partially summarized as follows:

1. Design and construction of a basin-wide sewage collection system for Scofield Town, Clear Creek, and five lake shore sub-divisions.

2. Stabilization and enhancement of 3.3 miles of Mud Creek riparian zone by SEUALG and Division of Water Quality. This includes check dams, placement of cedar trees for bank stabilization, willow transplants, and fencing for livestock exclusion.

3. Implementation of a Carbon County ordinance prohibiting disposal of fish entrails into the reservoir, with enforcement by Utah Division of Wildlife Resources (UDWR), Utah Division of Parks and Recreation (UDP&R) and Carbon County.

4. Proper fish management by UDWR and corresponding angler harvest which removes approximately 2,200 pounds of phosphorus annually from the reservoir.

5. Signing around the reservoir (both large and small) to educate the public on the pollution issues.

6. Implementation of county zoning laws protecting the environment, and also the regulation of low-impact development for industry and summer homes.

7. Development of needed angler parking on the east shoreline by Utah Department of Transportation (UDOT).

8. Formation of a citizens advisory council (Pleasant Valley Committee) to provide input on water quality issues at the reservoir, and to assist in coordinating interagency activities related to lake restoration.

9. Sediment reductions in Eccles Canyon from mine-related activities (i.e. road surfacing, reseeding impact sites, stream alteration around chronic mud slides, etc.)

10. Development of a new sewage facility and fish cleaning station at the east campground by UDP&R.

11. Acquisition and administration of the north campground by UDP&R with authority to reduce illegal wastewater discharge and shoreline livestock grazing.

The preceding efforts, though not inclusive, were accomplished with cooperation from many agencies. Involvement of agencies has been at all levels: municipal, county, state, federal and private. However, in spite of these efforts, it appears that eutrophication of the reservoir is progressing.

HYDROLOGY

Denton et al (1983) reported an annual water budget for Scofield Reservoir. Table 3.1 was extracted from their report. Values from this Table were reported as "typical" with no explanation as to the period of record used to develop them.

Using an inflow value of 49,317 acre feet and a capacity of 65,780 acre feet for the

reservoir a retention time of 1.33 years was calculated for the reservoir. Stephens (1985) correlated fish kills to hydrological condition associated with low inflow rates or decreased reservoir water storage from a review of existing data. He concluded that fish kills occur 80 percent of the time the annual flushing rate (total inflow divided by outflow) for the reservoir is less than 0.85. These fish kills probably occur as a result of several environmental factors that are intensified by decreased tributary inflow. He reported these conditions as large population of blue-green algae that release biological toxins, high oxygen demand due to respiration and decomposition of algal communities leading to an increased volume of the anaerobic hypolimnion, and an increased rate of warming of lake water.

Table 3.1 Annual water budget for Scofield Reservoir

INFLOW	Ac Ft.
Fish Creek	34,487
Mud Creek	8,441
Pondtown Creek	2,851
Woods Canyon Creek	1,043
Dry Valley Creek	941
Miller Creek	554
Shoreline	1,000
Precipitation: 16.1 in/yr[a]	2,888
Total Inflow:	52,205
OUTFLOW	
Deletion[b]	1,411
Discharge: Price River	45,066
Evaporation: 24.5 in/yr[c]	5,728
Total Outflow:	52,205

[a]Water Resources, 1978
[b]Recent addition outflow, used in Pleasant Valley for irrigation and mining.
[c]This approximate value was estimated by study personnel and should not be used as data values since detailed investigations were not made on this component.

Recent data obtained on reservoir volume when compared against average annual TSI Index values indicates an increased rate of eutrophication with a decrease in reservoir volume. Figure 3.1 depicts the overall average TSI values for the reservoir plotted against the low volume conditions for the same period of time. It is readily apparent that during drought conditions which have prevailed during recent history, there is a corresponding increase in productivity. This phenomenon is also linked to the existing anoxic conditions which have produced a high internal phosphorus load stimulating

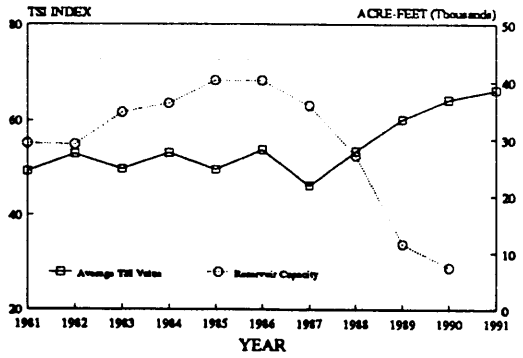

Figure 3.1 Plot of overall TSI averages and minimum storage for period 1981-90

higher productivity. In addition in recent years insufficient quantities of water have been entering the system to provide flushing to reduce phosphorus concentrations.

SOURCES OF POLLUTION

The Utah Division of Water Quality completed a study of Scofield Reservoir and its watershed through an EPA Clean Lakes Phase I study in 1983. The study identified the sources of pollution and determined that phosphorus and nitrogen were both limiting nutrients. Recommended remedial action for lake restoration was directed towards a reduction of phosphorus originating within the watershed.

Denton et al (1983) determined external phosphorus contributions to the reservoir as shown in Table 3.2 . Fish Creek contributes 52% (3508 Kg/yr) and Mud Creek contributes 29% (1943 Kg/yr) of all external phosphorus loads. The remaining tributaries, shoreline wash, and precipitation contribute 19% of the external phosphorus load. Slightly higher loading values with similar distributions were reported by Waddell et al (1983) for the 1979-80 water year.

The external sources of phosphorus include stream sediments, sewage, and agricultural wastes. Much has been done since 1983 to reduce human waste by installation of a sewer system for the Scofield area. However, nonpoint erosion and agricultural practices continue to be a problem. Sediment release by erosion in the watershed contributes to a large fraction of the phosphorus load into the reservoir. Intensive livestock grazing in the watershed, grazing within the riparian zones (stream banks), road construction, summer home construction, and mining activities all have accelerate the erosion process. Large numbers of animals grazing in the riparian areas contribute directly to the phosphorus load through animal waste products.

Table 3.2 Annual phosphorus loadings

Subbasin	Annual Load Phosphorus Kg/yr
Fish Creek (FCI)	3,508
Mud Creek (PVC-1)*	488
Mud Creek (PVC-2)*	528
Mud Creek (PVC-3)*	249
Mud Creek (PVC-4)*	323
Mud Creek (PVC-5)*	115
Mud Creek (PVC-6)*	240
Pondtown Ck (PC-1)	488
Woods Canyon Ck (WC-2)	72
Miller Canyon Ck (MC-1)	66
Dry Valley Creek (DVC-1)	89
Eccles Creek (EC-1)	337
Shoreline Wash (SW-1)	308
Precipitation	142
TOTAL	**6,723**

*The drainage was subdivided and annual loadings determined for each subbasin. Total load for Mud Creek was 1943 Kg/yr.

The Manti LaSal National Forest recently completed a water resource inventory for the Price River watershed. Data were compiled on 72,359 acres in and around the National Forest. Sediment yields were estimated and watershed improvement needs were identified. The work on these ongoing improvements need to be accelerated. Of

the land surveyed 7257 acres or 10.1 percent of the watershed was classified with high to extreme erosion potential. Water quality in the streams, based on suspended sediments was estimated to ranged from 52 mg/L in the Fairview Lakes to 276 mg/L in Mud Creek. Anything above 100 mg/L is considered high or very poor water quality. Erosion is the major source of sediments into Scofield Reservoir. Sediment and sediment related nutrients are one of the primary reasons for deteriorating water quality in the reservoir.

In addition to phosphorus loads from external sources the transport of phosphorus from lake sediments back into the water column is occurring internally. Internal loading of phosphorus involves chemical interactions within the reservoir sediments under anoxic conditions and the physical resuspension of sediment materials through natural processes. The natural processes involved are water turbulence due to wind action and the movement associated with large schools of carp under low water conditions. Since the reservoir was constructed in 1946, sediments have been deposited on the reservoir bottom. These sediments contain phosphorus that is stored in different chemical forms. The phosphorus is bound to other elements (iron and calcium) forming phosphate salts. However, when the lake stratifies water from the hypolimnion (bottom) does not mix with the surface water and dissolved oxygen in the hypolimnetic water column is used to oxidize organic materials. Eventually the hypolimnion becomes anoxic. Under these conditions phosphatc salts break down and the phosphorus is released into the water column. At turnover, when the water in the reservoir mixes in the spring and fall, this rich source of phosphorus becomes available for algal production. Recent dissolved oxygen studies indicate that internal phosphorus loading may be higher than was previously expected.

CURRENT STUDIES

Phytoplankton

Plankton studies at Scofield Reservoir have been conducted by Samuel R. Rushforth at Brigham Young University. These studies were conducted in 1975 under a 208 Areawide Planning Study, in 1981-82 and in 1990 under a 314 Clean Lakes Grant. (For a complete record of his findings refer to the State of Utah Scofield Reservoir Phase I Study, 1983 which contains the 1975 and 1981-82 data and Appendix B which contains 1990 data).

The 1975 report concluded:

1. Scofield Reservoir showed medium to high algal productivity. This productivity continued through the fall months.

2. A high algal diversity was present in the Scofield ecosystem during 1975. This diversity lasted throughout the summer and into the fall.

3. Obnoxious Cyanophyta were present in the lake during 1975, but did not achieve bloom proportions. The density of these organisms was 7,604 filaments per liter of Aphanizomenon flos-aquae, 521 filaments per liter of Anabaena spiroides var. crassa, 104 filaments per liter of Anabaena flos-aquae and 18,750 colonies per liter of Microcystis aeruginosa. These numbers

are small in comparison to other mesotrophic systems in the Intermountain West.

4. A number of species indicative of quite acceptable water quality were present in Scofield Reservoir during the fall of 1975.

5. A total of 42 species was collected from the two phytoplankton samples collected September 2, 1975.

From the 1981-82 studies Dr. Rushforth reported the following conclusions:

1. Scofield Reservoir is a meso-trophic to eutrophic system. It has moderately high algal productivity, with late summer and fall "blooms" of obnoxious Cyanophyta. Likewise, diatom species which predominate in the Scofield system are indicators of mesotrophic or eutrophic systems.

2. It seems significant that the density of noxious bluegreen algae present in the blooms formed during the late summer is less than found in some other eutrophic systems in western North America. This indicates that Scofield Reservoir is not as eutrophic as it could be.

3. This conclusion is further substantiated by the fact algae diversity in Scofield Reservoir is moderately high. Several of the taxa present are indicators of quite high water quality.

4. However, it also seems important to note that although several species of noxious Cyanophyta were present in Scofield Reservoir in 1975, they were present in much lower density than in the 1981 and 1982 years. This probably means that Scofield Reservoir is undergoing rapid eutrophication at the present time. This rate of eutrophication is ordinarily an indication that it is due to human-caused factors.

On July 25, 1990 Cyanophyta (bluegreen algae) comprised approximately 99% of all taxa present by relative density. Phytoplankton samples were collected at 3 sites on the reservoir. Water collected was representative of the water column from the surface to a depth of 3 times the secchi depth. Species rank in these samples was primarily Aphanizomenon flos-aquae and Anabaena spiroides var. crassa. Rushforth determined the reservoir to be in "poor condition". An additional set of similar samples was collected on August 23, 1990 for analysis. Again Cyanophyta biomass was very high indicative of a hypereutrophic state. Species rank in those samples was primarily Anabaena spiroides var. crassa and Sphaerocytis schroeteri.

Trophic Status

In an effort to determine eutrophication trends occurring in the reservoir a comparison of Carlson's (1977) trophic state index (TSI) values over an extended period of time was utilized. These index values were determined from summer values for Secchi Disk (SD) depth readings in meters, total phosphorus (TP) concentrations in mg/m^3 and chlorophyll-a (CLA) concentrations in mg/m^3 and a weighted combination of these components. TSI values range on a scale of 0-100 for these variables. The regression equations

presented below were used to determine TSI values for each respective component.

TSI = 60 - 14.41 ln SD = XSD
TSI = 9.81 ln CA + 30.6 = XCLA
TSI = 14.42 ln TP + 4.15 = XTP

TSI values are related to trophic condition through a specified range of the TSI values. By definition an oligotrophic lake exists, where TSI values are less than 40. A mesotrophic lake exists where TSI values are greater than 40 but less than 50. Finally, an eutrophic lake exists where the TSI values are greater than 50 with hypereutrophic lakes for values greater than 60.

Although data does not exist for all of the above parameters for the period of study (1981-1989), a graph of the existing data are found in Figure 3.2. For each parameter

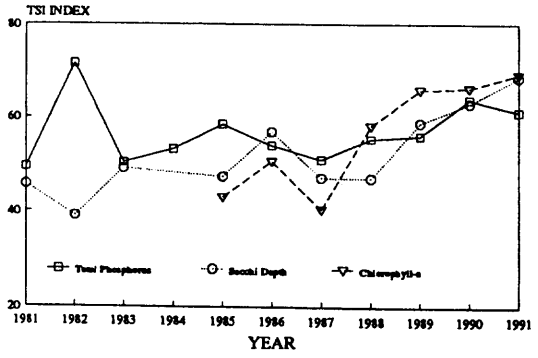

Figure 3.2 Plot of TSI values for the period 1981 to 1991

secchi depth, total phosphorus and chlorophyll-a, the graph depicts a general trend towards eutrophication throughout the study period. TSI values are representative of actual readings or concentrations. A review of these graphs shows that the total phosphorus concentration at the deep station has been fairly stable with an increase since 1987. Graphs for secchi depth and chlorophyll-a indicate an overall increase in algal numbers as evidenced by the decrease in transparency and increase in chlorophyll-a production. It is this increased algal productivity that results in a loss of uses and an increase in internal phosphorus loading to the reservoir waters.

An average TSI plot Figure 3.3 for all factors substantiates the trend towards eutrophication over the extended period of study.

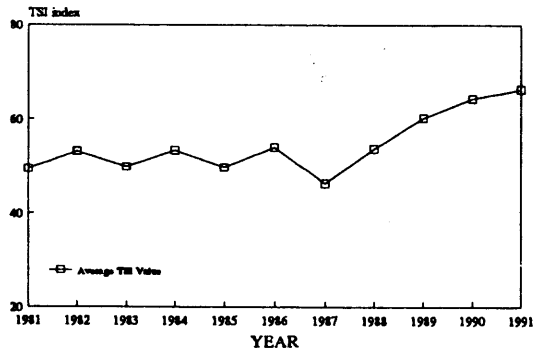

Figure 3.3 Plot of overall TSI average values for the period 1981 to 1990

Internal phosphorus loading

Although early studies by Messer and Ihnat (1983) indicate internal phosphorus loadings are affected by anaerobic condition, they concluded that historical internal phosphorus input to the reservoir were probably negligible. In an effort to document the release of phosphorus from the bottom sediments during anoxic conditions total phosphorus and dissolved oxygen concentrations near the bottom were monitored. Figure 3.4 represents a plot of

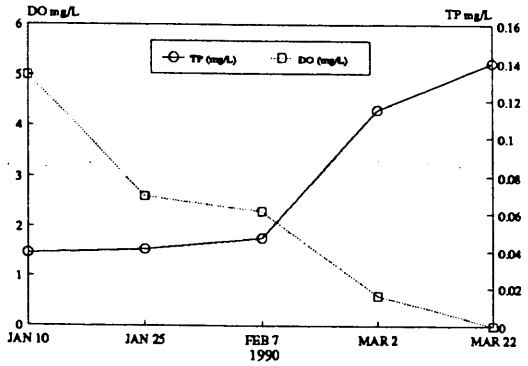

Figure 3.4 Dissolved oxygen and Total phosphorus correlation in hypolimnion

the data gathered from January 10 to March 22, 1990. It is obvious that total phosphorus concentrations increase with the depletion of oxygen and incurring anoxic conditions. Although release rates were not determined it appears that they are significant. This increased internal phosphorus loading adds to the potential for algal productivity. In addition to nuisance algal blooms which are linked to noxious tastes and odors and a loss of aesthetic enjoyment, the high algal productivity leads to a reduction of dissolved oxygen (DO) within the reservoir.

Excessive algal production in the Scofield ecosystem provides high quantities of organic material in the hypolimnion where decomposition (respiration) occurs. A primary component utilized for decomposition is oxygen. The large amount of organic material present requires extensive amounts of oxygen for anaerobic decomposition causing severe DO depletions or even anoxic conditions.

Fish kills have been documented at Scofield Reservoir and some if not all are due to an extensive loss of DO in the water column. In an effort to document DO depletion, an instrument was deployed in the water column at the deep site of the reservoir to determine the DO depletion during ice coverage conditions. This datasonde manufactured by the Hydrolab Corporation is capable of recording DO concentrations for a specified time interval over an extended period of time. The instrument was deployed at a depth of 2.5 meters with a maximum water depth of approximately 7.0 meters in the reservoir. This depth was selected after an initial profile conducted on January 10, 1990 determined it as a safe depth where aerobic conditions would probably exist throughout the study period. The instrument was programmed to take a DO reading every 2 hours. From these readings daily DO averages were computed. A plot of daily DO averages over the study period (January 10, through April 23, 1990) is graphically represented in Figure 3.5. On January 10 when the datasonde was initially deployed the DO profile depicted a gradual decline of DO concentration from 8.3 mg/l at the surface to 5.0 mg/l at the bottom. A review of the graph reveals a consistent decline in DO concentrations over time. On April 4, 1990 the last DO profile before ice off was obtained. The profile showed a DO concentration of 4.1 mg/l at the surface with

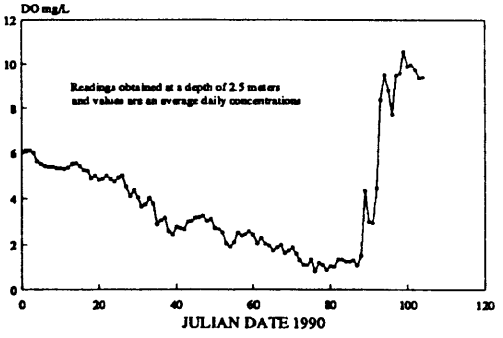

Figure 3.5 1989-90 Dissolved oxygen depletion in Scofield Reservoir

anoxic conditions below 5 meters. In addition, the DO concentration at 2.5 meters was only 1.5 mg/l. The overall DO depletion incurred during the study period was severe. It was determined that there was an approximate loss of 0.05 mg/l of DO per day at the study depth. If ice coverage would have extended an addition three weeks, under normal winter conditions, it was calculated than a maximum concentration at the surface would have been 3.0 mg/l, a critical level of DO for fish survival.

Bacteriological analysis

In an effort to assess the impact of ice fishing and agricultural components on the water quality of Scofield Reservoir, a monitoring program was instituted on May 1, 1989. This program was a joint venture between Price River Water Improvement District (PRWID) and the Southeast Region Office of the State Division of Wildlife Resources with support from the Division of Water Quality. The objectives are to assess the sources of coliform bacteria and nutrients, and evaluate the data obtained against water quality standards to determine the extent (if any) of potential health/water quality violations. Data for all of the points is summarized in Table 3.3. Seventeen sites were identified in the Mud Creek drainage and on the reservoir. Figure 3.6 depicts graphically the data obtained from sites on Mud Creek for the period of study. Sites selected were Mud Creek above project (MCAP), Mud Creek above Scofield Town (MCAT), Mud Creek below Scofield Town (MCBT), and Mud Creek above Scofield Reservoir (MCAS). Significant numbers of fecal coliforms are entering Mud Creek.

Table 3.3 Summary of fecal coliform data from Mud Creek and Scofield Reservoir

Julian Date	MCAP	MCAT	MCBT	MCAS
8	8		10	
22	0		0	5
36	0		4	0
65	0	2	10	10
78	0	0	5	0
99	0	0	0	0
113	0	5	0	5
142	0	56	52	86
156	6	289	235	249
171	100	2700	1700	1600
184	0	0	0	0
198	100	1600	1708	2500
219	0	50	150	5210
233	4	0	0	100
248	4	290	550	890
261	24	260	460	170
275	64	8	10	30
289	5	10	20	30
310	1	10	0	10
324	4	10	30	10
338	4	0	20	10
352	0	10	10	10

Only three samples obtained from the lake had reported coliform counts. The south bay had counts of 1 and 2 on days 156 and 275. Midlake east of island had a count of 2 on day 219.

Peak counts occur during the runoff season indicative of the movement of surface contaminated material into the stream channels. Due to the lack of additional data conclusions cannot be validated as to the source of these coliforms, however field observations would indicate that it is in fact due to the agricultural practices in the drainage. Fecal coliform counts in the reservoir water are typically very low and usually go undetected as indicated in Table 3.3.

Transbasin diversion

There is currently a proposal to build an additional reservoir, the Narrows Reservoir, in the upper watershed of Scofield Reservoir.

Storage water from this reservoir would be available for use by Sanpete county water users via a transbasin diversion. The proposal requests a diversion of 5,400 acre feet of water annually from inflow waters of Scofield Reservoir. It is not our intent to describe in detail this proposal or to make comment on it at this point in time. However, this information is added to develop an awareness of the potential impact of diverting waters from Scofield Reservoir and the tributary system which makes up the watershed. Water quality at Scofield Reservoir is at a critical stage and the impacts of this proposal on water quality and the beneficial uses defined for Scofield Reservoir need to be addressed.

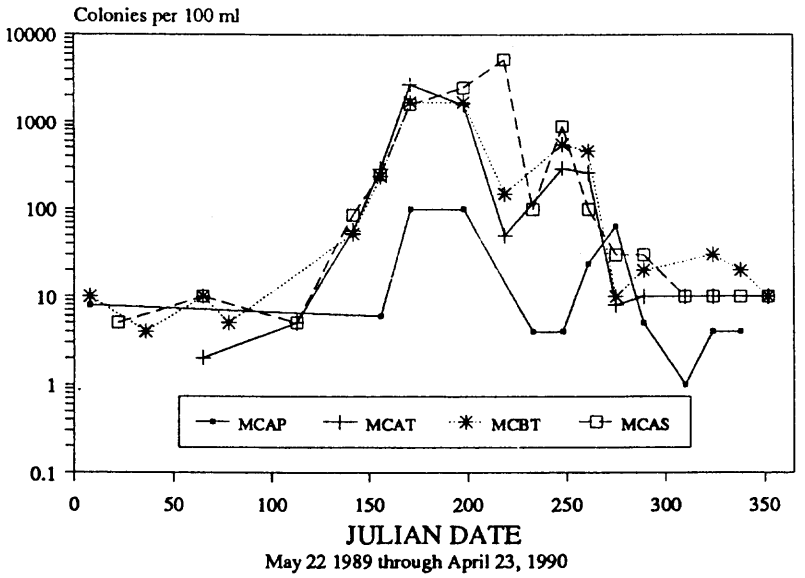

Figure 3.6 Summary of bacteriological data for Mud Creek and Scofield Reservoir

SECTION 4

CONCLUSIONS

EROSION CONTROL

Prior to the implementation of the Mud Creek (MC) and Fish Creek (FC) projects, overgrazing within the riparian zone, man's activities in the upper watershed and normal to heavy runoff conditions made streambank and soil conditions very susceptible to extensive erosion.

Measures taken during implementation to mitigate these conditions included fencing, installation of checkdams and juniper revetments, streambank sloping and shaping, and a revegetation program. All of these measures were effective in controlling isolated erosion problems and should ensure erosion control for the future. Fencing of treated areas was considered vital for protection and short term rehabilitation of streambanks. However, due to one noncooperative property owner a major treatment area was not fenced. Restoration of this area is dependent upon animal management practices employed by the property owner. The two remaining areas where treatment occurred were fenced to protect the streambanks and reseeded areas during the revegetative process. These areas also contained vertical and unstable banks which required protection while bank stability returned as part of a natural process.

Checkdams composed of gabions and retention structures were effective at reducing water velocities, thereby allowing stream sediments to settle. Secondary benefits from checkdams included pool development below the checkdams for fisheries enhancement.

Juniper revetments installed at the base of eroding streambanks provided a stable area to reestablishing streambanks. They provided an area for sediments to be deposited and revegetation to occur. As fine particles are deposited and accumulate on tree structures
the area of revetments is eventually filled with sediment and vegetation and confines the stream. Revetment areas with deposited soil provide the stability needed for development of young willow shoots, forbes and grasses. In some areas streambank sloping and reshaping was required to eliminate vertical banks and reduce erosion potential for these soils. Placement of revetments in these areas inhibited further erosion into these banks while vegetation grew and added to the stability of the soils and streambanks.

The revegetative program was essential to ensure soil stability for future erosion control. The project area has an increased coverage of vegetation, comprised of native grasses, forbes, and willows. Planted willow shoots have grown and are reaching a level where they are assured of perpetuation with proper management. It is anticipated that they will contribute markedly to future bank stability.

These methods appear to have been effective at increasing bank stability and reducing

erosion. Areas where the stream flows were cutting into banks has been reduced or eliminated, stream velocities have been reduced and erodible banks and soils have been protected. Visually it appears that erosion has been reduced as sediments have deposited and vegetation returned in these areas. Early indications are that future control of erosion will increase as vegetation and bank stability improve provided drastic changes do not occur to destroy them.

An effective technique to insure the revegetative process has been the construction of a protective fence adjacent to the stream for treated sections of the project. It has provided protection from grazing animals while initial sedimentation and growth of vegetation has occurred.

SEDIMENT CONTROL

Table 4.1 Data summary of total phosphorus and suspended sediments for Mud Creek project area

	Total Phosphorus		Suspended Solids	
Year	Above	Below	Above	Below
1987	0.059	0.058	29.4	32.9
1988	0.066	0.072	40.3	32.9
1989	0.022	0.056	25.8	27.2
1990	0.067	0.043	22.0	18.9

Insufficient total suspended solids data is available to determine conclusively, the effectiveness of restoration techniques for removal of sediments. Table 2.1 contains a summary of average total phosphorus and suspended solids concentrations (mg/L) for the years 1987-91 at stations above and below the project area. The data is limited and cannot be used to substantiate the visual evidence of sediment control. Insufficient data exists throughout the project to provide a meaningful interpretation related to loss of sediments due to implemented best management practices.

TOTAL PHOSPHORUS CONTROL

Total phosphorus loadings have been directly correlated with sediment loading during the Phase I Study period. Figure 2.1 is a plot of total phosphorus concentrations for Mud Creek below the project area. Although the graph does indicate that in recent years total phosphorus concentrations have declined with respect to the "typical concentrations" as reported by Denton, et al (1983) in the initial Phase I Clean Lake study, insufficient data is available to confirm the effectiveness of restoration techniques at reducing phosphorus in the project area.

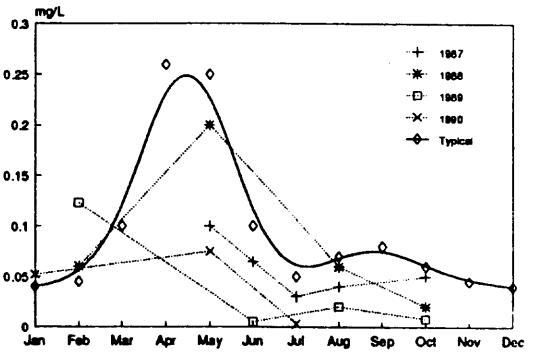

Figure 4.1 Plot of total phosphorus concentrations in Mud Creek below project

PHOSPHORUS AND SUSPENDED SOLIDS LOADINGS

The total phosphorus load to Scofield Reservoir as reported in the Scofield Reservoir Clean Lake study is 6,723 Kg/year. Calculations are based on estimated long term average flow rates with parameter constituent concentrations estimated on long term average values. For a complete understanding of loading determinations refer to the discussions in the referenced report (Denton, 1983). Although insufficient water quality data exists to determine annual average concentrations, from a review of the total phosphorus concentrations during recent years (Figure 2.1) and the fact that flow rates to the reservoir have decline in recent years, there is an indication that the external loading to the reservoir has declined. Even with this assumed decline in external phosphorus loads insufficient data is available to link this reduction to implemented techniques in the project areas as previously discussed. In lake concentrations of total phosphorus have shown an increasing trend in recent years which may support the conclusion that internal phosphorus loadings are increasing and in fact driving the eutrophication occurring in the reservoir.

LAKE WATER QUALITY

Lake water quality data substantiates the increase in eutrophication in Scofield Reservoir. The following is a summary of water quality conditions supporting this conclusion:

1. Trophic State Indices have continued to increase.

   A. 1991 data indicates an increasing trend in concentrations of total phosphorus during the productivity season (May through September) in epilimnetic water (Figure 5.2). The 1983 study determined the 1981-82 total phosphorus concentration during the productivity season in the epilimnion averaged 0.035 mg/L which equates to a TSI value of 55.42. The reported TSI value for 1991 is 61.22 with an average value from 1987 to 1991 of 57.50.

   B. Recent data indicates an increasing trend in the concentration of chlorophyll-a during the productivity season in epiliminetic waters (Figure 5.2). The 1983 study determined the 1981-82 chlorophyll-a concentration during the productivity season in the epilimnion averaged 8.5 ug/L which equates to a TSI value of 51.59. The reported TSI value for 1991 is 69.20 with an average value from 1987 to 1991 of 59.98.

   C. Recent data indicates a decreasing trend in secchi depth readings during the productivity season (Figure 5.2). The 1983 study determined the 1981-82 secchi depth readings during the productivity season averaged 3.4 meters which equates to a TSI value of 42.37. The reported TSI value for 1991 is 68.53 with an average value from 1987 to 1991 of 56.89.

   A review of the overall Carlson TSI values (Figure 5.3) shows a moderately stable TSI trend except during recent years where data depicts an increasing trend for average TSI values. Values have increased approximately 33.2 per

cent from 1981 to 1991 (49.79 to 66.32). The average TSI value from 1987 to 1991 is 58.12.

2. Phytoplankton studies conducted by Sam Rushforth, Ph.D., from Brigham Young University indicate that the reservoir has shifted from a mesotrophic/eutrophic system to a hypereutrophic system.

3. Severe anoxic conditions have been documented throughout the water column during ice coverage. These conditions have increased the internal phosphorus loadings to the reservoir from the bottom sediments.

4. The fishery at Scofield Reservoir has experienced a dramatic decline over the past decade as reported in the paper, "Nonpoint Source Pollution and Fisheries in Scofield Reservoir, Carbon County, Utah". High nutrient loads, anoxic conditions, and reduced flushing rates were identified as causes for the decline.

SECTION 5

RECOMMENDATIONS

In order to promote the goal of restoring beneficial uses of Scofield Reservoir through improved water quality and to document ongoing water quality changes in this system we recommend the following:

1. A continuation of a post-implementation monitoring program for the reservoir and major tributaries to obtain additional data to document long term changes in water quality.

2. Maintain the cooperative relationship with involved agencies in the local water quality task force to assist in planning and development of programs to improve water quality in the Scofield Reservoir watershed.

3. Investigate in-lake technologies to alleviate internal phosphorus loading and develop a proposal to address these problems.

4. Promote discussions and support studies to determine the impact of a transbasin diversion of water from the upper Scofield Reservoir watershed. Determine the impact on flushing rates, internal phosphorus loadings, and general water quality for Scofield Reservoir.

5. Maintain the "protective fence" around project areas to protect the streambanks and sensitive vegetation in the project area continues until riparian conditions are sufficiently stable to allow grazing activities under a controlled management schedule.

6. Maintain the current public awareness and education program to facilitate control of pollutants to the reservoir and generate support for future implementation activities.

7. Continue to support management activities by local and other governmental agencies to abate or control pollutant sources.

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APPENDIX A

PARAMETER ANALYSIS FOR MUD CREEK DRAINAGE

MUD CREEK BELOW VALLEY CAMP

DATE	Total P ug/L	TSS mg/L	NO2+ NO3 mg/L	NH3 mg/L	TKN mg/L
09/06/83	0.020	42.0	0.010	0.025	0.1
10/12/83	0.010	3.0		0.025	0.2
05/07/85	0.350		1.450	0.050	0.8
05/30/85	0.110		0.770	0.050	0.4
06/20/85	0.030		0.300	0.050	0.3
08/14/85	0.020		0.050	0.050	0.1
09/09/85	0.020		0.005	0.050	0.1
01/22/86	0.030		0.140	0.050	0.1
09/23/86	0.003		0.040	0.050	0.1
05/06/87	0.070	45.0	0.220	0.025	0.7
05/21/87	0.080	49.0	0.160	0.025	0.7
06/03/87	0.060	19.0	0.030	0.025	0.3
06/09/87	0.110	59.0	0.070	0.025	1.2
06/25/87	0.030	11.0	0.100	0.025	0.2
08/11/87	0.040	21.0	0.005	0.025	0.1
10/14/87	0.020	1.5	0.110	0.025	0.3
02/04/88	0.060	40.0	0.370	0.025	0.2
05/18/88	0.170	118.0	0.240	0.025	0.5
08/19/88	0.003	1.5	0.020	0.025	0.1
10/06/88	0.030	1.5	0.005	0.025	0.1
05/04/89	0.034	31.0	0.005	0.025	0.3
05/16/89	0.018	32.0	0.100	0.025	0.1
06/06/89	0.005	24.0	0.040	0.025	0.3
08/22/89	0.027	28.0	0.180	0.210	0.3
10/24/89	0.026	14.0	0.060	0.025	0.3
01/10/90	0.054	10.0	0.430	0.025	0.4
03/22/90	0.118	10.0		0.025	0.1
05/19/90	0.094	34.0	0.252	0.025	0.1
07/25/90	0.003	39.0	0.130	0.025	0.3
08/23/90		17.0	0.170	0.025	0.1
DATA SUMMARY					
YEAR					
1983	0.015	22.5	0.010	0.025	0.2
1985	0.106	ND	0.515	0.050	0.3
1986	0.016	ND	0.090	0.050	0.1
1987	0.059	29.4	0.099	0.025	0.5
1988	0.066	40.3	0.159	0.025	0.2
1989	0.022	25.8	0.096	0.062	0.3
1990	0.067	22.0	0.196	0.025	0.2

MUD CREEK ABOVE VALLEY CAMP

DATE	Total P ug/L	TSS mg/L	NO2+ NO3 mg/L	NH3 mg/L	TKN mg/L
05/21/87	0.070	50.0	0.160	0.025	0.9
06/03/87	0.030	17.0	0.030	0.025	0.5
06/09/87	0.060	38.0	0.070	0.025	0.4
06/25/87	0.030	8.0	0.080	0.025	0.2
08/11/87	0.040		0.010	0.025	0.1
10/14/87	0.030	1.5	0.110	0.025	0.1
02/04/88	0.060	1.5	0.340	0.025	0.3
05/18/88	0.170	116.0	0.250	0.025	0.4
08/19/88	0.003	1.5	0.020	0.025	0.1
10/06/88	0.030	1.5	0.060	0.025	0.1
05/04/89	0.030	27.0	0.570	0.025	0.3
05/16/89	0.120	51.0	8.000	0.025	0.5
06/06/89	0.013	21.0	5.000	0.025	0.1
08/22/89	0.021	30.0	13.000	0.025	0.1
10/24/89	0.020	6.0	0.150	0.025	0.1
01/10/90	0.038	10.0	0.430	0.025	0.1
03/22/90	0.003	10.0		0.025	0.3
05/19/90	0.077	31.0	0.248	0.025	0.1
07/25/90	0.003	48.0	0.130	0.025	0.3
08/23/90		20.0	0.190	0.025	0.1
DATA SUMMARY					
YEAR					
1987	0.043	22.9	0.077	0.025	0.4
1988	0.066	30.1	0.168	0.025	0.2
1989	0.041	27.0	5.344	0.025	0.2
1990	0.030	23.8	0.250	0.025	0.2

MUD CREEK AT JENSEN FENCE

DATE	Total P ug/L	TSS mg/L	NO2+ NO3 mg/L	NH3 mg/L	TKN mg/L
05/21/87	0.100	85.0	0.170	0.025	0.9
06/03/87	0.070	25.0	0.040	0.025	0.6
06/09/87	0.080	37.0	0.080	0.025	0.3
06/25/87	0.050	10.0	0.080	0.025	0.2
08/11/87	0.030	20.0	0.005	0.025	0.6
10/14/87	0.020	1.5	0.100	0.025	0.3
02/04/88					
05/18/88	0.019	140.0	0.250	0.025	0.7
08/19/88	0.020	1.5	0.005	0.025	0.1
10/06/88	0.030	1.5	0.005	0.025	0.1
05/04/89	0.040	28.0	1.820	0.025	0.4
05/16/89	0.764	39.0	0.060	0.025	0.1
06/06/89	0.005	25.0	0.100	0.025	0.2
08/22/89	0.027	28.0	0.100	0.025	0.1
10/24/89	0.016	8.0	0.130	0.025	0.1
01/10/90	0.039	19.0	0.350	0.025	0.1
03/22/90	0.229	31.0		0.025	0.9
05/19/90	0.097	28.0	0.149	0.025	0.1
07/25/90	0.008	16.0	0.120	0.025	0.5
08/23/90		17.0	0.050	0.025	0.1
DATA SUMMARY					
YEAR					
1987	0.058	29.8	0.079	0.025	0.5
1988	0.023	47.7	0.087	0.025	0.3
1989	0.170	25.6	0.442	0.025	0.2
1990	0.093	18.8	0.155	0.020	0.3

MUD CREEK ABOVE WINTER QUARTERS CREEK

DATE	Total P ug/L	TSS mg/L	NO2+ NO3 mg/L	NH3 mg/L	TKN mg/L
05/21/87	0.100	76.0	0.160	0.025	0.4
06/03/87	0.050	34.0	0.010	0.025	0.6
06/09/87	0.080	57.0	0.070	0.025	0.4
06/25/87	0.030	8.0	0.050	0.025	0.2
08/11/87	0.040	21.0	0.005	0.025	0.3
10/14/87	0.050	1.5	0.050	0.025	0.1
02/04/88	0.060	37.0	0.340	0.025	0.2
05/18/88	0.200	130.0	0.220	0.025	0.9
08/19/88	0.006	36.0	0.005	0.025	0.1
10/06/88	0.020	1.5	0.005	0.025	0.0
05/04/89	0.025	56.0	1.800	0.025	0.4
05/16/89	0.221	44.0	0.540	0.025	0.4
06/06/89	0.005	22.0	0.090	0.025	0.2
08/22/89	0.020	8.0	0.090	0.025	0.1
10/24/89	0.008	6.0	0.140	0.025	0.2
01/10/90	0.052	1.5	0.110	0.025	0.1
03/22/90	0.338	33.0		0.025	0.2
05/19/90	0.075	47.0	0.079	0.025	0.2
07/25/90	0.003	5.0	0.110	0.025	0.2
08/23/90		8.0	0.050	0.025	0.2
DATA SUMMARY					
YEAR					
1987	0.058	32.9	0.058	0.025	0.3
1988	0.072	51.1	0.143	0.025	0.3
1989	0.056	27.2	0.532	0.025	0.3
1990	0.043	18.9	0.087	0.025	0.2

WINTER QUARTERS CREEK ABOVE MUD CREEK

DATE	Total P ug/L	TSS mg/L	NO2+ NO3 mg/L	NH3 mg/L	TKN mg/L
05/21/87	0.070	24.0	0.090	0.025	0.5
06/03/87	0.040	6.0	0.005	0.025	0.7
06/09/87	0.040	10.0	0.060	0.025	0.4
06/25/87	0.050	5.0	0.060	0.025	0.3
08/11/87	0.110	6.0	0.005	0.025	0.5
10/14/87	0.060	26.0	0.020	0.025	0.2
02/04/88	0.050	1.5	0.160	0.025	0.2
05/18/88	0.100	62.0	0.140	0.025	0.6
08/19/88	0.003	1.5	0.005	0.025	0.1
10/06/88	0.020	1.5	0.005	0.025	0.2
05/04/89	0.030	16.0	0.010	0.025	1.5
05/16/89	0.382	73.0	0.910	0.025	0.2
06/06/89	0.015	13.0	0.100	0.025	0.3
08/22/89	0.022	1.5	0.020	0.025	0.2
10/24/89	0.028	12.0	0.020	0.025	0.3
01/10/90	0.016	35.0	0.250	0.025	0.1
03/22/90	0.003	1.5		0.025	0.1
05/19/90	0.068	19.0	0.270	0.025	0.1
07/25/90	0.003	3.0	0.110	0.025	0.3
08/23/90		3.0	0.050	0.025	0.2

DATA SUMMARY

YEAR					
1987	0.062	12.8	0.040	0.025	0.4
1988	0.043	16.6	0.078	0.025	0.3
1989	0.095	23.1	0.212	0.025	0.5
1990	0.022	12.3	0.170	0.025	0.2

MUD CREEK PROJECT AREA

Total Phosphorus (mg/L)

YEAR	ABOVE	BELOW
1987	0.059	0.058
1988	0.066	0.072
1989	0.022	0.056
1990	0.067	0.043

Total suspended solids (mg/L)

YEAR	ABOVE	BELOW
1987	29.4	32.9
1988	40.3	32.9
1989	25.8	27.2
1990	22.0	18.9

APPENDIX B
PHYTOPLANKTON SUMMARY

Algae taxa present in a total plankton sample collected from Scofield Reservoir (site 593127) from the lower half of the euphotic zone, July 25, 1990. The percent relative density, species rank in the sample, number of cells per liter, and the volume of cells (in cubic micrometers/liter) are also provided. Descriptive statistics are also provided at the end of the list of taxa.

Taxon	Relative Density	Rank	Number Per Liter	Cell Volume
APHANIZOMENON-AQUAE	99.57	1	2702160	51341040000
CENTRIC DIATOMS	0.04	3	38920	22184400
MELOSIRA GRANULATA	0.02	5	11120	10897600
PENNATE DIATOMS	0.02	4	27800	11120000
STEPHANODISCUS NIAGARAE	0.34	2	5560	175974000

*Shannon-Weaver Index [H'] = 0.03
**Species Evenness = 0.02
***Species Richness [d] = 0.16
Number of species = 5

Algae taxa present in a total plankton sample collected from Scofield Reservoir (site 593127) from the upper half of the euphotic zone, July 25, 1990. The percent relative density, species rank in the sample, number of cells per liter, and the volume of cells (in cubic micrometers/liter) are also provided. Descriptive statistics are also provided at the end of the list of taxa.

Taxon	Relative Density	Rank	Number Per Liter	Cell Volume
ANABAENA FLOW-AQUAE	0.17	3	5560	212086200
ANABAENA SPIROIDES VAR. CRASSA	50.15	1	105640	62536555920
APHANIZOMENON FLOW-AQUAE	49.64	2	3258160	61905040000
CENTRIC DIATOMS	0.01	6	27800	15846000
MELOSIRA GRANULATA	0.01	5	16680	16346400
PENNATE DIATOMS	0.02	4	55600	222400000

*Shannon-Weaver Index [H'] = 0.71
**Species Evenness = 0.40
***Species Richness [d] = 0.20
Number of species = 6

Algae taxa present in a total plankton sample collected from Scofield Reservoir (site 593099) from the lower half of the euphotic zone, July 25, 1990. The percent relative density, species rank in the sample, number of cells per liter, and the volume of cells (in cubic micrometers/liter) are also provided. Descriptive statistics are also provided at the end of the list of taxa.

Taxon	Relative Density	Rank	Number Per Liter	Cell Volume
ANABAENA SPIROIDES VAR CRASSA	33.50	2	27800	16456988400
APHANIZOMENON FLOW-AQUAE	65.37	1	1690240	32114560000
CENTRIC DIATOMS	0.05	4	38920	22184400
MELOSIRA GRANULATA	0.01	5	5560	5448800
PENNATE DIATOMS	0.00	6	5560	2224000
STEPHANODISCUS NIAGARAE	1.07	3	16680	5027922000

*Shannon-Weaver Index [H'] = 0.70
**Species Evenness = 0.39
***Species Richness [d] = 0.20
Number of species = 6

Algae taxa present in a total plankton sample collected from Scofield Reservoir (site 593099) from the upper half of the euphotic zone, July 25, 1990. The percent relative density, species rank in the sample, number of cells per liter, and the volume of cells (in cubic micrometers/liter) are also provided. Descriptive statistics are also provided at the end of the list of taxa.

Taxon	Relative Density	Rank	Number Per Liter	Cell Volume
ANABAENA SPIROIDES VAR CRASSA	35.11	2	88960	52662362880
APHANIZOMENON FLOS-AQUAE	64.51	1	5092960	96766240000
CENTRIC DIATOMS	0.01	4	27800	15846000
CHLAMYDOMONAS SPECIES	0.00	7	16680	6672000
PENNATE DIATOMS	0.01	6	22240	88960000
SCENEDESMUS QUADRICAUDA	0.01	5	5560	13344000
STEPHANODISCUS NIAGARAE	0.35	3	16680	527922000

*Shannon-Weaver Index [H'] = 0.67
**Species Evenness = 0.35
***Species Richness [d] = 0.23
Number of species = 7

Algae taxa present in a total plankton sample collected from Scofield Reservoir (site 593100) from the lower half of the euphotic zone, July 25, 1990. The percent relative density, species rank in the sample, number of cells per liter, and the volume of cells (in cubic micrometers/liter) are also provided. Descriptive statistics are also provided at the end of the list of taxa.

Taxon	Relative Density	Rank	Number Per Liter	Cell Volume
ANABAENA SPIROIDES VAR CRASSA	28.38	2	100080	59245158240
APHANIZOMENON FLOW-AQUAE	70.85	1	7784000	147896000000
CENTRIC DIATOMS	0.00	5	5560	3169200
GOMPHOSPHERIA APONINA	0.60	3	11120	1256560000
PENNATE DIATOMS	0.00	6	5560	2224000
STEPHANODISCUS NIAGARAE	0.17	4	11120	351948000

*Shannon-Weaver Index [H'] = 0.64
**Species Evenness = 0.36
***Species Richness [d] = 0.19
Number of species = 6

Algae taxa present in a total plankton sample collected from Scofield Reservoir (site 593100) from the upper half of the euphotic zone, July 25, 1990. The percent relative density, species rank in the sample, number of cells per liter, and the volume of cells (in cubic micrometers/liter) are also provided. Descriptive statistics are also provided at the end of the list of taxa.

Taxon	Relative Density	Rank	Number Per Liter	Cell Volume
ANABAENA SPIROIDES VAR. CRASSA	8.68	2	100440	59458270320
APHANIZOMENON FLOS-AQUAE	91.32	1	32922000	625518000000
CENTRIC DIATOMS	0.00	3	22320	12722400

*Shannon-Weaver Index [H'] = 0.30
**Species Evenness = 0.27
***Species Richness [d] = 0.07
Number of species = 3

Algae taxa present in a total plankton sample collected from Scofield Reservoir (site 593097) from the lower half of the euphotic zone, August 23, 1990. The percent relative density, species rank in the sample, number of cells per liter, and the volume of cells (in cubic micrometers/liter) are also provided. Descriptive statistics are also provided at the end of the list of taxa.

Taxon	Relative Density	Rank	Number Per Liter	Cell Volume
ANABAENA SPIROIDES VAR CRASSA	84.22	1	111200	578224000000
ANKISTRODESMUS FALCATUS	0.01	9	27800	6143800
APHANIZOMENON FLOS-AQUAE	0.15	3	5560	105640000
CENTRIC DIATOMS	0.01	8	11120	6338400
CENTRIC DIATOMS	0.09	4	111200	63384000
EUGLENA SPECIES	0.06	6	5560	40866000
OOCYSTIS SPECIES	0.01	7	5560	8340000
PENNATE DIATOMS	0.06	5	72280	43368000
SPHAEROCYSTIS SCHROETERI	15.39	2	22240	10564000000

*Shannon-Weaver Index [H'] = 0.46
**Species Evenness = 0.21
***Species Richness [d] = 0.32
Number of species = 9

Algae taxa present in a total plankton sample collected from Scofield Reservoir (site 593097) from the upper half of the euphotic zone, August 23, 1990. The percent relative density, species rank in the sample, number of cells per liter, and the volume of cells (in cubic micrometers/liter) are also provided. Descriptive statistics are also provided at the end of the list of taxa.

Taxon	Relative Density	Rank	Number Per Liter	Cell Volume
ANABAENA SPIROIDES VAR. CRASSA	95.36	1	689440	358508800000
APHANIZOMENON FLOS-AQUAE	1.83	3	361400	6866600000
CHLAMYDOMONAS SPECIES	0.00	5	5560	2224000
PENNATE DIATOMS	0.00	4	16680	10008000
SPHAEROCYSTIS SCHROETERI	2.81	2	22240	105640000000

*Shannon-Weaver Index [H'] = 0.22
**Species Evenness = 0.14
***Species Richness [d] = 0.15
Number of species = 5

Algae taxa present in a total plankton sample collected from Scofield Reservoir (site 593099) from the lower half of the euphotic zone, August 23, 1990. The percent relative density, species rank in the sample, number of cells per liter, and the volume of cells (in cubic micrometers/liter) are also provided. Descriptive statistics are also provided at the end of the list of taxa.

Taxon	Relative Density	Rank	Number Per Liter	Cell Volume
ANABAENA SPIROIDES VAR CRASSA	81.24	1	77840	40476800000
ANKISTRODESMUS FALCATUS	0.00	7	5560	1228760
CENTRIC DIATOMS	0.56	4	489280	278889600
CERATIUM HIRUNDINELLA	1.88	3	5560	936304000
MELOSIRA GRANULATA	0.33	5	16680	163130400
PENNATE DIATOMS	0.09	6	77840	46704000
SPHAEROCYSTIS SCHROETERI	15.90	2	16680	7923000000

*Shannon-Weaver Index [H'] = 0.59
**Species Evenness = 0.30
***Species Richness [d] = 0.25
Number of species = 7

Algae taxa present in a total plankton sample collected from Scofield Reservoir (site 593099) from the upper half of the euphotic zone, August 23, 1990. The percent relative density, species rank in the sample, number of cells per liter, and the volume of cells (in cubic micrometers/liter) are also provided. Descriptive statistics are also provided at the end of the list of taxa.

Taxon	Relative Density	Rank	Number Per Liter	Cell Volume
ANABAENA SPIROIDES VAR. CRASSA	94.67	1	222400	115648000000
ANKISTRODESMUS FALCATUS	0.00	9	16680	3686280
APHANIZOMENON FLOS-AQUAE	0.78	3	50040	950760000
CENTRIC DIATOMS	0.16	4	339160	193321200
PENNATE DIATOMS	0.04	5	88960	53376000
SCENEDESMUS QUADRICAUDA	0.01	6	5560	13344000
SPHAEROCYSTIS SCHROETERI	4.32	2	11120	5282000000
WISLOUCHIELLA PLANKTONICA	0.00	8	11120	44448000
CHLAMYDOMONAS SPECIES	0.00	7	11120	4448000

*Shannon-Weaver Index [H'] = 0.24
**Species Evenness = 0.10
***Species Richness [d] = 0.35
Number of species = 10

Algae taxa present in a total plankton sample collected from Scofield Reservoir (site 593100) from the lower half of the euphotic zone, August 23, 1990. The percent relative density, species rank in the sample, number of cells per liter, and the volume of cells (in cubic micrometers/liter) are also provided. Descriptive statistics are also provided at the end of the list of taxa.

Taxon	Relative Density	Rank	Number Per Liter	Cell Volume
ANABAENA SPIROIDES VAR CRASSA	91.40	1	289120	150342400000
ANKISTRODESMUS FALCATUS	0.00	8	33360	7372560
APHANIZOMENON FLOS-AQUAE	4.95	2	428120	8134280000
CENTRIC DIATOMS	0.03	6	72280	41199600
ACHLAMYDOMONAS SPECIES	0.01	7	44480	17792000
EUGLENA SPECIES	0.38	4	5560	623387200
PENNATE DIATOMS	0.03	5	72280	43368000
SPHAEROCYSTIS SCHROETERI	3.21	3	11120	5282000000

*Shannon-Weaver Index [H'] = 0.37
**Species Evenness = 0.18
***Species Richness [d] = 0.27
Number of species = 8

Algae taxa present in a total plankton sample collected from Scofield Reservoir (site 593100) from the upper half of the euphotic zone, August 23, 1990. The percent relative density, species rank in the sample, number of cells per liter, and the volume of cells (in cubic micrometers/liter) are also provided. Descriptive statistics are also provided at the end of the list of taxa.

Taxon	Relative Density	Rank	Number Per Liter	Cell Volume
ANABAENA SPIROIDES VAR. CRASSA	97.75	1	550440	286228800000
ANKISTRODESMUS FALCATUS	0.00	8	38920	8601320
APHANIZOMENON FLOS-AQUAE	0.18	4	27800	528200000
CENTRIC DIATOMS	0.03	5	139000	79230000
OOCYSTIS SPECIES	0.00	9	5560	8340000
PEDIASTRUM DUPLEX	0.23	3	5560	667200000
PENNATE DIATOMS	0.00	6	22240	13344000
SPHAEROCYSTIS SCHROETERI	1.8	2	11120	5282000000
WISLOUCHIELLA PLANKTONICA	0.00	7	22240	8896000

*Shannon-Weaver Index [H'] = 0.12
**Species Evenness = 0.06
***Species Richness [d] = 0.30
Number of species = 9

* **H'** $= - \sum_{i=1}^{S} P_i \text{ LOG } P_i$

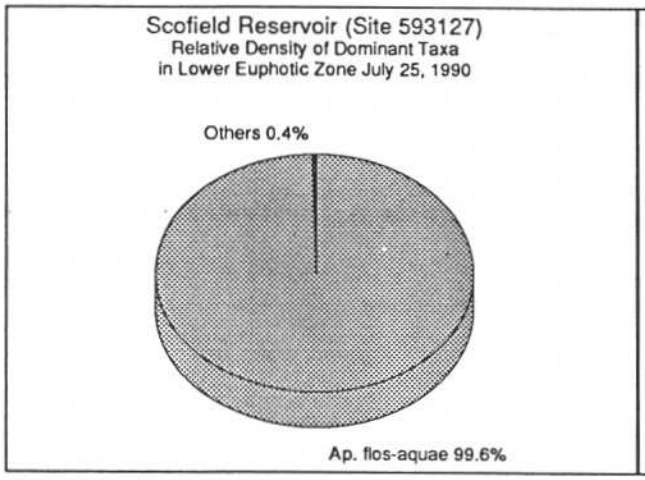
Where: P_i = porportion of the total number of individuals in the ith species;
S = the number of species

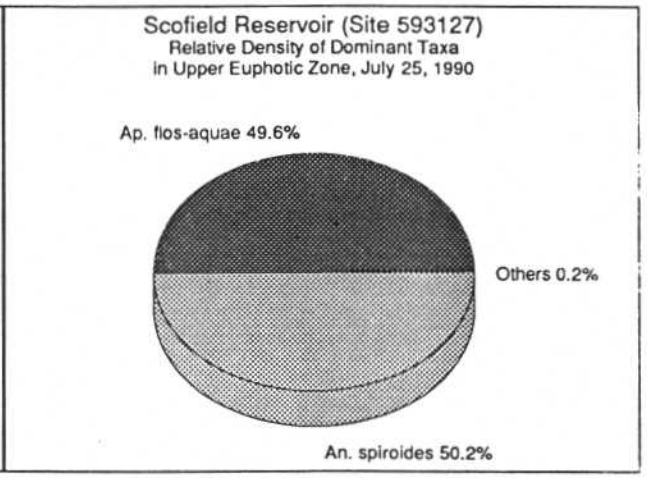
** **Species Evenness** = H'/ log S

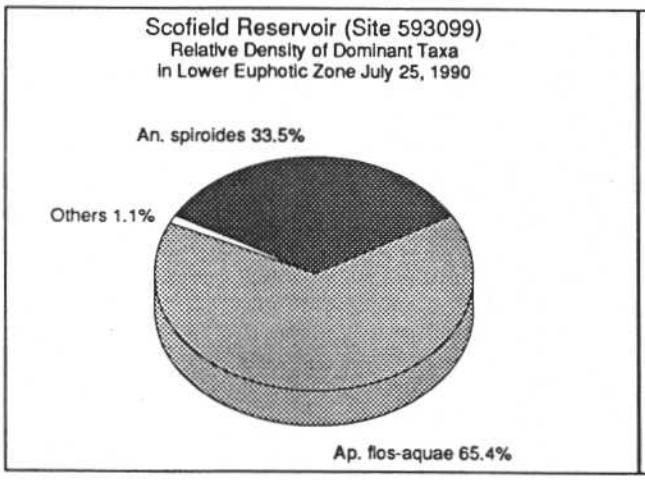
Where: S = the number of species;
H' = Shannon-Weaver Index.

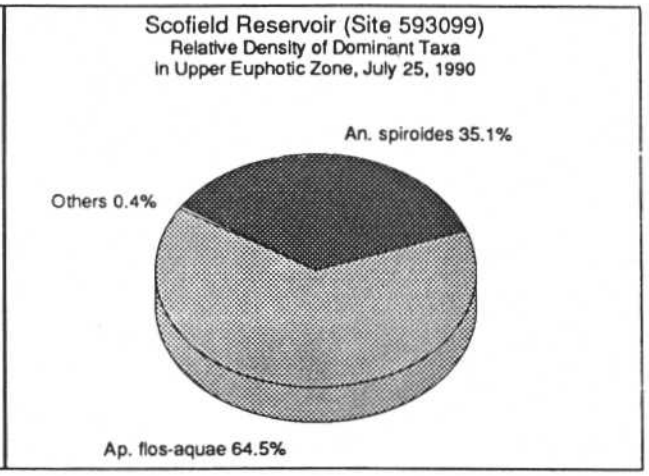
*** **Species Richness** = S-1 / log N

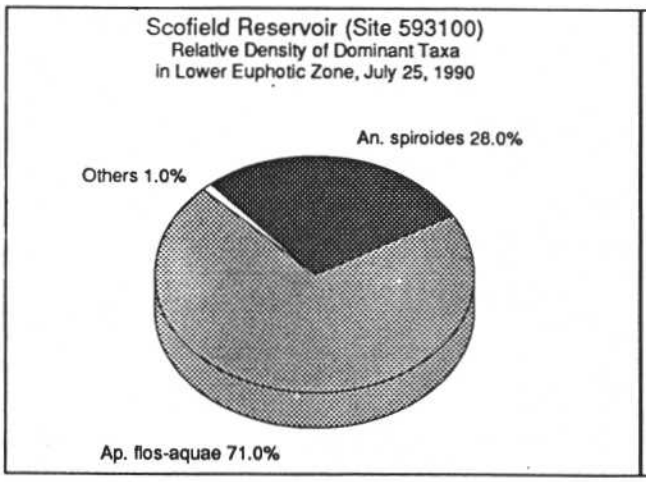
Where: S = the number of species;
N = the number of individuals.

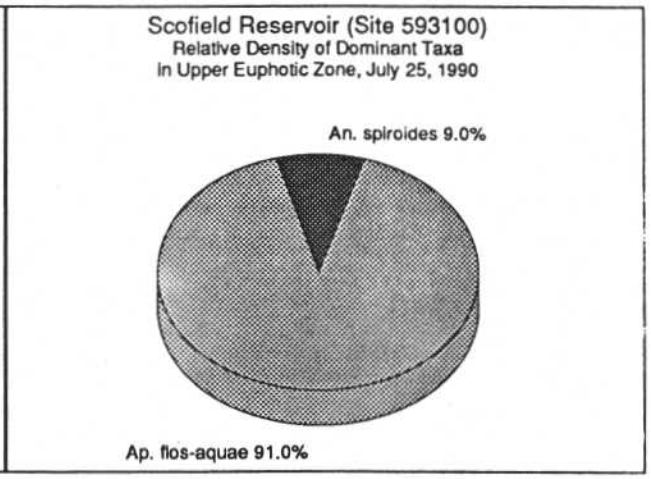












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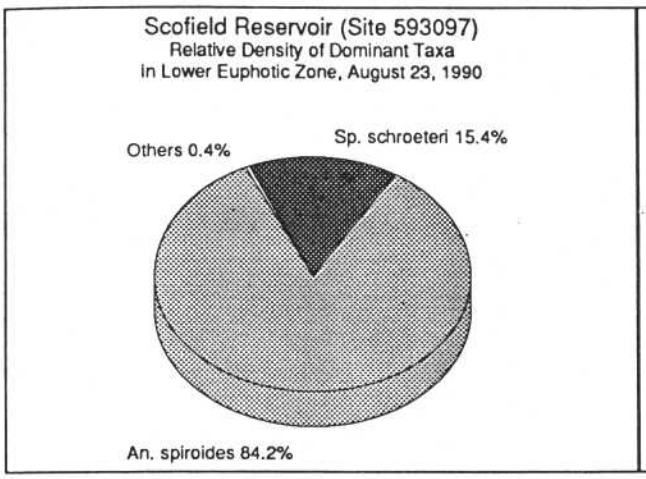

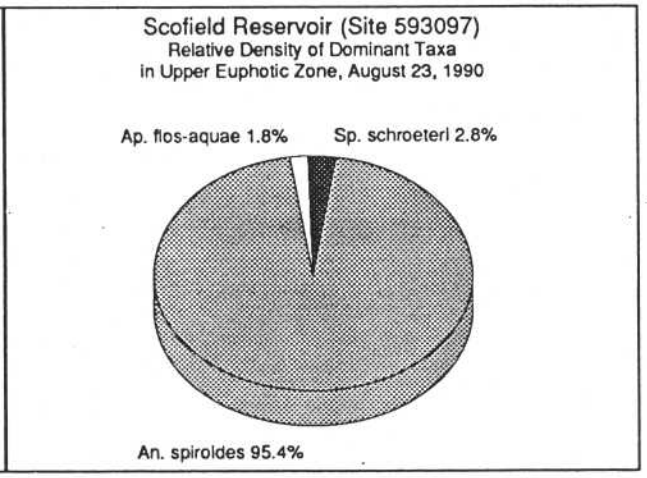

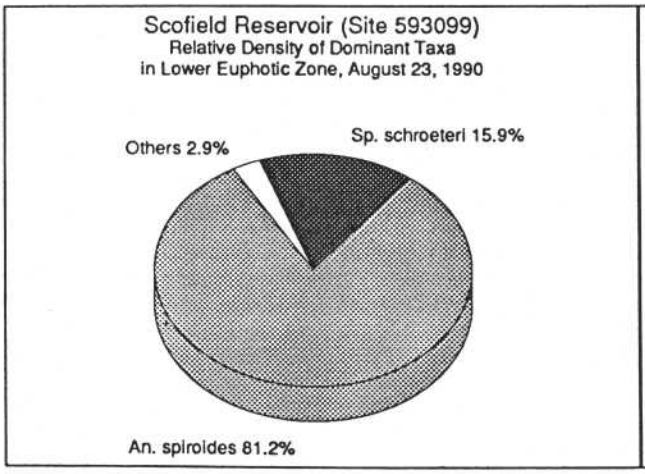

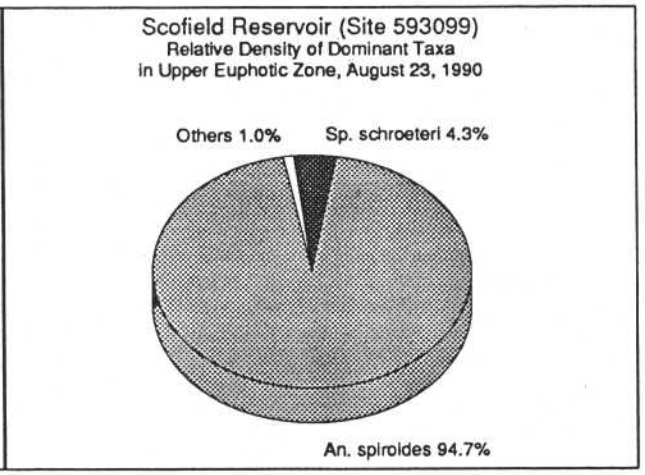

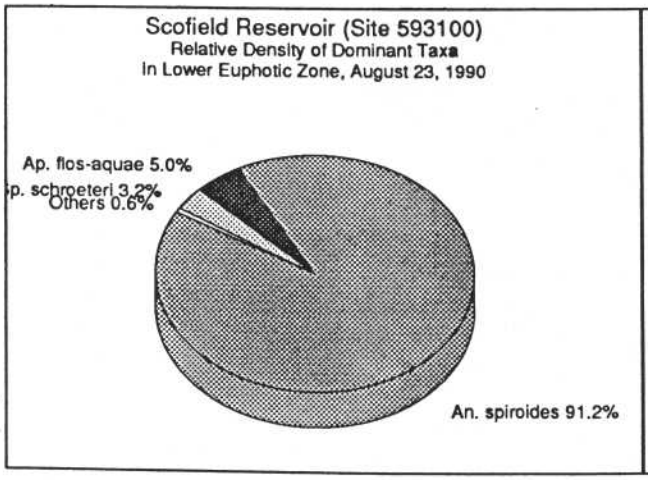

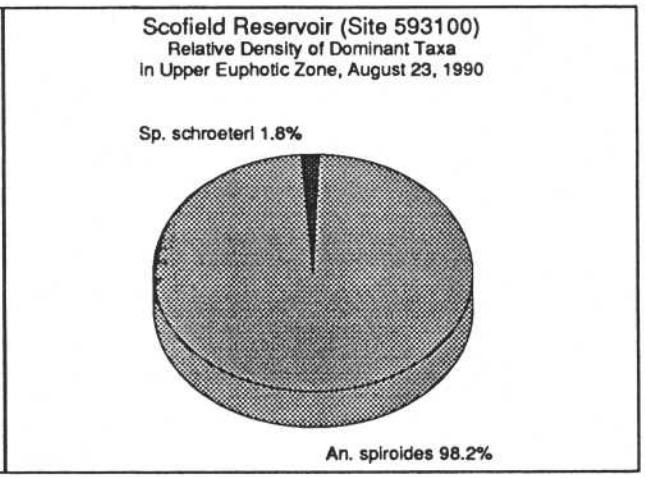

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APPENDIX C

WATER QUALITY FOR SCOFIELD RESERVOIR TRIBUTARIES

Price River below Scofield Reservoir STORET 593096

DATE	Total P Mg/L	TSS Mg/L	NH3 Mg/L	NO2 +NO3 Mg/L	TKN Mg/L
06/18/80	0.010	2.5	0.100	0.400	1.40
07/29/80	0.030	7.0	0.100	0.200	0.20
09/18/80	0.100	2.5	0.100	1.040	0.70
AVE	**0.047**	**4.0**	**0.100**	**0.547**	**0.77**
01/21/81	0.050	2.5	0.300	0.350	1.00
02/26/81	0.030	2.5	0.200	0.500	0.50
04/02/81	0.050	2.5	0.200	0.540	0.50
04/21/81	0.005	7.0	0.050	0.380	0.50
04/28/81	0.020	2.5	0.100	0.320	0.90
05/05/81	0.020	2.5	0.100	0.470	0.50
05/13/81	0.010	2.5	0.100	0.320	0.80
05/28/81	0.030	7.0	0.050	0.200	0.30
06/11/81	0.030	2.5	0.050	0.230	0.30
06/24/81	0.020	2.5	0.050	0.170	0.40
07/08/81	0.010	2.5	0.050	0.300	0.30
07/22/81	0.020	2.5	0.050	0.220	0.40
08/17/81	0.020	9.0	0.100	0.230	0.50
08/31/81	0.010	2.5	0.050	0.650	0.70
09/28/81	0.040	20.0	0.100	0.890	0.60
11/03/81	0.005	1.5	0.050	0.250	0.50
12/01/81	0.070	1.5	0.050	0.010	0.50
AVE	**0.026**	**4.3**	**0.097**	**0.355**	**0.54**
01/12/82	0.030	1.5	0.100	0.050	0.40
02/17/82	0.050	5.0	0.200	0.570	0.50
03/23/82	0.120	1.5	0.050	0.005	0.30
04/22/82	0.150	1.5	0.100	0.005	0.50
05/04/82	0.080	1.5	0.200	0.130	0.70
05/20/82	0.050	4.0	0.050	0.050	0.30
06/03/82	0.020	3.0	0.100	0.005	0.50
06/15/82	0.005	1.5	0.050	0.040	0.40
06/30/82	0.060	4.0	0.050	0.005	0.40
07/13/82	0.050	5.0	0.100	0.005	0.50
07/30/82	0.200	1.5	0.050	0.005	0.50
08/19/82	0.100	1.5	0.050	0.005	0.40
08/26/82	0.050	7.0	0.050	0.150	0.90
09/01/82	0.100	5.0	0.050	0.005	0.30
09/16/82	0.120	1.5	0.050	0.005	0.10
12/15/82	0.050	1.5	0.050	0.050	0.40
AVE	**0.077**	**2.9**	**0.081**	**0.068**	**0.44**
04/06/83	0.010	1.5	0.100	0.200	0.40
06/01/83	0.010	9.0	0.100	0.080	0.50
07/06/83	0.010	1.5	0.050	0.140	0.60
08/03/83	0.010	3.0	0.100	0.060	1.00
09/06/83	0.020	20.0	0.050	0.010	0.30
10/12/83	0.020	5.0	0.100	0.010	0.40
11/03/83	0.010	1.5	0.100	0.130	0.50
11/30/83	0.010	1.5	0.050	0.070	0.50
AVE	**0.013**	**5.4**	**0.081**	**0.088**	**0.53**

Fish Creek above Scofield Reservoir STORET 593165

DATE	Total P Mg/L	TSS Mg/L	NH3 Mg/L	NO2 +NO3 Mg/L	TKN Mg/L
06/18/80	0.0300	32.0	0.1000	0.350	0.50
07/29/80	0.0200	10.0	0.1000	0.150	0.10
09/18/80	0.1000	23.0	0.0500	0.160	0.30
11/20/80	0.0025		0.0500	0.025	0.30
AVE	**0.0381**	**14.0**	**0.0750**	**0.171**	**0.30**
01/21/81	0.0250	2.5	0.2000	0.400	0.70
04/02/81	0.0200	38.0	0.0500	0.110	0.10
04/21/81	0.0200	13.0	0.0500	0.330	0.30
04/28/81	0.0400	50.0	0.0500	0.490	0.40
05/05/81	0.0600	43.0	0.0500	0.560	0.50
05/13/81	0.0100	2.5	0.1000	0.360	0.30
05/28/81	0.1000	21.0	0.0500	0.005	0.20
06/11/81	0.0100	19.0	0.0500	0.190	0.10
06/24/81	0.0600	2.5	0.0500	0.070	0.30
07/08/81	0.0300	42.0	0.0500	0.130	0.40
07/22/81	0.0050	2.5	0.1000	0.720	0.60
08/10/81	0.0300	172.0	0.2000	0.450	0.70
08/17/81	0.0050	2.5	0.0500	0.210	0.40
08/31/81		2.5	0.0500	0.380	0.30
09/28/81	0.0100	8.0	0.0500	0.180	0.20
11/03/81	0.0300	76.0	0.0500	0.070	0.30
12/01/81	0.0400	43.0	0.0500	0.110	0.20
AVE	**0.0309**	**31.8**	**0.0735**	**0.280**	**0.35**
05/04/82	0.1500	313.0	0.0500	0.560	0.90
05/20/82	0.1500	78.0	0.0500	0.520	0.90
06/03/82	0.0900	87.0	0.0500	0.320	0.50
06/15/82	0.0100	20.0	0.0500	0.180	0.30
06/30/82	0.0400	5.0	0.0500	0.005	0.10
07/13/82	0.0400	5.0	0.0500	0.005	0.30
07/30/82	**2.3***	11.0	0.0500	0.100	0.60
08/19/82	0.0900	5.0	0.0500	0.005	0.30
09/01/82	0.1500	4.0	0.0500	0.005	0.05
09/16/82	0.1000	1.5	0.0500	0.005	0.30
10/07/82	0.0600	3.0	0.0025	0.005	0.10
AVE	**0.0880**	**48.4**	**0.0457**	**0.155**	**0.40**
07/22/83	0.0100		0.0250		0.50
09/06/83	0.0200		0.0250	0.010	0.20
10/12/83	0.0280		0.0250	0.020	0.40
AVE	**0.0193**		**0.0250**	**0.015**	**0.37**

DATE	Total P Mg/L	TSS Mg/L	NH3 Mg/L	NO2 +NO3 Mg/L	TKN Mg/L
01/05/84	0.020	1.5	0.200	0.080	0.60
03/01/84	0.030	1.5	0.400	0.080	0.60
04/04/84	0.120	1.5	0.100	0.210	0.60
05/02/84	0.005	6.0	0.050	0.300	0.50
05/31/84	0.070	22.0	0.050	0.380	0.60
07/11/84	0.030	13.0	0.100	0.220	0.40
08/07/84		17.0	0.100	0.050	0.50
09/06/84	0.160	4.0	0.050	0.005	0.40
10/03/84	0.290	7.0	0.100	0.120	0.70
10/24/84	0.040	3.0	0.100	0.040	0.40
11/28/84	0.040	12.0	0.100	0.030	0.30
AVE	**0.081**	**8.0**	**0.123**	**0.138**	**0.51**
01/09/85	0.060	6.0	0.400	0.030	0.70
02/13/85	0.070	1.5	0.400	0.040	0.80
03/12/85	0.070	1.5	0.400	0.500	0.60
05/08/85	0.040	8.0	0.100	0.210	0.50
05/30/85	0.100		0.050	0.270	0.60
06/20/85	0.020		0.050	0.160	0.50
08/14/85	0.040		0.050	0.020	0.10
09/11/85	0.030	11.0	0.100	0.005	0.40
AVE	**0.054**	**5.6**	**0.194**	**0.154**	**0.53**
01/22/86	0.020		0.200	0.070	0.60
09/23/86	0.030		0.100	0.050	0.10
AVE	**0.025**		**0.150**	**0.060**	**0.35**
05/06/87	0.060	6.0	0.003	0.300	0.60
05/21/87	0.015	3.0	0.003	0.030	0.50
06/03/87	0.020	1.5	0.050	0.005	0.50
06/09/87	0.020	1.5	0.070	0.060	0.70
06/25/87	0.020	4.0	0.050	0.060	0.40
08/11/87	0.040	9.0	0.003	0.005	0.50
10/14/87	0.020	1.5	0.003	0.005	0.40
AVE	**0.028**	**3.8**	**0.026**	**0.066**	**0.51**
05/18/88	0.200	1.5	0.003	0.040	0.60
08/18/88	0.003	6.0	0.080	0.005	0.30
AVE	**0.101**	**3.8**	**0.041**	**0.023**	**0.45**
05/03/89	0.045	1.5	0.003	0.005	0.70
05/15/89	0.204	27.0	0.003	0.690	0.70
06/05/89	0.023				0.50
06/06/89	0.007	1.5	0.003	0.080	0.20
07/03/89	0.048				0.20
08/07/89	0.302				0.90
08/22/89	0.032	17.0	0.160	0.020	0.80
09/05/89	0.042				0.80
10/24/89	0.052	7.0	0.250	0.020	1.30
11/06/89	0.003				0.10
AVE	**0.076**	**10.8**	**0.084**	**0.163**	**0.62**

DATE	Total P Mg/L	TSS Mg/L	NH3 Mg/L	NO2 +NO3 Mg/L	TKN Mg/L
05/07/85	0.1500	538.0	0.0500	0.710	0.40
05/30/85	0.0400	197.0	0.0500	0.320	0.20
06/20/85	0.0200	60.2	0.0500	0.180	0.10
08/14/85	0.0050	17.8	0.0500	0.010	0.05
09/11/85	0.0200	13.6	0.0500	0.005	0.05
AVE	**0.0470**	**165.3**	**0.0500**	**0.245**	**0.16**
09/23/86	0.0800		0.0500	0.050	0.05
AVE	**0.0800**		**0.0500**	**0.050**	**0.05**
05/06/87	0.0700	41.0	0.0250	0.320	0.70
05/21/87	0.0400	9.0	0.0250	0.130	0.80
06/03/87	0.0200	6.0	0.0250	0.050	0.60
06/09/87	0.0200	6.0	0.0250	0.100	0.50
06/25/87	0.0200	5.0	0.0250	0.060	0.20
08/11/87	0.0300	8.0	0.0250	0.005	0.05
10/14/87	0.0300	1.5	0.0250	0.005	0.10
AVE	**0.0329**	**10.9**	**0.025**	**0.096**	**0.42**
05/18/88	0.0900	57.0	0.0250	0.005	0.50
08/19/88	0.0025	8.0	0.0250	0.005	0.10
10/06/88	0.0100	1.5	0.0250	0.005	0.10
AVE	**0.0342**	**22.2**	**0.025**	**0.005**	**0.23**
05/04/89	0.0310	26.0	0.0250	0.010	0.40
05/16/89	0.0025	84.0	0.0250	1.020	0.20
06/05/89	0.0100				0.10
06/06/89	0.0060	1.5	0.0250	0.070	0.20
07/03/89	0.0490				0.20
08/07/89	0.0360				0.00
08/22/89	0.0310	6.0	0.0025	0.005	0.20
09/05/89	0.0160				0.20
10/24/89	0.0100	1.5	0.0250	0.020	0.20
11/06/89	0.0025				0.10
AVE	**0.0194**	**23.8**	**0.0205**	**0.225**	**0.18**

DATE	Total P Mg/L	TSS Mg/L	NH3 Mg/L	NO2 +NO3 Mg/L	TKN Mg/L
01/22/90	0.031				1.00
03/19/90	0.024				0.90
03/22/90	0.056	1.5	0.510		1.00
05/03/90	0.062				0.80
05/19/90	0.077	20.0	0.003	0.005	0.70
07/25/90	0.121	12.0	0.140	0.110	0.40
08/23/90		7.0	0.510	0.050	1.50
AVE	**0.062**	**10.1**	**0.291**	**0.055**	**0.90**
YEARLY AVERAGES					
1980	0.047	4.0	0.100	0.547	0.77
1981	0.026	4.3	0.097	0.355	0.54
1982	0.077	2.9	0.081	0.068	0.44
1983	0.013	5.4	0.081	0.088	0.53
1984	0.081	8.0	0.123	0.138	0.51
1985	0.054	5.6	0.194	0.154	0.53
1986	0.025		0.150	0.060	0.35
1987	0.028	3.8	0.026	0.066	0.51
1988	0.101	3.8	0.041	0.023	0.45
1989	0.076	10.8	0.084	0.163	0.62
1990	0.062	10.1	0.291	0.055	0.90

DATE	Total P Mg/L	TSS Mg/L	NH3 Mg/L	NO2 +NO3 Mg/L	TKN Mg/L
01/10/90	0.0150	1.5	0.0250	0.200	0.05
03/22/90	0.0050	5.0	0.0250		0.40
05/03/90	0.0310				0.30
05/19/90	0.0400	12.0	0.0250	0.151	0.10
07/25/90	0.0025	1.5	0.0250	0.110	0.20
08/23/90		8.0	0.0250	0.030	0.10
AVE	**0.0187**	**5.6**	**0.0250**	**0.123**	**0.19**
YEARLY AVERAGES					
1980	0.0381	14.0	0.0750	0.171	0.30
1981	0.0309	31.8	0.0735	0.280	0.35
1982	0.0880	48.4	0.0457	0.155	0.40
1983	0.0193	0.0	0.0250	0.015	0.37
1984					
1985	0.0470	165.3	0.0500	0.245	0.16
1986	0.0800	0.0	0.0500	0.050	0.05
1987	0.0329	10.9	0.0250	0.096	0.42
1988	0.0342	22.2	0.0250	0.005	0.23
1989	0.0194	23.8	0.0205	0.225	0.18
1990	0.0187	5.6	0.0250	0.123	0.19

Pondtown Creek above Scofield Reservoir STORET 593168

DATE	Total P Mg/L	TSS Mg/L	NH3 Mg/L	NO2 +NO3 Mg/L	TKN Mg/L
06/18/80	0.0100	30.0	0.050	0.450	0.40
07/29/80	0.0500	11.0	0.100	0.050	0.10
09/18/80	0.1000	29.0	0.050	0.100	0.30
11/20/80	0.0500	2.5	0.050	0.025	0.40
AVE	**0.0525**	**18.1**	**0.063**	**0.156**	**0.30**
04/02/81	0.0400	15.0	0.050	0.240	0.10
04/21/81	0.0300	11.0	0.050	0.210	0.40
04/28/81	0.0300	35.0	0.050	0.670	0.40
05/05/81	0.1500	38.0	0.050	0.710	0.40
05/13/81	0.0100	2.5	0.100	0.440	0.20
05/28/81	0.1000	93.0	0.050	0.090	0.30
06/11/81	0.0200	45.0	0.050	0.140	0.20
06/24/81	0.0400	14.0	0.050	0.130	0.30
07/08/81	0.0200	2.5	0.100	0.190	0.40
07/22/81	0.0400	2.5	0.050	0.190	0.30
08/10/81	0.6000	**6120***	0.200	1.400	1.20
08/17/81	0.0300	26.0	0.050	0.050	0.80
08/31/81	0.0300	35.0	0.300	0.530	0.40
09/28/81	0.0400	35.0	0.050	0.330	0.30
11/03/81	0.0300	9.0	0.050	0.005	0.20
12/01/81	0.0300	45.0	0.050	0.130	0.20
AVE	**0.0775**	**27.2**	**0.081**	**0.341**	**0.38**

Mud Creek above Scofield Reservoir STORET

DATE	Total P Mg/L	TSS Mg/L	NH3 Mg/L	NO2 +NO3 Mg/L	TKN Mg/L

DATE	Total P Mg/L	TSS Mg/L	NH3 Mg/L	NO2 +NO3 Mg/L	TKN Mg/L
05/20/82	0.1500	291.0	0.050	0.840	0.60
06/03/82	0.0800	98.0	0.050	0.550	0.60
06/15/82	0.0200	27.0	0.050	0.280	0.40
06/30/82	0.0800	16.0	0.050	0.005	0.30
07/13/82	0.0600	8.0	0.050	0.005	0.30
07/30/82	0.2500	14.0	0.050	0.005	0.30
08/19/82	0.1000	6.0	0.050	0.005	0.40
09/01/82	0.1000	3.0	0.050	0.005	0.50
09/16/82	0.1000	41.0	0.050	0.005	0.20
AVE	**0.1044**	**56.0**	**0.050**	**0.189**	**0.40**
09/06/83	0.0200	15.0	0.025	0.010	0.40
10/12/83	0.0400	5.0	0.025	0.010	0.200
AVE	**0.0300**	**10.0**	**0.025**	**0.010**	**0.30**
05/07/85	0.2800		0.100	0.900	0.90
05/30/85	0.0500		0.100	0.370	0.10
06/20/85	0.0100		0.050	0.080	0.40
08/14/85	0.0400		0.050	0.030	0.20
09/11/85	0.0500		0.050	0.005	0.10
AVE	**0.0860**		**0.070**	**0.277**	**0.34**
09/23/86	0.0700		0.050	0.020	0.05
AVE	**0.0700**		**0.050**	**0.020**	**0.05**
05/06/87	0.0500	21.0	0.025	0.090	0.70
05/21/87	0.0700	9.0	0.025	0.070	0.80
06/03/87	0.0400	19.0	0.025	0.005	0.70
06/09/87	0.0400	8.0	0.025	0.040	0.70
06/25/87	0.0700	20.0	0.025	0.070	0.20
08/11/87	0.0700	22.0	0.025	0.005	0.60
10/14/87	0.0400	1.5	0.025	0.005	0.10
AVE	**0.0543**	**14.4**	**0.025**	**0.041**	**0.54**
05/18/88	0.1500	125.0	0.025	0.420	0.90
08/19/88	0.0100	1.5	0.025	0.005	0.30
10/06/88	0.0400	1.5	0.025	0.060	0.20
AVE	**0.0667**	**42.7**	**0.025**	**0.162**	**0.47**

DATE	Total P Mg/L	TSS Mg/L	NH3 Mg/L	NO2 +NO3 Mg/L	TKN Mg/L
01/02/82	0.0500	32.0	0.100	0.0500	0.1
02/17/82	0.0500	35.0	0.050	0.2100	0.2
03/23/82	2.3500	600.0	0.100	0.1800	0.2
04/22/82	0.4000	240.0	0.050	0.4000	0.8
05/04/82	1.1000	950.0	0.050	1.4000	1.8
05/20/82	0.2900	375.0	0.050	0.9300	0.2
06/03/82	0.2200	222.0	0.050	0.4500	0.5
06/15/82	0.1000	146.0	0.050	0.2100	0.3
06/30/82	0.1200	57.0	0.050	0.0050	0.4
07/13/82	0.0700	34.0	0.050	0.0050	0.4
07/30/82	2.9000	51.0	0.050	0.1000	0.3
08/19/82	0.1500	42.0	0.050	0.0050	0.2
09/01/82	0.1500	44.0	0.050	0.0050	0.3
09/16/82	0.0500	6.0	0.050	0.0050	0.3
10/07/82	0.2500	118.0	0.003	0.0050	0.2
AVE	**0.5500**	**196.3**	**0.054**	**0.2640**	**0.4**
09/06/83	.0400	47.0	0.025	0.0100	0.2
AVE	**0.0400**	**47.0**	**0.025**	**0.0100**	**0.2**
03/01/84	0.0800	56.0	0.025	0.1700	0.2
AVE	**0.0800**	**56.0**	**0.025**	**0.1700**	**0.2**
01/29/85	0.0300	41.0	0.050	0.1800	0.3
05/07/85			0.050	1.4800	0.9
05/30/85	0.1300		0.100	0.6700	0.3
06/20/85	0.0100		0.050	0.2100	0.3
08/14/85	0.0100		0.050	0.0100	0.1
09/09/85	0.0100		0.050	0.0050	0.1
AVE	**0.0380**	**41.0**	**0.058**	**0.4258**	**0.3**
01/22/86	0.0300		0.050	0.18000	0.1
09/23/86	0.0100		0.050	0.0200	0.1
AVE	**0.0200**	**0.050**	**0.1000**	**0.1**	
05/06/87	0.0900	61.0	0.025	0.1700	0.5
AVE	**0.0900**	**61.0**	**0.025**	**0.1700**	**0.5**

DATE	Total P Mg/L	TSS Mg/L	NH3 Mg/L	NO2 +NO3 Mg/L	TKN Mg/L
05/04/89	0.0140	16.0	0.025	**48.6***	0.30
05/16/89	0.2700	29.0	0.025	1.130	0.30
06/05/89	0.0190				0.20
06/06/89	0.0025	7.0	0.025	0.050	0.30
07/03/89	0.0910				0.20
08/07/89	0.0860				0.30
08/22/89	0.0050	4.0	0.003	0.005	0.10
09/05/89	0.0380				0.30
10/24/89	0.0200	5.0	0.025	0.020	0.10
11/06/89	0.0025				0.20
AVE	**0.0548**	**12.2**	**0.021**	**0.301**	**0.23**
01/10/90	0.0260	1.5	0.025	0.160	0.20
03/22/90	0.0240	1.5	0.025		0.20
05/03/90	0.0430				0.40
05/19/90	0.0660	22.0	0.025	0.390	0.10
07/25/90	0.0025	7.0	0.025	0.110	0.20
08/23/90		4.0	0.025	0.050	0.10
AVE	**0.0323**	**7.2**	**0.025**	**0.178**	**0.20**

DATE	Total P Mg/L	TSS Mg/L	NH3 Mg/L	NO2 +NO3 Mg/L	TKN Mg/L
06/05/89	0.0320				0.3
07/03/89	0.0930				0.1
08/07/89	0.0380				0.2
09/05/89	0.0340				0.1
11/06/89	0.0130				0.2
AVE	**0.0420**			**0.2**	
01/10/90	0.0270				0.4
01/22/90	0.0330				0.1
03/19/90	0.0260				0.4
05/03/90	0.0430				0.3
AVE	**0.0323**			**0.3**	

YEARLY AVERAGES					
1980	0.0525	18.1	0.063	0.156	0.30
1981	0.0775	27.2	0.081	0.341	0.38
1982	0.1044	56.0	0.050	0.189	0.40
1983	0.0300	10.0	0.025	0.010	0.30
1984					
1985	0.0860	0.0	0.070	0.277	0.34
1986	0.0700	0.0	0.050	0.020	0.05
1987	0.0543	14.4	0.025	0.041	0.54
1988	0.0667	42.7	0.025	0.162	0.47
1989	0.0548	12.2	0.021	0.301	0.23
1990	0.0323	7.2	0.025	0.178	0.20

YEARLY AVERAGES					
1980					
1981					
1982	0.5500	196.3	0.054	0.2640	0.4
1983	0.0400	47.0	0.025	0.0100	0.2
1984	0.0800	56.0	0.025	0.1700	0.2
1985	0.0380	41.0	0.058	0.4258	0.3
1986	0.0200	0.0	0.050	0.1000	0.1
1987	0.0900	61.0	0.025	0.1700	0.5
1988					
1989	0.0420				0.2
1990	0.0323				0.3

*** Represents an "a typical value" which is considered erroneous and has not been used in average calculations.**

APPENDIX D

Scofield Reservoir TSI Data

Station: Southwest of Perry boatcamp above dam

	Total Phosphorus ug/L	Chlorophyll-a ug/L	Secchi Depth Meters	TP TSI	CLA TSI	SD TSI	Ave TSI
YEAR							
1983	25.00		2.30	50.57		48.00	49.28
1984							
1985	60.00	3.18	2.40	63.19	41.95	47.38	50.84
1986	25.00	8.90	1.40	50.57	52.05	55.15	52.59
1987	23.00	3.03	2.30	49.36	41.47	48.00	46.28
1988	53.00	32.00	1.93	61.40	64.60	50.53	58.84
1989	48.00	50.30	1.33	59.97	69.04	55.89	61.63
1990	82.00	215.00	1.70	67.69	83.29	52.35	67.78
1991	42.00	61.45	0.73	58.05	71.00	64.53	64.53

Station : South of Island

YEAR							
1983	30.00		2.65	53.20		45.96	49.58
1984							
1985	31.00	3.93	2.40	53.67	44.03	47.38	48.36
1986	40.00	6.70	1.10	57.34	49.26	58.63	55.08
1987	30.00	3.50	2.10	53.20	42.89	49.31	48.46
1988	30.00	12.75	3.17	53.20	55.57	43.37	50.71
1989	38.00	28.60	0.81	56.60	63.50	63.04	61.05
1990	44.00	24.27	0.43	58.72	61.89	72.16	64.26
1991	62.00	39.90	0.40	63.66	66.76	73.20	67.88

Station: West Bay

YEAR							
1983	20.00		1.60	47.35		53.23	50.29
1984-6							
1987	25.00	1.90	3.00	50.57	36.90	44.17	43.88
1988	27.00	11.27	2.43	51.68	54.36	47.21	51.08
1989	27.00	33.40	1.20	51.68	65.02	57.37	58.02
1990	67.00	10.40	0.74	64.78	53.57	64.34	60.90
1991	55.00	54.60	0.58	61.94	69.84	67.85	66.54

ANNUAL AVERAGES

YEAR	Total Phosphorus ug/L	Chlorophyll-a ug/L	Secchi Depth Meters	TP TSI	CLA TSI	SD TSI	Ave TSI
83	25.00		2.18	50.37		49.06	49.72
84							
85	45.50	3.56	2.40	58.43	42.99	47.38	49.60
86	32.50	7.80	1.25	53.95	50.65	56.89	53.83
87	26.00	2.81	2.47	51.04	40.42	47.16	46.21
88	36.67	18.67	2.51	55.42	58.18	47.04	53.55
89	37.67	37.43	1.11	56.08	65.85	58.77	60.23
90	64.33	83.22	0.96	63.73	66.25	62.95	64.31
91	53.00	51.98	0.57	61.22	69.20	68.53	66.32

Values were calculated by averaging annual station values in columns.
Average TSI values were calculated by averaging TP, CLA, and SD TSI values.

PARAMETER ANALYSIS FOR LAKE STATIONS

Scofield Reservoir southwest of Perry boat camp
STORET STATION 593100

Date	Total P ug/L	Secchi Depth meters	Chlorophyll-a mg/L
09/07/83	0.020	3.3	
10/12/83	0.030	1.3	
05/30/85	0.130	1.7	2.7
06/20/85	0.010	3.5	1.2
08/14/85	0.050		4.4
09/11/85	0.050	2.0	4.4
09/23/86	0.025	1.4	8.9
05/06/87	0.030	1.9	2.8
06/24/87	0.020	2.7	3.3
08/11/87	0.020		3.0
05/18/88	0.110	2.4	11.9
08/19/88	0.020	1.6	76.4
10/06/88	0.030	1.8	7.4
05/04/89	0.033	0.9	43.9
05/15/89	0.042	1.2	44.3
06/05/89	0.013		
06/06/89	0.008	2.7	5.9
07/03/89	0.013		
08/07/89	0.162		
08/22/89	0.045	0.5	107.1
09/05/89	0.067		
05/03/90	0.044		
05/19/90	0.070	0.9	24.2
07/25/90	0.132	0.3	602.5
08/23/90		0.5	18.3
05/21/91	0.052	0.4	
08/08/91	0.027	1.2	73.0
09/25/91	0.040	0.6	49.9

Annual data summary

1983	0.025	2.30	
1985	0.060	2.40	3.18
1986	0.025	1.40	8.90
1987	0.023	2.30	3.03
1988	0.053	1.93	32.00
1989	0.048	1.33	50.30
1990	0.082	1.70	215.00
1991	0.042	0.73	61.45

Scofield Reservoir south of island
STORET STATION 593099

Date	Total P ug/L	Secchi Depth meters	Chlorophyll-a mg/L
09/07/83	0.020	1.8	
10/12/83	0.040	3.5	
05/30/85	0.060	1.2	4.5
06/20/85	0.030	4.0	1.6
08/14/85	0.010		5.8
09/14/85	0.050	2.0	3.8
09/23/86	0.040	1.1	6.7
05/06/87	0.040	1.5	5.8
06/24/87	0.030	2.7	2.3
08/11/87	0.020		2.4
05/18/88	0.050	5.0	15.4
08/19/88	0.020	1.5	10.1
10/06/88	0.020	3.0	25.5
05/04/89	0.027	0.6	20.5
05/15/89	0.020	0.9	58.8
06/05/89	0.018		
06/06/89	0.006	1.5	6.5
07/03/89	0.026		
08/07/89	0.116		
08/22/89	0.045	0.25	
09/05/89	0.048		
05/03/90	0.032		
05/19/90	0.098	0.5	27.5
07/25/90	0.003	0.5	30.8
08/23/90		0.3	14.5
05/21/91	0.054	0.2	27.5
08/08/91	0.079		30.8
09/24/91	0.082	0.6	14.5

Annual data summary

1983	0.030	2.65	
1985	0.031	2.40	3.93
1986	0.040	1.10	6.70
1987	0.030	2.10	3.51
1988	0.030	3.17	12.75
1989	0.038	0.81	28.60
1990	0.044	0.43	24.27
1991	0.062	0.40	39.90

Scofield Reservoir west bay
STORET STATION 593098

Date	Total P ug/L	Secchi Depth meters	Chlorophyll-a mg/L
09/07/83	0.020	2.2	
10/12/83	0.020	1.0	
06/24/87	0.020	3.0	1.9
08/11/87	0.030		1.8
05/18/88	0.040	5.0	7.7
08/19/88	0.010	1.0	17.2
10/06/88	0.030	1.3	8.9
05/04/89	0.054		
05/15/89	0.022	0.9	58.8
06/06/89	0.005	1.5	7.9
05/19/90	0.067	0.74	10.4
05/21/91	0.058	0.25	
09/24/91	0.051	0.90	54.6

Annual data summary

1983	0.020	1.60	
1987	0.025	3.00	1.90
1988	0.027	2.43	11.27
1989	0.027	1.20	33.40
1990	0.067	0.74	10.40
1991	0.055	0.58	54.60

SYNOPSIS OF WATER QUALITY ISSUES AT SCOFIELD RESERVOIR

WALTER K. DONALDSON
UTAH DIVISION OF WILDLIFE RESOURCES
FEBRUARY 24, 1989

1. Fisheries Management

Scofield Reservoir is ranked as one of the top trout fishing waters in Utah. It is located in the northwest corner of Carbon County, along the east slope of the Wasatch Plateau. The dam, constructed in 1946, impounds most of the headwater streams forming the Price River. The impoundment at full capacity stores almost 65,780 usable acre-feet of water, is 2,908 surface acres in size, and has a maximum depth of 49 feet. Mean depth at maximum pool is rather shallow at 25 feet.

The reservoir is operated for multiple use: Irrigation, culinary water, industry, and outdoor recreation (particularly fishing). Actual drawdown for nonrecreation use varies considerably between June-September, but usually ranges between 25,000-35,000 acre-feet annually (U.S.G.S. Water Resources Data). A dead storage pool of 8,000 acre-feet is retained in the reservoir for fish production and recreation. Water is stored on federal land (Bureau of Reclamation), with shoreline use rights reverting to private land owners as water levels recede during summer drawdown. The authority to administer and develop federal lands at the reservoir for recreation purposes has been granted to the Utah Division of Parks and Recreation (UDP&R) via a Memorandum of Agreement with the Bureau of Reclamation (dated April 19, 1963). A new agreement between these two agencies has either been recently approved and signed, or is under review for renewal.

Regarding the fishery this reservoir is noted statewide for its trout production and angling opportunity, particularly family fishing. UDWR manages the reservoir under the basic yield concept (put-grow-take) primarily with rainbow trout and secondarily with cutthroat trout. UDWR annually stocks 600,000 fingerling rainbow trout (3"), which grow to 10.5" in one year. This growth rate, over 0.5" per month, is considered excellent on a statewide basis. Occasionally the trout fishery is depressed by two factors. The first is food competition from infestation and expansion of the Utah chub. This rough fish species had to be chemically eradicated twice (1958 and 1977) to re-establish the trout fishery. The second is periodic fish kills which occur during drought years. The cause of these kills is related to the annual blue-green algae blooms (Aphanizomenon sp.) which occur during July-August. These blooms result from high nutrient levels of phosphates and nitrates. These algae blooms cause fish kills in several ways: 1) Dissolved oxygen depletion in the water as the algae decays, and 2) Stress through the elimination of visceral fat reserves during the bloom. (Zooplankton cannot or will not use blue-green algae as a food source, so their numbers decline during this summer bloom. Fat reserves for trout are used up during this period due to the reduction in zooplankton.) Fish kills can occur during summer or fall, depending on the cause. Fish kills have been documented in 1961 (winter), 1977, 1981, and 1987. In 1987, UDWR estimated the mortality

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of stocked rainbow trout at 500,000 fish.

Angling pressure at Scofield Reservoir has remained somewhat stable over the past 34 years. Public claims that angling pressure has increased every year since World War II are simply not true. Periodic creel census data taken since 1955 indicate a range between 67,700-81,200 angler-days: 1955 = 71,700 angler-days, 1984 = 67,700 angler-days, and 1986 = 81,200 angler-days. The amount of annual pressure at Scofield Reservoir depends on angler success. When anglers have good fishing success, pressure increases; when anglers have poor fishing success, pressure declines. One reason behind the stable pressure at the reservoir is the lack of public access to the shoreline. Only 41% of the shoreline is public land. Public access on private property has been steadily decreasing since 1981, as shown by complete trespass restrictions for the entire northwest shoreline (between Upper Fish Creek bridge and the northern UDP&R campground).

Year-round fishing has increased potential fishing opportunity at the reservoir by six months. The 1986 creel census indicated a redistribution of angling pressure throughout the year, rather than the normal concentrations observed during the six month season prior to year-round fishing. Ice fishing comprised only 13% of the total pressure in 1986. Also a reduction in pressure of 44% was observed during the traditional opening weekend of fishing (Memorial Day weekend) since implementation of year-round fishing.

Average harvest of trout ranges from 223,000 to 252,000 fish annually. Composition of harvest by angling method is: boat=35%, shore=48%, and ice=18%. As expected, the total harvest would decline below the average (amount unknown) during years of significant fish kills. The percent return-to-the-creel for stocked fingerling trout ranges between 35-40%. This return rate is considered excellent on a national basis for trout.

Scofield Reservoir provides substantial economic benefits to the recreation and tourism industry in the state of Utah. The economic value of this reservoir during the 1980's ranges between $2,044,000-$2,454,000 annually. This value is derived from the 1985 National Hunting and Fishing Survey (U.S. Fish and Wildlife Service), which calculated $30.20 as the expenditure per angler-day in Utah. Some individuals in Carbon County claim no economic benefit from angling at Scofield Reservoir, since 81% of the use comes from residents along the Wasatch Front (UDWR 1986 Creel Census). Wasatch Front anglers do not pass through Price or Helper, and their angler dollars are not spent on local merchandise. However, approximately 10% of angling pressure comes from Carbon County anglers (8,200 angler-days). Using the same expenditure per angler-day, these anglers spend between $206,000-$248,000 annually in Carbon County for fishing recreation.

2. Water Quality Issues

In 1972, Congress passed PL 92-500 (Federal Water Pollution Control Act) for the purpose of restoring and maintaining national waters. In the mid-1970's the Southeastern Utah Association of Local Governments (SEUALG) coordinated efforts for the development of the Waste Water Quality Management-208 Plan for Emery, Carbon, and Grand counties (June, 1977). This document was the first of its kind to identify water quality problems within the Scofield Reservoir watershed. It noted the enriched state (eutrophic) of the reservoir by the blue-green algae

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blooms and anoxic hypolimnion during summer stratification. The 208 Plan also suggested the presence of a health risk from raw sewage entering the reservoir, but without verification. Sources of nutrient loading in the reservoir were identified on a general level. Sources included: livestock grazing around the reservoir, human sewage from Scofield Town, human sewage from summer home development in the watershed, coal mine effluent, and wastes from recreational users (human waste, litter, boat motor fluids, fish entrails). Control measures suggested were: 1) County permits on new summer home development based on density and location, not arbitrary acreage (rezoning); 2) Provide specific water quality standards to regulate environmental problems (rezoning and law enforcement); 3) Provide a central sewage collection system for Scofield Town and adjacent summer homes; 4) Reduce litter and pollution from recreation by providing sanitary facilities around the reservoir, improving shoreline bank stability, and increasing law enforcement for compliance of litter and environmental laws; and 5) SEUALG should assume a leadership role for clean-up efforts, monitoring water quality, and future studies involving water quality. The 208 Plan suggested areas needing future study; i.e. better identification of major sources of nutrient loading, the role that livestock grazing plays in nutrient loading, clarification of the real health issues from sewage at Scofield Town, summer homes, and recreation users, and interactions within the reservoir aquatic community due to nutrient loading.

An outgrowth of the 208 Plan was a study on Scofield Reservoir conducted by the Utah Bureau of Water Pollution Control in 1979-1980. Their results were presented in the Utah Clean Lakes Inventory and Classification, Vol. 2, April, 1982. The condition of the reservoir was ranked between the mesotrophic and eutrophic state, or fairly nutrient rich. Phosphorus was identified as the limiting nutrient. Bacteriological counts (coliforms), used to identify sewage from warm-blooded animals, found the only large concentrations entering the reservoir at the Mud Creek inlet. Classification of the reservoir by use was culinary source with treatment (1C); water recreation excluding swimming (2B); cold water fish and aquatic life production (3A); and irrigation and stockwatering (4). Pollution problems in the reservoir included sewage disposal from cabin sites, recreation use on private lands, and livestock grazing near the shoreline. Two general recommendations were made to control nutrient pollution: 1) More adequate sewage facilities for structures around the reservoir; and 2) Better control of livestock related nutrients by diverting these associated waters onto wetlands and storage ponds. This study highly recommended the development of a Phase I diagnostic and feasibility plan to implement restoration and protection measures for the reservoir.

A study presented March, 1981 (Water Quality in Pleasant Valley, Utah - Clyde et al) evaluated shallow ground and surface water along Mud Creek. Peaks in nitrate and phosphate levels were noted during spring run-off. The study suggested this high loading during run-off may contribute to eutrophication of the reservoir. Bacteriological sampling of wells indicated limited contamination by sewage. (Only two wells had occasional coliform bacteria counts.) Fecal coliform ratios (0.3-1.0) indicated the major source of sewage-related bacteria in Mud Creek was from livestock.

These studies, along with others not mentioned, identified Scofield Reservoir as a priority water in the state needing water quality improvements. The Utah

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Bureau of Water Pollution Control (R. Denton) completed a Phase I - 314 Clean Lakes Study at Scofield Reservoir on December, 1983. The purposes of the 314 study were to identify and quantify the sources of phosphate and nitrate loading in the reservoir and drainage; evaluate the impacts of nutrient loading in the reservoir; and formulate restoration alternatives for the reservoir. The 314 study again ranked the reservoir at an early eutrophic state. Phosphorus was again identified as the limiting nutrient, and also the focal point for nutrient reduction efforts. Two phosphorus sources were linked to the summer blue-green algae blooms: External loading and internal loading. External loading consists of phosphorus entering the reservoir from the surrounding watershed. Approximately 77% of all external loading comes from Upper Fish Creek (3,508 kg) and Mud Creek (1,613 kg) annually. The remaining tributary streams contribute about 18% of the external loading. Shoreline phosphorus comprises only 5% of the annual external loading (308 kg). Except for the Mud Creek drainage, between 70-90% of the external phosphorus loading originates from sediments natural to the drainage. External loading in the Mud Creek drainage originates from sediment-produced activities (coal mining in Eccles Creek and summer home development), inadequate sewage facilities for Scofield and Clear Creek towns, and livestock overgrazing in the riparian zone and portions of the watershed. Shoreline external loading (5%) is small in comparison to the remainder (95%), and is usually attributed to natural sediments, recreation users, summer home sewage disposal, and shoreline livestock grazing.

According to the 314 study, internal loading of phosphorus involves chemical interactions within the reservoir which makes this element available for biological use. Since the construction of the reservoir in 1946, phosphorus has been stored in the bottom sediments in a variety of forms. The majority, inorganic phosphate salts, are chemically bonded to other elements (i.e. iron and calcium) and considered fairly stable. These phosphate salts are usually not available for biological use except during summer when the reservoir stratifies. During stratification (July-August), the bottom portion of the reservoir goes anoxic (loses oxygen). Phosphate salts, particularly those bonded with iron, are released into the water column from the sediments making them available for blue-green algae growth. Note that of all phosphates stored in the reservoir sediments over the years, only a small portion are ever released back into the water column. Over time, much of the phosphates entering the reservoir are permanently stored in the sediments; hence the reference to eutrophic reservoirs as "nutrient sinks".

The 314 study discussed numerous lake restoration alternatives, proposing four as the most feasible and hopefully beneficial. These are: 1) Purchase and develop the South Shore Wetland into a nutrient trap by diverting the polluted waters from Mud Creek; 2) Initiate a public awareness campaign on the need to reduce pollution of entering Scofield Reservoir; 3) Change water releases from the reservoir to reduce the anoxic hypolimnion during summer and stabilized decaying macrophytes during fall; and 4) Continue the citizens advisory council (Pleasant Valley Committee) under coordination by SEUALG to monitor project implementation and provide interagency input and progress evaluation. Only alternatives #2 and #4 have been implemented.

Phase II of the Clean Lakes study was cooperatively developed, funded and initiated via SEUALG, Utah Bureau of Water Pollution Control, and the EPA during

the mid-1980's. Phase II is a work plan focusing on streambank stabilization of Mud Creek (3.3 miles). The stabilization project would reduce sediment loading in the stream, along with the corresponding nutrients. This project todate has involved many agencies, including UDWR.

The most recent study is the Utah Water Quality Report (Bureau of Water Pollution Control - October, 1988), whose purpose is to asses nonpoint source pollution and water management plans under Section 319 of the 1987 Federal Clean Water Act. SEUALG was again identified as the lead water quality agency for the area, and identified Scofield Reservoir as the priority site for improved water quality in the area. This 319 document identifies current progress and needs within the following areas: 1) Design, construction, and operation of wastewater treatment facilities for Scofield Town, Clear Creek Town, and four summer home sub-divisions (lakeshore) between August, 1985 through 1989; 2) Completion of the Phase II 314 project to stabilize Mud Creek streambanks between spring, 1985 through summer, 1989; 3) Need to install and maintain year-round public sanitation facilities (sewage and trash) along the shoreline for recreation users; and 4) Transfer and control of the county park on the north end to the UDP&R for reductions in illegal waste dumping and surface erosion.

3. Problem Identification

The aforementioned studies have all identified the most critical water quality problem within the reservoir and its watershed. This problem is the continual nutrient enrichment of Scofield Reservoir through both external and internal loading. Key nutrients are phosphates and nitrates. Phosphates are the limiting factor, and are therefore the focal point for lake restoration plans. Most phosphates originate naturally from sediments within the drainage. Primary restoration efforts should continue to deal with better watershed management (particularly riparian stabilization and watershed livestock management) for sediment control, reductions in sedimentation through man-caused activities (industrial road construction and summer home development), decreases in streambank erosion through reductions in livestock grazing within riparian zones and shoreline wetlands, and the construction and operation of a sewage collection system serving the local towns and four of the lakeshore home sub-divisions. The UDWR has actively supported these efforts as technical advisors and with actual "hands-on" participation.

A secondary issue involves aesthetics and recreational users, particularly anglers. Some littering and occasional disposal of human waste do occur at the reservoir. The visibility of litter is particularly noticeable during the winter ice fishing season. Except for UDP&R campgrounds (north and east ends), no facilities are available for sanitation and trash around the shoreline. The UDP&R campgrounds are closed during winter months. Lack of recreation waste facilities is due to limited funds, and the confusion over which agency will assume maintenance responsibility. Aesthetic values are currently maintained and improved through news media releases on angler ethics, signing around the reservoir, and law enforcement. Since the recent threat of ice fishing closure, UDWR has increased its efforts in these three areas starting in mid-January, 1989 (Clark Warren, SER Law Enforcement). Ice angler awareness of the need to reduce littering is remarkable. Based on hundreds of onsite angler interviews this winter, the actual occurrence of litter and human waste disposal is minimal.

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In fact, I must personally commend ice anglers at this reservoir for their outstanding environmental ethics.

The claim that anglers (particularly during winter) are creating a health hazard to the Carbon County water supply is simply not based on factual data. Bacteriological sampling taken during the early 1980's demonstrated low fecal coliform counts within the reservoir itself (0-23/100ml)(Table 1). Fecal coliform counts in the Price River below the dam were 0/100ml. The only high fecal coliform counts of concern were taken from the lower end of Mud Creek (2,400-4,300/100ml). Fecal count ratios further showed these particular coliforms were coming from livestock. In addition water released from the reservoir for culinary purposes is adequately treated at the facility located on the Price River (lower Price Canyon). This treatment facility, operated by the Price River Water Improvement District, has an excellent record for maintaining drinking water standards (Phil Palmer, personal communication). The capability of this facility is quite adequate to treat existing and near future culinary water demands. The treatment facility has only two chronic treatment problems: 1) Odor associated with low river flows (hypolimnetic releases from the reservoir during ice cover), which is a perennial problem caused by nutrient enrichment; and 2) Elimination of colloidal silts (very fine suspended silts) originating from the White River drainage.

The continued harassment of UDWR over ice fishing at Scofield Reservoir, is aggravating to Division personnel. The time and money spent dealing with this annual brush fire prevents completion of other priority projects. The real motives behind these health-related claims appear suspect. Several individuals in the area have provided UDWR the following perceptions: 1) Some anglers feel ice fishing has ruined summer fishing through overharvest, so closure would improve fishing; 2) Some lakeshore cabin owners resent having to pay sewage hook-up and maintenance fees recently required by the new Scofield Special Service District, and feel anglers must also pay some form of disposal fee; 3) Some local officials feel no economic benefit is gained from angling at the reservoir, so let UDWR handle all the "...problems, since they created them through their management programs"; and 4) Personal reasons (i.e. vendetta from prior UDWR arrests, dislike of UDWR, increased media exposure, etc.)

4. Lake Restoration Status

Despite the controversy, much has been accomplished towards improving water quality in the Scofield Reservoir drainage.

- *Designation of SEUALG as the lead coordinating agency for clean water management and restoration at the reservoir.*
- *Data analysis, collection, and documentation of the real water quality issues at the reservoir.*
- *Development of 314-Phase II work plans to implement restoration techniques.*
- *Design and construction of a basin-wide sewage collection system for Scofield Town, Clear Creek Town, and four lakeshore sub-divisions.*
- *Formation of the Scofield Special Service District to operate the sewage collection system.*
- *Stabilization and enhancement of 3.3 miles of Mud Creek riparian zone by SEUALG and Bureau of Water Pollution Control. This includes check dams, placement of cedar trees for bank stabilization, willow transplants, and fencing for livestock*

exclusion.
- Implementation of a Carbon County ordinance prohibiting disposal of fish entrails into the reservoir, with enforcement by UDWR, UDP&R, and Carbon County.
- Proper fish management by UDWR and corresponding angler harvest which removes approximately 2,200 pounds of phosphorus annually from the reservoir.
- Signing around the reservoir (both large and small) to educate the public on the pollution issues.
- Implementation of county zoning laws protecting the environment, and also the regulation of low-impact development for industry and summer homes.
- Development of needed angler parking on the east shoreline by UDOT.
- Year-round law enforcement of environmental laws by UDWR, UDP&R, and Carbon County.
- Formation of a citizens advisory council (Pleasant Valley Committee) to provide input on water quality issues at the reservoir, and to assist in coordinating interagency activities related to lake restoration.
- Reclamation and soil stabilization of old coal mine sites in the drainage by Utah Division of Oil, Gas and Mining (i.e. Columbine and Jones mines, Kinney and Blue Seals mines, Old Eccles Mine, Winterquarters Mine, North and South Clear Creek mines, etc.)
- Sediment reductions in Eccles Canyon from mine-related activities (i.e. road surfacing, reseeding impact sites, stream alteration around chronic mudslides, etc.)
- Identification and elimination of high nitrate hydraulic fluids used in long wall mining at Skyline Mine.
- Development of a new sewage facility and fish cleaning station at the east campground by UDP&R.
- Acquisition and administration of the north campground by UDP&R, with authority to reduce illegal waste water discharge and shoreline livestock grazing.

The preceding efforts, though not inclusive, were accomplished with cooperation from many agencies. Involvement of agencies has been at all levels: municipal, county, state, federal, and private.

5. Future Needs/Recommendations

The closure of Scofield Reservoir to fishing, particularly ice angling, would have no impact on the nutrient problem. The use of legislation to pursue closure, based on assumed health hazards created by anglers, would have no factual premise. If legislative closure were accomplished, it would take management of fisheries and water quality out of the hands of trained professionals and place it in the political arena. Worse, it would divert attention and efforts away from the real pollution problems at the reservoir and possibly negate the excellent work already accomplished. Economically it could negatively impact Utah's recreational fishing industry by reducing expenditures at both the state level (over $2,000,000) and the county level (over $200,000).

The following recommendations are supported by the UDWR. They address the need for nutrient reduction in the reservoir. Also included are recommendations to reduce impacts associated with the reservoir's aesthetic values. Many of these recommendations have already been proposed by other agencies, and are currently under implementation.

1. The citizens advisory council (Pleasant Valley Committee) should be continued, with participation from all involved agencies. The lead agency for this committee should be SEUALG. This committee would continue to act as a sounding board for review of old projects, and implementation of new projects.

2. Public education should continue to address the water quality problems of Scofield Reservoir. Efforts should focus on improving angler ethics to reduce litter, and on enlightening the local communities on the real issue of nutrient enrichment.

3. Increase efforts to reduce sediment loading throughout the drainage. Specific sites include:

- Continue streambank stabilization work (structure placement and willow transplants) and riparian exclusion of livestock through fencing on Mud Creek.

- Evaluate grazing practices on private and USFS lands, particularly the riparian zones of Upper Fish Creek and Pondtown Creek. UDWR stream inventory work has shown some streambank degradation associated with livestock during late summer.

- Enforce strict sediment control measures for onsite development projects relative to summer homes and coal mining. A current site of concern is the Eccles Creek mining complex.

- Encourage exclusion of livestock grazing from the immediate shoreline area. UDP&R should focus on livestock restrictions at both the north end campground and portions of federal land adjacent to the Upper Fish Creek inlet. SEUALG should pursue acquisition and fencing of the entire South Shore wetlands. Ownership entanglements of this wetlands parcel are prohibiting the project at this point in time.

4. Acquire funding to install and maintain year-round sanitation and trash facilities around the reservoir for recreation users. Todate UDWR has declined to become involved with funding sanitary facilities due to statute limitations. UDP&R personnel state they do not have available funds to provide sanitary facilities outside established campgrounds. UDWR is only authorized to manage and protect wildlife, not to manage and provide facilities for recreation users (Utah Code, annotated 23-14-1). At the state level, the Utah Parks and Recreation Board is authorized to provide for the health and recreational opportunity of the people (Utah Code, annotated 63-11-13). The issue of UDP&R providing facilities on their administered lands, adjacent to waters managed for fisheries by UDWR, must be resolved at the Director's level. Perhaps other funding sources are available to provide these facilities (i.e. nonpoint source 319 Clean Water funds).

5. Continue to enforce laws associated with water quality and the environment. UDWR and UDP&R should focus on litter, disposal of fish entrails, illegal "gray" water discharge, unlawful stream alterations that create additional sedimentation, etc. County enforcement should focus on compliance with permits related to zoning regulations.

6. Continue fish management efforts to sustain annual trout harvests in the reservoir. Angler harvest is providing a direct removal of nutrients from the reservoir.

7. Study efforts should focus on:

- Update on current nutrient loading (external) into the reservoir since implementation of restoration measures. Monthly water samples should be analyzed during 1989 and evaluated for nitrates and phosphates.

- Evaluate coliform bacteria content in the reservoir and its major tributaries. Samples should be collected bi-weekly for one year, and analy at a certified laboratory.

- Continue periodic monitoring of trout populations and their habitats in Mud Creek (Sec. 1) and Eccles Creek (Sec. 1).

UTAH NATURAL RESOURCES
Wildlife Resources

memorandum

February 21, 1989

TO: *Timothy H. Provan, Director*

FROM: *Walt Donaldson, SER*
Fisheries Program Manager

SUBJECT: *Update on the Water Pollution Issues at Scofield Reservoir*

Public attention has again been drawn to Scofield Reservoir over a perceived litter/pollution problem created by ice anglers. The problem focuses on claims that ice anglers are leaving large amounts of human waste, along with other types of litter, on the reservoir. Further, human waste is claimed to cause health hazards for residents in Carbon County, who use Scofield Reservoir as a source for culinary water.

Littering is a perennial problem associated with all outdoor recreation, and usually caused by a minority of users. The perception of a health hazard has caused some individuals in Carbon County to contact their legislators and pursue action to close the reservoir to ice fishing. State legislators from Carbon County recently contacted the Utah Division of Wildlife Resources (UDWR) over the need to correct the problem. They stated if action was not taken, they would introduce legislation the following year (1990) to close ice fishing at the reservoir.

The issue of water quality is not new for Scofield Reservoir and its surrounding watershed. Numerous agencies have planned and initiated programs since 1976 to improve water quality. UDWR has been involved with most of these projects, and has been the lead agency on several. UDWR continues to support the concept of improving water quality in the Scofield drainage. Better water quality will enhance trout production and angling opportunity within the reservoir and its tributaries.

The real pollution problem is nutrient enrichment (eutrophication) of Scofield Reservoir. The critical nutrients are phosphates and nitrates. Most nutrients are found naturally in the watershed, and transported as sediments into the reservoir. Excess nutrient loading is associated with human abuse of the watershed (livestock overgrazing, uncontrolled industrial development, lack of wastewater treatment facilities, etc.). Unfortunately the real problem is clouded in misconceptions. These misconceptions seem to persist despite many news releases and public meetings dealing with the problem. The public at large fails to realize that pollution due to human waste originating from dispersed recreation is only a minuscule part of the eutrophication problem. The following

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summary is provided to clarify the water quality issues at the reservoir.

Please contact me if you have any questions or comments.

cc: UDWR-Bruce Schmidt, SLO
-Glenn Davis, SLO
-Paul Woodbury, SLO-LE
PRWID-Phil Palmer
SEUALG-Leah Ann Lamb
Utah Bureau of Water Pollution Control-Harry Judd
Southeastern Utah Health District-Robert Furlow
Mike Dmitrich, Carbon Co. Representative
UDP&R-Mike Jackson, Scofield
Carbon Co. Commisiion-Linda Varner
-Emma Kuykendall

Why Scofield Reservoir Is Eutrophic: Effects of Nonpoint-Source Pollutants on a Water-Supply Reservoir in Utah

Doyle Stephens

U.S. Geological Survey, Salt Lake City, Utah

ABSTRACT

Studies since 1979 have classified Scofield Reservoir as meso-eutrophic or eutrophic. The principal pollutants are nutrients, trace metals, and sediments associated with nonpoint sources such as construction of roads and mine portals, domestic-waste disposal, animal grazing, and natural deposits of rock containing phosphate. Blooms of blue-green algae, which have resulted in fish kills, have corresponded to years of decreased inflow. Biota populations during wet years were quite diverse, with only minimal numbers of undesirable blue-green algae. During 1981, however, the minimum usable water storage decreased to 31 percent of the 25-year average and blue-green algae blooms resulted in serious fish kills. Concentrations of mercury in the water in Scofield Reservoir have caused concern for water users but none of the concentrations have exceeded revised State standards. The mercury originates from coal particles within the drainage basin, and most of it is bound as silicate in the reservoir sediments and is not readily soluble.

Several management practices have been implemented to decrease nonpoint-source pollution. Among these are an improved waste-disposal station for recreational vehicles, a containerized-waste system for fish cleaning, and streambank stabilization.

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OBJECTIVES OF THE INVESTIGATION

Extensive research on Scofield Reservoir in central Utah has been done during the last few years by the Utah Division of Environmental Health and the U.S. Geological Survey. The objectives of the State studies were the quantification of nonpoint sources of nutrients entering the reservoir, determination of the trophic conditions, and identification of possible restoration methods. The Geological Survey, in cooperation with the U.S. Bureau of Land Management, was interested primarily in the determination of the effects on the reservoir of coal mining within the drainage basin. Eutrophic conditions, large sediment loads, and trace-metal contamination were problems anticipated prior to the start of the studies. Due to differences in objectives and the period of study, there was little duplication of effort, and complementary data bases were compiled.

DESCRIPTION OF THE AREA

Scofield Reservoir, at an elevation of about 2,320 meters (7,600 feet) in central Utah (fig. 1), was formed in 1926 and enlarged in 1945 by dams on the Price River. Useable capacity of the reservoir is 81 cubic hectometers (65,780 acre-feet) and maximum depth is 14 meters (47 feet). The drainage basin for the reservoir is 400 square kilometers (154 square miles) and is primarily mountainous with elevations ranging from 2,312 to 3,183 meters (7,586 to 10,443 feet). The drainage basin contains large coal deposits and the area has been mined since the late 1800's. The major source of inflow to the reservoir is Fish Creek which contributed 72 percent of the total inflow during the 1980 water year. Minor inflows were from Mud Creek (16 percent), and Lost and Pondtown Creeks and from precipitation (12 percent). Agricultural use of the basin is limited to grazing of sheep (15,000 head) and

cattle (5,000 head). Ninety-three percent of the drainage basin is forest or range land.

The reservoir supplies water for domestic use to 20,000 people downstream, and it provides recreational opportunities for about 70,000 visitors per year. There are 1,100 recreational camping or cabin units on the shores. Sanitary facilities for the camps, cabins, and the town of Scofield (200 people) are limited to pit privies and septic tanks.

ALGAL BLOOMS AND FISHKILLS

Periodic data for algal populations and blooms are available since 1975. Colonies of objectionable blue-green algae were identified in the reservoir in 1975, but their numbers did not reach bloom proportions, most likely because of increased tributary flow and high water in the reservoir. During most wet years, algal populations are quite diverse with few blooms of blue-green algae. Considerable data on the algal community have been collected since 1981, and this may be summarized by examining the fluctuations of two blue-green algae, Aphanizomenon flos-aquae and Anabaena flos-aquae, and the diatom Stephanodiscus minutula, which are good indicators of eutrophication in reservoirs in Utah. The density of these blue-green algae and the percentage of the diatom (relative to all diatoms) are plotted in figure 2 for 1981-84. Although both groups of organisms are indicators of eutrophication, their densities typically are inverse. Increased densities of the blue-green algae indicate blooms during August 1981 and October, 1982. Possible bloom conditions for the diatom are indicated during early August 1981, September 1981, and August 1983. The phytoplankton bloom in August-September 1981, resulted in a considerable fishkill. The bloom of blue-green algae in October 1982, did not result in a major fish kill because water storage had reached an historic high in June and was still relatively high during October.

Similarly, the diatom bloom of August 1983 occurred at a time when the water storage historically was very large.

Fishkills in Scofield Reservoir have been reported during 6 years since 1960, and most were associated with small discharges from the principal inflowing stream or decreased reservoir water storage (table 1). During most years, Fish Creek contributes about 70 percent of the annual inflow to the reservoir. The Utah Division of Wildlife Resources (Walter Donaldson, written commun., 1984) has found that fishkills occur in years when the annual value for mean daily discharge of Fish Creek is less than 1.13 cubic meters per second or 40 cubic feet per second. This observation has been verified by all data since 1960 with the exception of 1963 and 1966. In 1963, the flow from Fish Creek decreased to 63 percent of the 25-year average daily flow of 1.5 cubic meters per second (53 cubic feet per second), and the minimum water storage in the reservoir was only 52 percent of the 25-year average. The flushing rate (total inflow divided by Price River outflow) in 1963 was about 1, which may have prevented a fish kill. During 1966, the average daily flow of Fish Creek was 67 percent of the 25-year average, but minimum water storage in the reservoir was 143 percent of the average.

Analysis of published (Waddell and others, 1983, p. 17; and Denton and others, 1983, p. 28) and calculated water budgets since 1960 indicate that fishkills occur 80 percent of the time the annual flushing rate for the reservoir is less than 0.85. No fishkills have been reported during years when the flushing rate was greater than 1.1. It is likely that fish kills result from a combination of environmental factors that are intensified by decreased tributary inflow. These factors are large populations of blue-green algae that release biological toxins, oxygen demands due to respiration and

decomposition of algal populations, increased rate of warming of lake water, and increased volume of the anaerobic hypolimnion.

Considerable reservoir data were collected before and after the 1981 summer fishkill (Utah Department of Health, 1984), which indicate the relationship between total reservoir water storage and the actual volume of fish-habitable water (fig. 3). Total water storage began decreasing in June and during August it decreased 15 percent. The volume of fish-habitable water containing a minimum dissolved-oxygen concentration of 5.5 milligrams per liter (mg/L), which is sufficient to support a fishery, decreased at about the same rate until August. During the first one-half of August, the habitable water decreased about 60 percent. This was due to an expansion of the anaerobic hypolimnion and decreased volume of total storage which greatly decreased the living area for fish and resulted in an estimated fishkill of 200,000.

TROPHIC STATE OF THE RESERVOIR

Due to recurring algal blooms and large concentrations of nutrients, Scofield Reservoir has been classified as eutrophic (Denton, 1980, p. 167) to [illegible]eutrophic (Waddell and others, 1983, p. 44 ; and Denton and others, 1983, [illegible]). Data collected by the U.S. Geological Survey since 1979 indicate that 47 percent of all measurements of total phosphorus in the epilimnion and 69 percent of phosphorus measurements in the hypolimnion have exceeded the Utah water-quality standard of 0.025 milligrams per liter. The seasonal cycling of total phosphorus using data collected by the Utah Division of Environmental Health and the Geological Survey is shown in figure 4. Phosphorus concentrations typically increase in the hypolimnion during winter stratification due to release from the sediments in the reservoir. During turnover in May or June, concentrations generally decrease in the hypolimnion

and increase in the epilimnion. The increase in algal and bacterial populations during the summer coupled with increased stratification and development of an anaerobic hypolimnion, decreases the phosphorus concentration in the epilimnion. In July or August, when summer stratification is maximum, release of phosphorus from the anaerobic sediments results in large concentrations in the hypolimnion. During fall turnover in late August or September, the phosphorus accumulated in the hypolimnion is released to the overlying waters and surface concentrations of phosphorus typically increase. It is during the August-September turnover that recycled phosphorus is made available to the blue-green algae and late summer blooms can occur.

Denton and others (1983, p. 52) reported that ratios of nitrogen to phosphorus mostly were greater than 15 during 1981, indicating phosphorus limitation of algal populations. During 1982, ratios in the spring indicated phosphorus limitation and summer ratios generally identified a nitrogen limitation. Bioassay tests of algal-growth potential indicated that on June 27, 1984, when the ratio of nitrogen to phosphorus in the reservoir water was 13 to 1, the water was primarily phosphorus limited. Additions of small concentrations of nitrogen (as nitrate) as well as phosphorus (as orthophosphate), however, stimulated nearly four times as much algal growth as phosphorus alone. On July 31, 1984, when the nitrogen to phosphorus ratio was 40 to 1, the addition of nitrogen as well as phosphorus to the test algae resulted in nearly 17 times the growth of phosphorus alone. By September 19, the ratio was 50 to 1, but the addition of nitrogen resulted in only a 2-fold increase in algal mass compared to phosphorus alone. It is likely that phosphorus is limiting during most years, particularly when large populations

of blue-green algae such as Aphanizomenon and Anabaena are present, which are capable of fixing atmospheric nitrogen into a form available to organisms.

SOURCES OF NUTRIENTS

Due to basin slopes of 0.38 in Boardinghouse and Eccles Canyons and the construction of extensive roads and coal-mine portals in Eccles Canyon, large quantities of sediment are transported into Mud Creek and then into Scofield Reservoir. Suspended sediment loads in Mud Creek during July-September storms averaged 18,000 kilograms (20 tons) during 1983-84. Loads during thunderstorms in spring were believed to be even larger. Soils in the Mud and Fish Creek drainages contain considerable quantities of naturally occurring phosphorus. Soils collected in Boardinghouse and Eccles Canyons during 1984 contained 300 to 500 milligrams of total phosphorus per kilogram. Suspended stream sediments from the Fish Creek drainage were reported to contain 440 to 900 milligrams of total phosphorus per kilogram with biologically available phosphorus averaging about 49 percent (Denton and others, 1983, p. 122).

Considerable loads of nitrogen and phosphorus are discharged to the reservoir by Mud and Fish Creeks, the major inflowing streams to Scofield Reservoir (table 2). Loads of nitrogen and phosphorus increased considerably during 1984 compared to 1983, although the total inflow to the reservoir was nearly the same. The distribution of loads also changed considerably during 1984, showing a greater proportion of nutrients, relative to total discharge, entering from the Fish Creek drainage. During 1980 and 1983, the proportion of total nutrient loads, relative to discharge, was greater for the Mud Creek drainage. The increased loads in Mud Creek during 1984 may be due in part to increased construction in Eccles Canyon. There is no evidence to explain the increased loads during 1984 in Fish Creek.

BY GEOLOGICAL SURVEY

Clyde and others (1981, p. 50) reported that wells in the Scofield area yielded water with an average phosphorus concentration of 170 micrograms per liter, except in several of the subdivisions adjacent to the lake. In these areas, the water from several shallow wells contained mean total phosphorus concentrations greater than 1,400 micrograms per liter. Relatively large concentrations of nitrate nitrogen also were common is the same wells, with concentrations ranging from 1,000 to 14,000 micrograms per liter. Contamination of the ground water by disposal of domestic waste was suspected.

PHOSPHORUS IN LAKE SEDIMENTS

Selective chemical extraction of phosphorus from sediments in Scofield Reservoir by Messer and Jhnat (1983, p. 8) indicated that nearly 200 milligrams of phosphorus per kilogram of sediment was potentially available for biological uptake. Although the quantity of phosphorus in the sediments is quite large, the actual quantity released is small due to the large concentrations of iron in the sediments. The phosphorus is in the form of iron-oxide gels, which release phosphorus when the iron in the gel is reduced to the ferrous form during anaerobic periods of stratification. Release rates of available orthophosphorus from intact sediment cores were determined under aerobic and anaerobic conditions by the author. Some differences in release rates depended on the sampling location of the core. Generally under anaerobic conditions at a typical hypolimnion temperature of 15° Celsius, however, phosphorus release peaked within 15 days at a rate of about 2 milligrams per square meter (mg/m^2) per day and decreased to about 1.3 milligrams per square meter per day for the remaining 17 days of the experiment. Under aerobic conditions at a typical epilimnion temperature of 20° Celsius, the maximum release rates were about 0.6 milligrams per square meter per day, decreasing

DEPOSITORY

to about 0.3 milligrams per square meter per day after 28 days. These rates are slightly less than those reported for Deer Creek Reservoir (75 kilometers or 47 miles to the northwest) by Messer and Ihnat (1983, p. 8).

The quantity of orthophosphorus released from the sediments during summer stratification was calculated using data obtained during 1983. The reservoir was stratified from the end of July to the end of September, about 70 days. During this time, water covering about 380 hectares (950 acres) was anaerobic. Using a release rate of 1.3 milligrams per square meter per day, a total of 360 kilograms (0.4 tons) of phosphorus could have been released from the sediments to the hypolimnetic water. This indicates that phosphorus release from anaerobic lake sediments is of minor importance when compared to loads of total phosphorus entering from streams (table 2).

TRACE METALS

The presence of an active mining industry and large sediment loads created by construction of road and mine-portals in the basin indicated that trace metals may be a pollution problem in the reservoir. Prior to November 1984, the State water-quality standards for the protection of aquatic wildlife did not incorporate water hardness into the allowable concentrations for trace-metals. Due to the accumulation of literature indicating that trace-metal toxicity to aquatic wildlife is dependent on water hardness, trace-metal standards were revised to less stringent concentrations. This necessitated revisions in the interpretation of the effects of trace metals on Scofield Reservoir; particularly for mercury, which had been identified previously as a potential pollutant problem (Clyde and others, 1981, p. 38). Under the old standards, 39 of 46 analyses for total mercury in reservoir waters indicated concentrations in excess of State standards of 0.05 micrograms per liter. The mean of all the violations was 0.17 micrograms per

liter. Under the revised standard of 1 microgram per liter, none of the samples exceeded the standard. Analyses of fish tissue also indicated the existence of small concentrations of mercury in the reservoir waters, but the concentrations were considerably less than the allowable limit for edible fish (Denton and others, 1983, p. 52). The small concentrations of mercury likely originate from coal particles transported into the reservoir. The composition of coal in the area indicates that the mercury content may be as large as 0.25 part per million by weight (Smith, 1981, p. 15).

Manganese and zinc are the only other trace metals that are potential pollutants in the reservoir. The standards of the U.S. Environmental Protection Agency (1976) for a public-water supply specify that a total manganese concentration of 50 micrograms per liter shall not be exceeded. During periods of stratification, concentrations of total manganese may range from 500 to 700 micrograms per liter in the anoxic hypolimnion in Scofield Reservoir. The concentrations increase considerably in the hypolimnion during summer stratification and abruptly decrease during spring and late summer turnover. It is during these turnover periods that the concentrations increase in the epilimnion due to mixing with hypolimnetic water that is enriched in manganese. Concentrations of manganese in the epilimnion rarely exceeded the standard during 1979-82, but during the late summer turnover in 1983 and 1984, near-surface concentrations tended to range from 80 to 120 micrograms per liter. Total, and to a lesser extent, dissolved-iron concentrations were similar in magnitude to that of total manganese during periods of stratification and mixing.

Concentrations of total zinc in the reservoir occasionally exceed 150 micrograms per liter, but the dissolved form rarely exceeded the State standard of 50 micrograms per liter. Some cycling of both forms of zinc occurs

BUREAU OF LAND MANAGEMENT

in the surface and bottom waters, but it does not conform to well-defined periods of stratification and mixing as does the manganese.

EXTRACTIONS FROM SEDIMENT CORES

Sediment cores were collected at five sites in the reservoir, radioisotope methods were used to determine sedimentation rates, and chemical extractions were performed (Skei and Paus, 1979) to provide an estimate of the ease with which trace metals may be removed from the sediment. In general, isotope-dating methods indicated that sedimentation rates within the reservoir were not uniform. Sedimentation rates near the major sources of inflow could not be determined accurately, but they were believed to be greater than rates in the central part of the reservoir. Sediments accumulating in the shallow areas periodically move toward the center of the lake, where the sedimentation rate is about 1 centimeter (0.4 inch) per year. An even smaller rate of deposition--0.3 centimeter (0.1 inch) per year--has been determined for an area near the dam, where the velocity of the current is least.

Concentrations of arsenic, cadmium, and cobalt in all cores were very small, and these elements primarily were present in a tightly bound form. Copper concentrations in the sediments ranged from 15 to 20 micrograms per gram. Most of the copper was present in the non-silica fraction, most likely tightly bound to clays or in sulfide compounds. Generally, the quantity of copper potentially available to the biota was about 5 ~~milligrams~~ micrograms per gram. Concentrations of manganese at most sites showed a gradual decrease in concentration from the sediment surface to the bottom of the 20 to 40 centimeter (8- to 16-inch) core. Concentrations of total manganese varied from 400 to 700 micrograms per liter in the surface segments and decreased about one-third in the bottom segments of the core. This is a typical pattern for manganese in lake sediments. The oxidized forms of manganese are

deposited in the sediments and gradually buried. As oxygen is excluded from the cores and reducing conditions are established, the oxides are reduced and solubilized, releasing manganese with a +2 valence which migrates upward in the pore water (Skei and Paus 1979, p.244).

Mercury concentrations in the sediments generally were less than 0.02 micrograms per gram, particularly in the shallow, recently deposited alluvium from Mud and Fish Creeks. Sediments from deeper sites had considerably larger concentrations of mercury, with a maximum concentration of 6 micrograms per gram. At sites where concentrations were larger, the concentrations were present in the least soluble (silicate) form. Concentrations in a biologically available form did not exceed 0.02 micrograms per gram, and they generally were present in concentrations less than 0.01 micrograms per gram.

CONTROL OF EUTROPHICATION THROUGH MANAGEMENT

The State of Utah has proposed several management practices for controlling nonpoint and point sources of nutrients (Denton and others, 1983, p. 65-87). These methods consist of integrating public-education programs with physical-, chemical-, and biological-management practices to decrease the rate of eutrophication and restore reservoir quality. These practices may be categorized as lakeshore management and reservoir management.

Lakeshore management would decrease the quantity of sewage-associated nutrients entering the lake from nonpoint sources, such as holding tanks and leach fields. It would prohibit the installation of additional sewage-holding tanks in subdivisions around the lakeshore, require sanitary dump stations for recreational-vehicle parks, and require centralized septic tanks with drainfields located far from the lakeshore in several subdivisions. An extensive wetlands would be created near the mouth of Mud Creek, which would be managed to exclude animal grazing and to encourage plant growth to decrease

nutrient concentrations in the inflowing water. The plant growth would be periodically harvested and removed from the area. Streambanks also would be stabilized along the creek drainage near the reservoir by planting willows. The wetlands proposal could not be funded and it has been temporarily suspended from consideration.

Reservoir management is designed to decrease the effects of eutrophication by controlling nutrients after they reach the reservoir. Fishery practices such as no-limit or commercial fishing would decrease the nutrient load caused by chemical treatment periodically used to control rough fish. Fish cleaning with return of the entrails to the reservoir, is estimated to contribute more than 180 kilograms (400 pounds) of phosphorus annually (Denton and others, 1983, p. 166). Prohibition of fish cleaning on the reservoir and along the shore, and construction of fish-cleaning stations in the camping areas would decrease this source of nutrients. Public education and more restroom facilities would be used to decrease waste disposal by boaters. Additional water-management tools that were considered but rejected as being too costly or in conflict with water users were alum treatment to precipitate phosphorus followed by flyash addition to seal the nutrients in the sediments ($160 to $600 per hectare or $400-$1500 per acre); aerators to decrease anaerobic conditions under which phosphorus leaches from the sediments ($6,000 to $12,000 annually); dredging to remove sediment ($1,000 per hectare or $2,500 per acre); installation of a large pipe, which would allow hypolimnetic water to be discharged during the summer (greater than $43,000); water drawdown during midsummer to encourage complete water mixing and prevent formation of an anoxic hypolimnion.

Several practices had been implemented by 1985. An improved waste-disposal system for recreation vehicles and a containerized fish-cleaning

station with grinder and waste-system connections are in use at the State park campground. Posting of anti-pollution signs has increased public awareness, and the channel has been stabilized along the downstream reach of Mud Creek. Subsequent monitoring and study is planned by the State to determine the effectiveness of these control practices.

All lakes are different, and the effect of nonpoint-source pollutants cannot be predicted unless the chemistry and biology of each lake are understood. Management practices to control eutrophication need to be deferred until the dynamics of specific lake systems are fully known.

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Table 1.-- Fishkills in Scofield Reservoir and minimum reservoir water storage, ratio of inflow to outflow, and discharge for Fish Creek.

Water year	Fishery response	Minimum useable water storage (thousand cubic meters)	Percent of 25-year average minimum storage	Total inflow Total outflow	Fish Creek mean daily discharge (cubic meters per second)
1960	major summerkill	2,070	7	.95	.88
1961	major winterkill	680	2	1.09	.42
1972	minor summerkill	24,040	80	.74	.91
1976	minor summerkill	38,350	127	.84	1.01
1977	major summerkill	21,840	73	.49	.29
1981	major summerkill	9,390	31	.73	.89

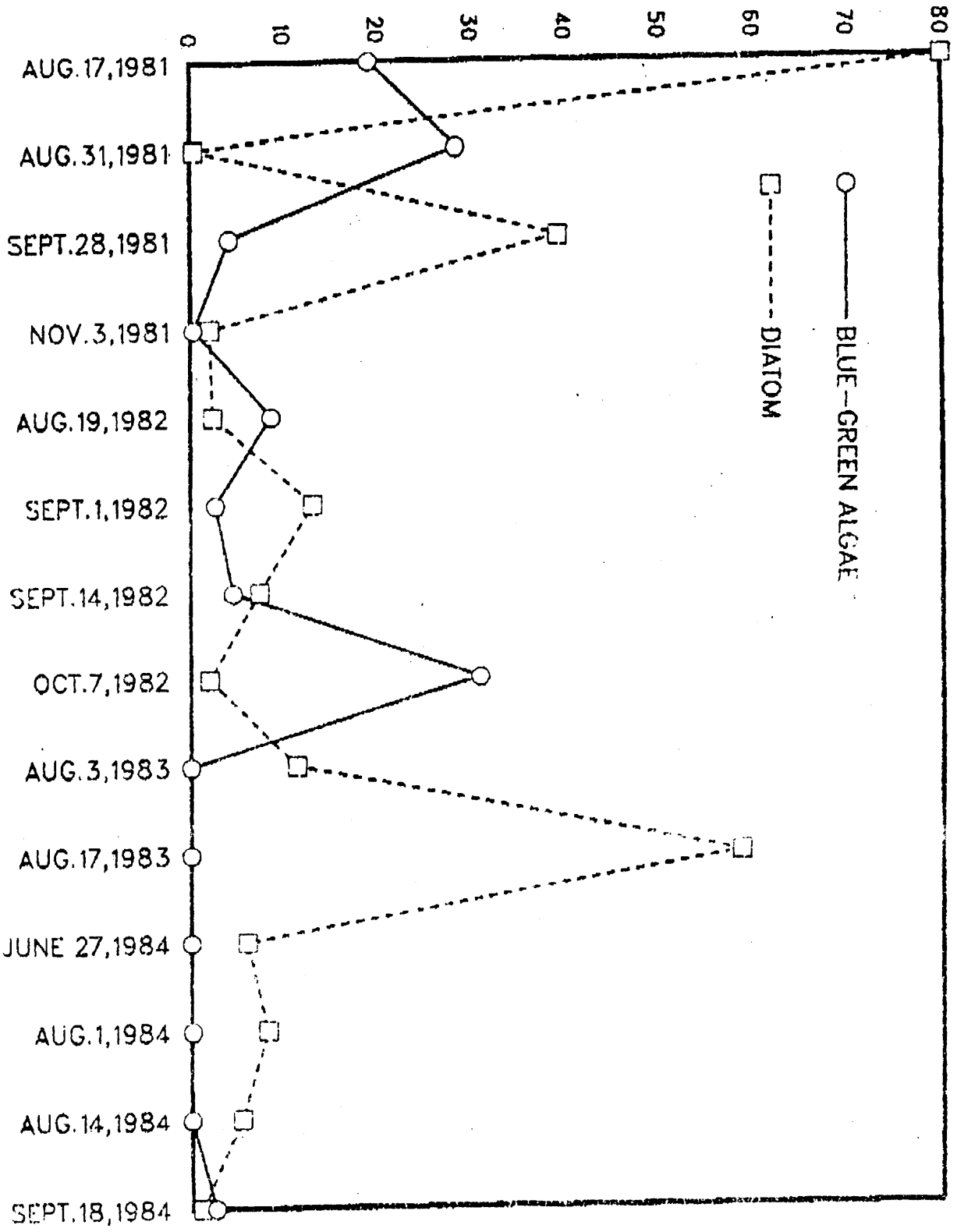
Table 2.--Loads of nitrogen and phosphorus to Scofield Reservoir from gaged inflow sources during 1980,1983-84 water years. Numbers in parentheses are the percent of total.

	Water Year								
	1980			1983			1984		
Stream	Inflow (million cubic meters)	Dissolved nitrogen (metric tons)	Total phosphorus (metric tons)	Inflow (million cubic meters)	Dissolved nitrogen (metric tons)	Total phosphorus (metric tons)	Inflow (million cubic meters)	Dissolved nitrogen (metric tons)	Total phosphorus (metric tons)
Fish Creek	74.9 (82)	57 (79)	4.0 (71)	100.9 (81)	37 (79)	15 (73)	96.6 (78)	110 (81)	79 (86)
Mud Creek	16.2 (18)	15 (21)	1.6 (29)	23.9 (19)	10 (21)	5 (27)	27.5 (22)	25 (19)	13 (14)
Total	91.1	72	5.6	124.8	47	20	124.1	135	92

0 1 2 3 4 5 KILOMETERS
0 1 2 3 4 5 MILES
DRAINAGE BASIN BOUNDARY
UTAH

Fig. 2

DENSITY OF BLUE-GREEN ALGAE, IN CUBIC CENTIMETERS PER LITER, AND THE DIATOM, IN RELATIVE PERCENTAGE OF THE TOTAL POPULATION OF DIATOMS



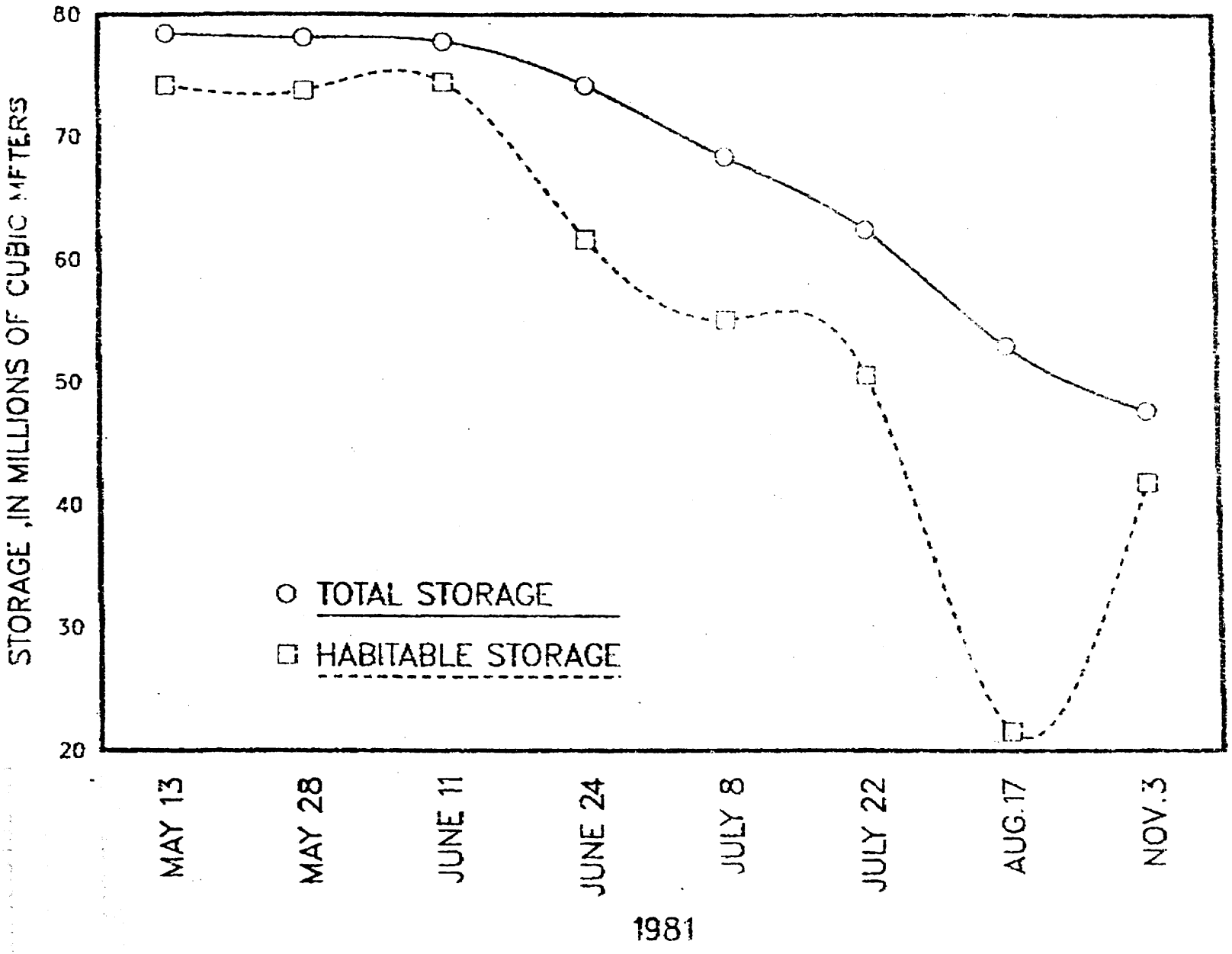


FIGURE 3.--Total and fish-habitable water storage in Scofield Reservoir during the 1981 fishkill

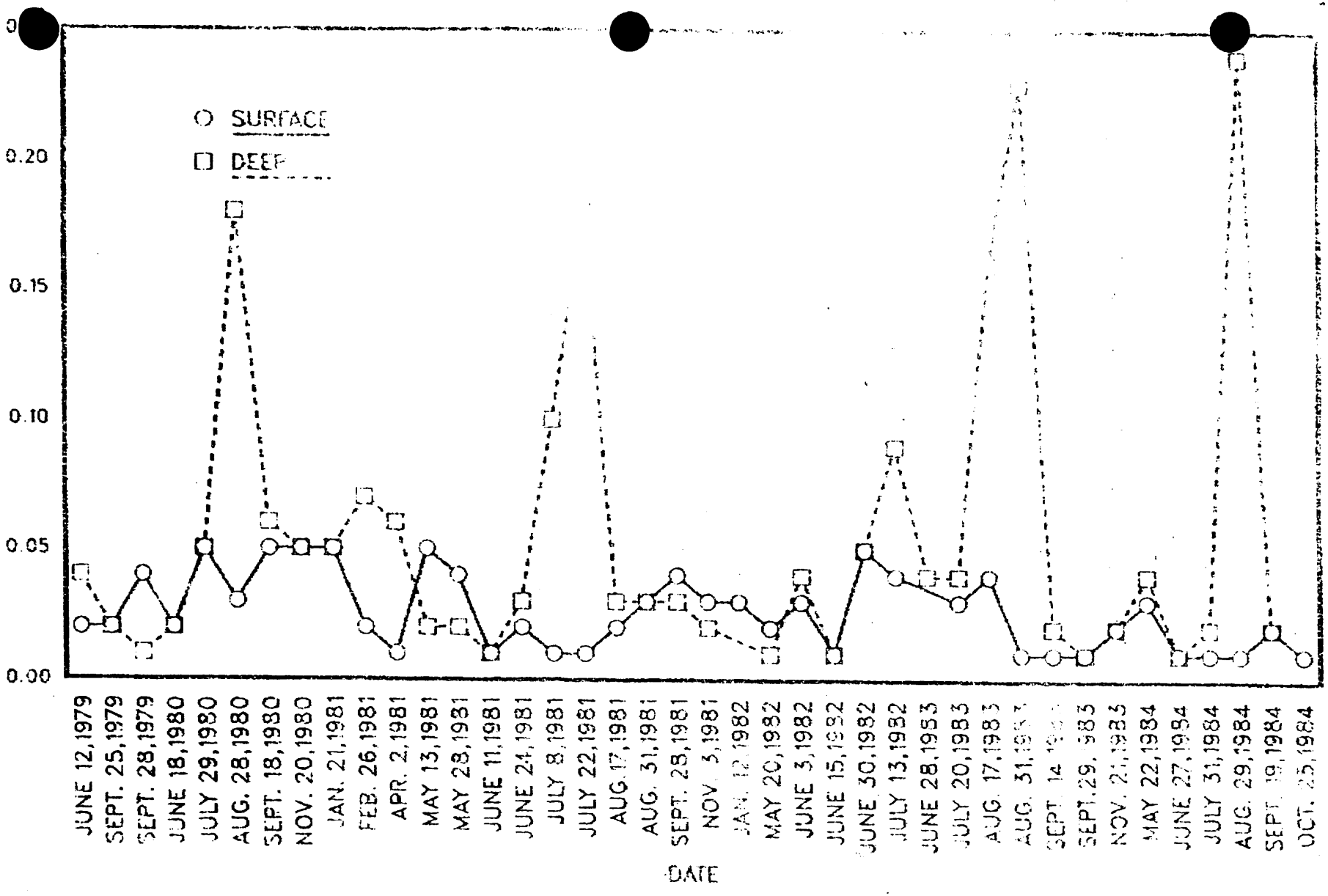


FIGURE 4 — Total phosphorus in surface and deep water in Scofield Reservoir, 1979–84

SCOFIELD RESERVOIR

PHASE I

314 CLEAN LAKES STUDY

1980 - 1982

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The preparation of the report was made possible through a Grant (No. S008234-01) to the Utah Department of Health from the United States Environmental Protection Agency.

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ACKNOWLEDGEMENTS

We would like to thank those who have made this study possible. The grant application to EPA was initiated by Mr. Randy Isham. The support of Mr. Calvin Sudweeks, Director and Mr. Jay Pitkin, Assistant Director, of the Bureau of Water Pollution Control is appreciated. Personnel and material assistance and coordination was offered by Mr. William Tate, the former chief of the Planning Section, Mr. Michael Reichert, the present chief of the Planning Section, Dr. Marv Maxell, the former chief of the Monitoring Section, and Mr. Russell Hinshaw, the present chief of the Monitoring Section. Mr. Richard Denton of the Planning Section is the Project Officer and Mr. Myron Cox is the Projects Water Quality Specialist.

Field data and sample collections were completed by Richard Denton, Myron Cox, Mark Ellis, Tom English, Scott Goodwin, Roy Gunnell, Virginia Hale, Bob Halloran, Russ Hinshaw, Scott Hopkins, Rick Milton, Reed Oberndorfer, Mike Reichert, Bill Tate and Diane Wynne. Staff of the Bureau of Water Pollution Control also provided help in analysis of data, assessment of reservoir restoration alternatives, and public participation. Personnel at the Utah State Health Laboratory, Dr. Francis Urry, Director, completed the chemical and bacteriological analyses for the study. Special thanks is extended to the secretarial staff for countless hours spent in typing and assistance compiling the report.

Dr. Samuel Rushforth of Brigham Young University performed the algae identifications and algae analyses. The stream aquatic invertebrate identifications and analyses were performed by Dr. Robert Winget of Brigham Young University. Modeling of the aquatic ecosystem and analyses of the chemical and physical data were performed by Drs. LaVere Merritt and Woodruff Miller of Brigham Young University. Dr. Jay Messer of Utah State University performed the sediment core analysis and dating, the watershed soil analysis, and phosphorus availability in sediments and soils.

Data, information, and narratives were provided by James Paraskeva and Nancy Ingold, Southeastern Utah Association of Governments. Rich Walker, Carbon County Planner provided verbal and written comments. Additional thanks is extended to the members of the Carbon County Commission and the Pleasant Valley Citizen Advisory Committee. The Committee has spent much time and effort in support of the project, and in initiating public support and awareness of the problems associated with Scofield Reservoir. The support and assistance of the Southeastern Utah District Health Department is appreciated. The assistance of Mr. Patrick Walsh and the other personnel at Scofield Reservoir State Park of the Utah State Parks and Recreation Department is appreciated. Dennis Kelly of the U.S. Forest Service provided information and valuable comments.

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The Utah State Division of Wildlife Resources provided fish for pesticide analyses and resource data. The assistance of Randy Radant, John Livsey, Walt Donaldson of the Southeastern Region in addition to Glen Davis and George McGlaughlin of the state office is acknowledged.

A special thanks is extended to Garth Frandsen for his support, equipment and horses during the Fish Creek soils survey expedition.

Last, but not least Ms. Diane Wynne, Project Officer in EPA Region VIII, Denver, oversaw the grant and offered help and suggestions.

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INTRODUCTION

Scofield Reservoir is an important cold water sport fishery located in Pleasant Valley on the north end of the Wasatch Plateau. It is in the center of an important recreational area where an increasing number of cabins and second homes are being constructed. Pleasant Valley is a major coal mining area of the Wasatch Plateau coal fields. The reservoir is a source of irrigation and culinary water for the lands and people in the Price-Helper, Utah area.

Fish kills in the reservoir, late-summer blue-green algal blooms, and hypolimmetic oxygen deficits have raised concerns about nutrient loads into the reservoir. A Clean Lakes 314 Water Quality Study was jointly funded by the Environmental Protection Agency, the Utah Department of Health and Carbon County. Field and laboratory monitoring of water quality in the reservoir and watershed started in September 1980 and continued until October, 1982. The objectives of the study were to:

1. Obtain background information pertinent to the reservoir.

2. Identify and quantify the point and nonpoint sources of phosphorus and nitrogen in the reservoir and watershed. Determine the land uses and their effects upon stream nutrient loadings.

3. Construct phosphorus and nitrogen budgets for the reservoir.

4. Determines phosphorus availability from reservoir sediments and watershed soils.

5. Determine the trophic state of the reservoir.

6. Evaluate the biological resources of the Scofield drainage including algal population dynamics, benthos, and fisheries resources.

7. Formulate a primary alternative for the control of, and if possible, the reduction of phosphorus and nitrogen in the reservoir. Evaluate other suggested restoration techniques. Calculate the costs, benefits, and feasibility of all suggested restoration techniques.

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SECTION 1

BACKGROUND INFORMATION

A summary of the geology of Scofield Reservoir basin is given in this section. See Appendix A for a more complete description.

Lake Identification and Location

Name:	Scofield Reservoir
State:	Utah
Counties:	Carbon, Utah
Nearest Municipality:	Scofield, Utah
Latitude/Longitude:	39° 46' 10" Lat./111° 09' 10" Long
EPA Region:	Region VIII
EPA Major Basin Name:	Colorado River Code: 11
EPA Minor Basin Name:	Green River Code: 6
Major Tributaries:	Pleasant Valley Creek, Fish Creek, Pondtown Creek, Miller Canyon Creek, Dry Valley Creek
Receiving Water Body:	Price River
Water Quality Standards:	Domestic Source, 1C; Recreation and Esthetics, 2B; Aquatic Wildlife, 3A; and Irrigation, 4

Use designations pertaining to Scofield Reservoir as given in Wastewater Disposal Regulations, Part II Standards of Quality of Waters of the State, 1965; Revised 1978, are:

Class 1C - Protected for domestic purposes with prior treatment by standard complete treatment processes as required by the Utah State Division of Health.

Class 2B - Protected for boating, water skiing, and similar uses, including recreational bathing (swimming).

Class 3A - Protected for cold water species of game fish and other cold water aquatic life, including the necessary aquatic organisms in their food chain.

Class 4 - Protected for agricultural uses including irrigation of crops and stockwatering.

Geological Description

Scofield Reservoir drainage lies in the Northern Wasatch Plateau and is shown in Figure 1-1. The economically important Wasatch Plateau coal field covers most of the drainage basin. The entire plateau is comprised of Cretaceous and Tertiary sedimentary rocks.

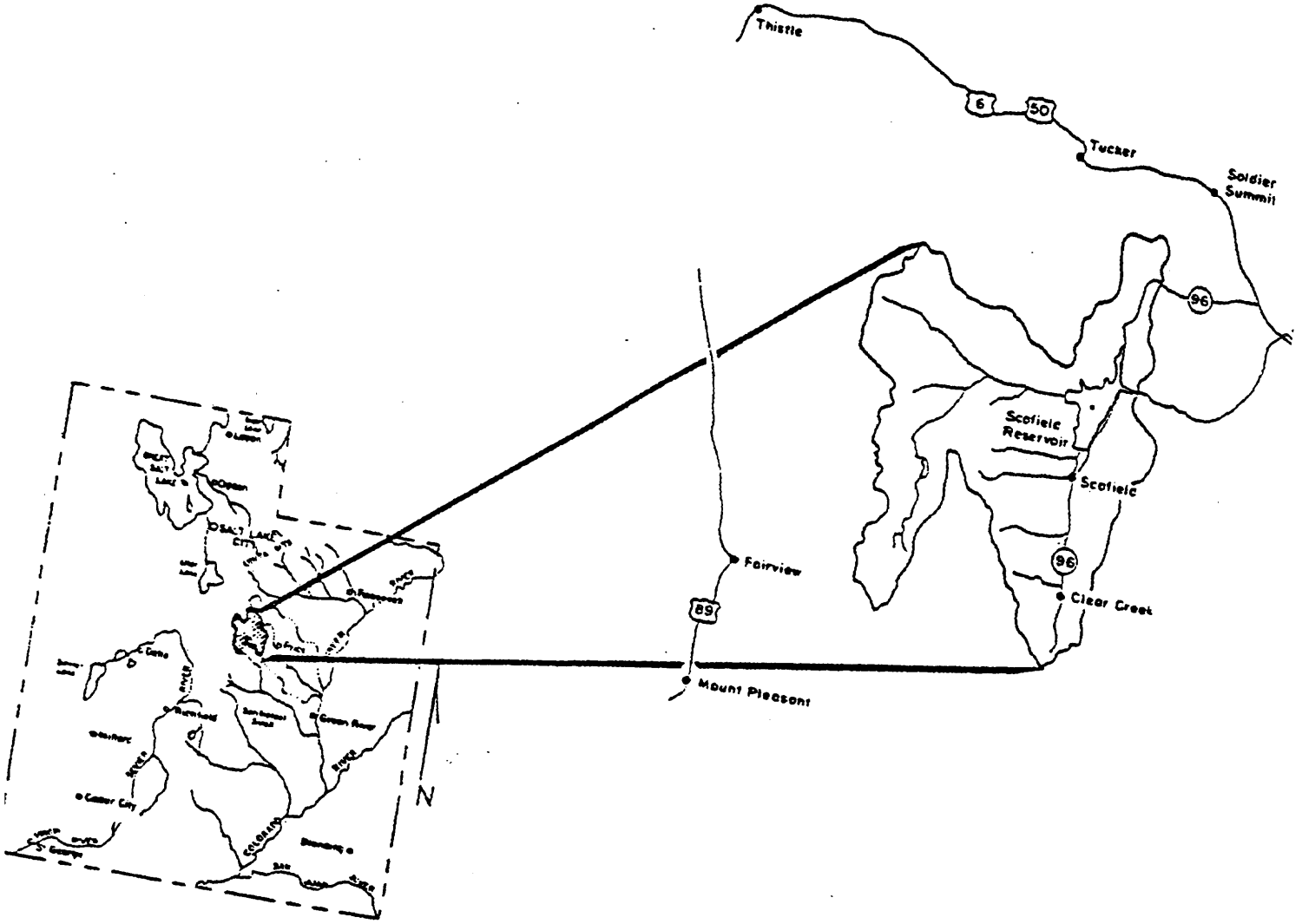

Figure 1-1 Location Map of Scofield Reservoir (from Clyde et al. 1981)

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The plateau consists of relatively flat-lying strata that has been deeply dissected by streams forming large canyons and side canyons and giving great local relief in much of the watershed. The high point is Monument Peak at 10,452 ft. elevation and the reservoir is at 7,618 ft. Slopes are steep in much of the basin ranging up to 50% to 70% in most of the main subbasins.

Groundwater capacity and movement is limited in most of the basin. No significant unconsolidated aquifers exist. Numerous faults and fractures lace the basin thus springs and seeps are often associated with these features. A small alluvial aquifer is found just to the south of the reservoir along Pleasant Valley Creek but it yields only an estimated 15 ac-ft/year (Hansen, 1980).

Description of Public Access

Public access to Scofield Reservoir can be attained through the Scofield Lake State Park. The State Park presently occupies 20 developed acres and 60 undeveloped acres. The Carbon County Park, and a private boat camp, Singleton's, offer boat launching and/or recreational facilities for the public. Information concerning the services available as given in Table 1-1.

Most of the Scofield Reservoir shoreline is privately owned, much of which has been closed to the public, reportedly because of past instances of vandalism and littering.

Public shore access is primarily in the State and County Park areas of the north arm and channel leading to the dam, with additional shore fishing occurring along the right-of-way of U-96 adjacent to the southeastern shore of the lake. The Bureau of Reclamation (BOR) owns property that is available to the public in the channel area west of the dam and also on the west side of the lake at the mouth of Fish Creek. The area in and around Singleton's Boat Camp is currently under investigation as to ownership. BOR claims and surveys may establish federal ownership. These access points are shown on Figure 1-2.

The main route to Scofield Reservoir from Carbon and Emery Counties is by way of US-50 from Price to Colton, then 13 miles to the reservoir on U-96. The majority of lake users come from the "Wasatch Front" area of Utah (Utah, Salt Lake, Davis and Weber Counties) via US-50 up Spanish Fork Canyon to Colton and over to the reservoir on U-96. Completion of the new road in Eccles Canyon through upper Huntington Canyon north of Electric Lake and across to Gooseberry Valley connecting U-96 in Pleasant Valley with U-31 in Fairview Canyon will increase the number of miners and fishermen coming to Pleasant Valley from Sanpete County. Table 1-2 gives the distance to towns and cities in the area.

There are no regular scheduled public transportation services to Scofield Reservoir. Price, Utah is the closest city offering bus, rail and small aircraft facilities.

Table 1-1. Description of public access points around Scofield Reservoir.

Name	Responsible Agency	Type	Land Area(ac.)	Lake Frontage	Type and Capacity of Facilities
State Park	Utah Dept. of Parks & Recreation	State Park	20 Dev. 60 Undev.	350 ft.	Boat ramp for large boats. Parking for 80 cars and boat trailers. 40 stalls for campers and trailers. Five-cleaning stations.
County Park	Carbon County	County Park	50	400 ft.	Boat ramp for large boats. Parking for 60 cars and boat trailers. Parking for 100 campers and trailers.
Single-ton's	Private	Boat Launch	12	250 ft.	Boat launching and camp, tie-up areas for boats, limited parking. Boats for rent. Store.

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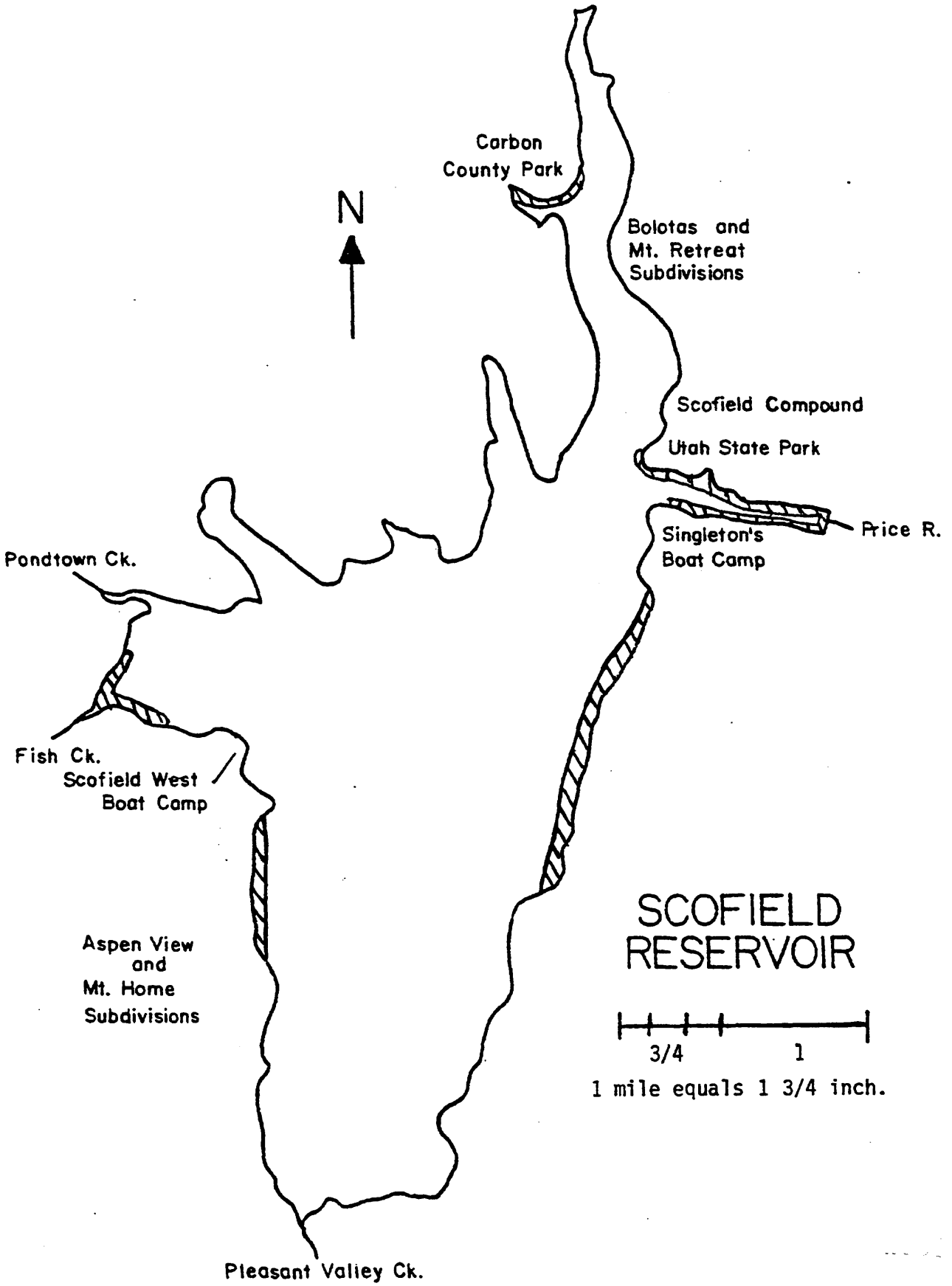

Figure 1-2. Public Access points and recreational developments at Scofield Reservoir.

Table 1-2. Distances of major population centers from Scofield Reservoir.

City	Via	Distance Miles	Kilometers
Duchesne	U-96, US-50, U-33	73	117
Fairview	U-96, U-31	28	45
Fairview	U-96, US-50, US-89	71	114
Huntington	U-96, US-50, U-10	59	94
Moab	U-96, US-50, I-70, US-163	154	246
Ogden	U-96, US-50, I-15	139	222
Price	U-96, US-50	39	62
Provo	U-96, US-50, I-15	65	104
Salt Lake City	U-96, US-50, I-15	107	171

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Description of Size and Economic Structure of Potential User Population

The people of Utah, with a 1980 census population of 1,461,037 comprise most of the potential users of Scofield Reservoir. The seven county area around Scofield Reservoir which extends into the 80 km radius from the lake had a total population of 187,272 in 1970 and 292,974 in 1980. This area had one of the fastest population and economic growths in the State primarily due to increases in energy production (coal, gas and oil). Statistical data on the population of the seven counties are given in Table 1-3.

Many of the people using the Scofield Reservoir area for fishing, boating, camping and other recreational purposes, come from Utah, Salt Lake, Davis and Weber Counties along the "Wasatch Front" of Utah from distances greater than 80 km and up to 200 km.

There is large seasonal increase in population in the Pleasant Vally-Scofield Town, and Clear Creek Town areas during the summer and fall months. Scofield Town, which normally has 75 to 100 winter residents, has 200 to 300 residents during the summer. There are nine developed subdivisions and camps surrounding Scofield Reservoir in addition to the dispersed camping on undeveloped land in the area. The State Park and the County Park provide short-term facilities. The Bolotas and Mt. Retreat Subdivisions on the east side of the north arm of the lake have 127 units while Scofield Campsite northwest of the State Park and on the east shore of the north area has 51 units. These are privately owned and operated and together with the 53 units at Singleton's Boat Camp on the south side of the channel across from the State Park and the 57 units at Scofield West Boat Camp on the west side of the lake, can greatly increase the number of people living near the lake during the summer. The new subdivisions of Mt. Home with 25 units on 12.5 acres and Aspen View with 6 units on 3 acres are located up the slope about one-half mile from the southwest shore of the lake.

Recreational establishments around the lake are given in Table 1-4 and shown in Figure 1-2.

Approximately 200 people live in the Pleasant Valley area year around, the local population fluctuates widely depending on the coal market and the number of miners employed in the coal mines in the Pleasant Valley area. Price, Utah is the major center of population close to Scofield Reservoir, 38 miles distant, and had a population of 10,500 in 1980.

The average income in Carbon and Emery counties is higher than the state average because of higher mining wages. Sanpete County, which has primarily an agricultural economy, has income levels below the state average (see Table 1-5). The construction of an all-weather road (U-31) connecting Fairview with the Huntington Canyon mining areas has helped in making mining jobs available to workers from the Fairview - Mt. Pleasant areas. Workers from those two areas are presently being bused the long distance of 77 miles through Thistle and Soldiers Summit to work in the

Table 1-3. Land area and population of central Utah surrounding Scofield Reservoir.

County	Land Area in Miles ^{2}	1970 Pop.	Pop. Density Per Mile ^{2} in 1970	1980 Pop.	Pop. Density Per Mile^2 in 1980	Pop. 1970-80 % Change
Carbon	1,474	15,647	10.6	22,179	15.0	+41.7
Duchesne	3,260	7,299	2.2	12,565	3.9	+72.1
Emery	4,442	5,137	1.2	11,451	2.6	+122.9
Juab	3,412	4,574	1.3	5,530	1.6	+20.9
Sanpete	1,597	10,976	6.9	14,620	9.2	+33.2
Utah	1,998	137,776	69.0	218,106	109.2	+58.3
Wasatch	1,194	5,863	4.9	8,523	7.1	+45.4
TOTALS	17,377	187,272	10.8	292,974	16.9	+56.4

Source: Utah State Census Data Center, 1981. Statistics for Utah, 1980 Census; and Utah Industrial Development Division, 1980. County Economic Facts, 1980 ed.

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Table 1-4. Recreational camping and cabin units in the Scofield Reservoir Area.

Name	Land Developed Acreas	Number Recreational Units	Density (Units/ac)	Percent of Total Use
State Park	20	90	4.5	8
County Park	50	300	6.0	26
Bolotas	20	110	3.7	7
Scofield Campsite	7.3	51	3.3	2
Mt. Retreat	5	17	3.4	1
Aspen View	3	6	2.0	0
Mt. Home	12.5	25	2.0	2
Singleton's	12	43	3.3	3
Scofield West	27	57	3.7	9
Dispersed (Undeveloped Private Land)	157	460	3.0	40
TOTAL	313.8	1,169	3.63	100

Source: Land Design, 1982. Pleasant Valley Growth Management Plan. Carbon County Planning Department, 1983.

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Table 1-5. Number and percent * of nonagricultural employees by county and major industrial classification, 1979.

	Carbon County	Duchesne County	Emery County	Juab County	Sanpete County	Utah County	Wasatch County
Mining	2,210(27%)	790(22%)	1,935(42%)	80 (5%)	35 (1%)	270 (1%)	60 (3%)
Contract Construction	305 (4%)	180 (5%)	915(20%)	95 (6%)	150 (4%)	4,520 (7%)	330(16%)
Manufacturing	310 (4%)	145 (4%)	25 (1%)	440(26%)	865(26%)	13,475(21%)	140 (7%)
Transportation & Public Utilities	640 (8%)	170 (5%)	485(10%)	65 (4%)	85 (3%)	2,230 (3%)	40 (2%)
Wholesale & Retail Trade	1,795(22%)	900(26%)	350 (6%)	390(23%)	550(16%)	12,990(20%)	480(24%)
Finance, Insurances, Real Estate	240 (3%)	75 (2%)	45 (1%)	40 (2%)	85 (3%)	2,135 (3%)	70 (3%)
Service & Miscellaneous	850(10%)	280 (8%)	235 (5%)	130 (8%)	365(11%)	18,550(29%)	310(15%)
Government	1,890(23%)	975(28%)	655(14%)	460(27%)	1,205(36%)	10,605(16%)	605(30%)

* Total may not add up to 100% due to rounding off.

Source: Bureau of Economic and Business Research, 1980. County Economic Facts, 1980 ed.
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Skyline Mine. The completion of an all-weather road up Eccles Canyon and through the upper Huntington Creek drainage connecting with the present U-31 south of Gooseberry Reservoir will make the distance from Fairview to the Pleasant Valley mining areas only about 23 miles. This road will probably also increase recreation traffic to Scofield Reservoir from Sanpete County.

The sheep and cattle growing activities are also very important in the Scofield Reservoir drainage with a small amount of timbering primarily for mining timbers. About 5,000 cattle and 15,000 sheep graze on the watershed each year, (Clyde et al., 1981).

Adequate housing is in short supply in Pleasant Valley during times of high coal production and mining employment. The problems of limited available potable water rights, steep slopes and high ground water level around the town of Scofield and in Pleasant Valley combine to limit the number of dwellings that can be built in the area under present conditions (Land Design, 1982).

Scofield Reservoir is very important to the economy of Carbon County. It serves as an important storage reservoir for irrigation water used on farms in the lower Price River basin. It is also an important source of culinary water for homes in the Price-Helper area, the most populated part of the county. The reservoir is one of the most important sport fisheries in the central part of the state with high growth rates and good returns of the fish that are planted.

Summary of Historical Lakes Uses

The Price River Water Conservation District was formed in 1922. The district bonded for $750,000 to raise money to build Pleasant Valley (Scofield) Reservoir, to buy reservoir land and water rights, and to move the Denver and Rio Grande Railroad tracks in the reservoir area. Approximately $600,000 were actually spent for these activities. The purpose of the dam was for supplying additional irrigation downstream, largely along the Price River. (Wayman, 1928)

The first dam was built in 1925. Construction plans called for a rolled clay and gravel and rock fill dam with puddled clay forming the core, and faced by a hand-laid dry rock wall. (Snyder, 1936). Filling of the reservoir was started immediately after construction. A partial failure of the dam, which was attributed to excessive settlement, occurred on May 21, 1927 when the reservoir contained 54,000 acre feet of water. The quantity of water stored in the reservoir after the partial dam failure was restricted by the State Engineer. Twenty drill holes in 1936 determined that a pervious sandstone foundation carried water around the dam to seep areas. The present USBR dam was constructed, starting in 1943, 800 feet downstream of the old dam by the W. W. Clyde Company. The Denver and Rio Grande Railroad was considered a vital transportation link in the war effort and possible failure of the old dam was considered a threat to the railway. Construction of the new dam was completed June 15, 1946 giving a reservoir with storage capacity of 73,600 acre-feet of water.

The uses of the reservoir water include:

1. Irrigation for 14,000 acres in the Price River drainage.
2. Culinary water for 20,000 people in the Price-Helper area.
3. Fishing.
4. Waterskiing and pleasure-boating.
5. Habitat for waterfowl and other birds and animals.
6. Snowmobiling

The Utah State Park is a major avenue of access to the lake. Visitation data for Scofield Lake State Park for 1981-82 is given in Table 1-6 and for 1972-82 in Table 1-7. The data shows the seasonal variations with usage during the fishing season indicating primarily a fishery-based recreational use of the lake. Scofield Reservoir was treated for rough fish during the fall of 1977 and reopened for fishing in 1979. Fishing pressure was increased in 1977 to remove the fish prior to treatment. Activity on the lake in 1978 was limited to boating, waterskiing and other nonfishing activities. The heavy fishing pressure during 1979 was in response to the reopened fishing.

The greatest recreational usage on Scofield Reservoir is fishing followed by waterskiing and pleasure-boating. Some snowmobiling and cross-country skiing occur during the winter. According to data published by the Bureau of Reclamation, there were 122,450 total visitation days in 1979 in the Scofield Reservoir area, distributed as follows: fishing, 78,297; camping, 18,392; sightseeing, 6,594; hunting, 5,742; boating, 5,720; picnicking, 3,923; and waterskiing, 3,032. Their data gave a total sport-fishing catch of 200,000 fish from the reservoir in 1979.

Scofield Reservoir is an important stopping place for waterfowl in the Rocky Mountain flyway. Large flocks of birds use the shallow southern and western arms of the reservoir in the fall. Some broods of young were observed each spring in the shallow nesting areas indicating that a small population of waterfowl summers on the reservoir.

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Table 1-6. Visitations to Scofield State Park, 1981 - 1982.

YEAR	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	YEAR TOTAL
1981	219	481	67	26	7,648	17,544	16,430	13,599	11,140	4,907	1,755	91	73,897
1982	627	833	913	390	10,440	15,718	16,886	9,108	4,821	2,601	66	154	62,557

Table 1-7. Annual visitations to Scofield State Park, 1972-1982.

YEAR	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982
	19,959	20,612	22,879	29,610	38,572	58,155	15,981	122,453	74,564	73,897	62,557

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Population Segments Adversely Affected by Lake Degradation

Problems of concern associated with continued degradation of water quality are:

1. Aesethetics deterioration caused by increased algae and macrophyte growth which increase turbidity, unsightly debris, odors, etc.

2. Lower summer and winter dissolved oxygen (DO) levels in the hypolimnion. Extended periods of anoxic conditions in the hypolimnion results in additional phosphorus releases from the sediments which tend to stimulate additional growth in phytoplankton and macrophytes.

3. Fewer fish as a result of worsening habitat and fish kills such as occurred in shallow areas in August of 1981. The fish kill was likely due to low oxygen concentrations resulting from respiration in extensive blue green algae blooms and macrophytes.

4. Taste and odor problems in culinary water used downstream brought about by the large growth of taste and odor causing algae.

Scofield is presently a very productive body of water supporting a good rainbow and cutthroat trout fishery. The growth rates for the two species are excellent. One problem occurring during the study was the loss of most of the fingerling rainbow trout year-class planted in the spring of 1981. The cause of the loss was not pinpointed but was likely caused by low DO levels which was rendered more serious by toxins released by blue-green algae decomposition. There is concern that further eutrophication of the reservoir will lead to additional fish kills, especially during summers such as 1981 when low water levels, high temperatures, and decreased oxygen levels were experienced. Increasing eutrophication, caused by high and increasing nitrogen and phosphorus loads into the reservoir, would probably lead to larger blooms of toxin, taste and odor-producing blue-green algae. Blue green algae have become a problem and could contribute to fish kills in the reservoir. Blue greens cause particularly bad tastes and odors in these waters used for culinary purposes in the Price-Helper area.

Comparison of Lake Uses of Other Lakes in Region

Scofield Reservoir, like most other Utah reservoirs, serves as an important source of irrigation water. The water is stored in reservoirs primarily during the spring runoff. The high plateau areas of the Scofield drainage receive over 30 inches of precipitation compared to less than 12 inches in Castle Valley (Price and Waddell, 1973). Most the reservoirs supply summer irrigation water to hot, low-land areas with high evaporation rates. Some, such as Scofield Reservoir and Joe's Valley Reservoir, are also used as sources of culinary water.

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There are twenty other public lakes and reservoirs within 80km of Scofield Reservoir. Data dealing with visitation data at other state parks are given in Table 1-8 while comparative use data for several major reservoirs are given in Table 1-9.

The major reservoirs in the area are very important sources of recreation due to their accessibility, relatively large sizes, and high aquatic productivity when compared to existing, smaller, high-mountain natural lakes. They are also important to migratory birds as stop-over resting areas as well as nesting areas for summer resident species.

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Table 1-8. Comparative visitations, 1972-1980 of Utah State Parks at lakes within 80 km of Scofield Reservoir.

STATE PARK	1972	1973	1974	1975	1976	1977	1978	1979	1980	TOTAL
Deer Ckeek Reservoir	45,904	93,693	132,388	214,280	241,407	263,856	351,571	477,177	494,748	2,365,024
Huntington North Lake	43,792	45,852	48,952	48,776	104,183	94,911	117,518	94,923	96,810	695,717
Millsite Reservoir	7,579	16,160	16,972	16,080	19,143	17,874	15,384	28,626	34,662	182,480
Palisade Lake	74,820	55,059	11,179	23,823	36,492	31,910	39,831	36,850	20,328	330,292
Scofield Reservoir	19,959	20,612	22,879	29,610	38,572	58,155	15,981	122,453	74,564	402,785
Starvation Reservoir	54,096	99,293	65,254	63,273	44,952	106,247	103,990	72,160	32,001	641,266
Utah Lake	63,229	250,240	252,467	292,874	398,628	490,651	443,618	516,905	581,357	3,388,969

Data Compiled by Utah Department of Parks and Recreation.

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Table 1-9. Comparative lake uses of some public lakes and reservoirs within 80 km of Scofield Reservoir.

	Deer Creek Res.	Huntington North Res.	Joe's Valley Res.	Scofield Res.	Soldier Creek Res.	Starvation Res.	Strawberry Res.
Surface Area (acres)	3,435	237	1,160	2,804	752	3,445	6,500
VISITATIONS							
Sightseeing	37,850	10,673	8,300	6,594	2,306	14,360	4,449
Picnicking	3,000	25,800	4,200	3,923	1,729	3,140	0
Camping	96,000	4,050	41,000	18,892	13,258	17,887	8,898
Swimming	2,880	13,700	150	0	576	950	0
Waterskiing	37,652	16,000	50	3,032	576	2,650	0
Boating	125,220	14,600	4,300	5,720	10,376	12,859	0
Fishing	179,790	8,000	31,200	78,296	28,246	17,776	197,977
Hunting	996	1,800	2,400	5,742	576	0	8,898
Other	400	300	250	0	2,000	338	2,224
Total Visitations	483,788	94,923	91,950	122,450	59,643	72,160	222,446
Fish-Sport Catch	105,000	3,000	60,000	200,000	148,000	14,200	289,836

Data Compiled by the Bureau of Reclamation
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Point Source Pollution Discharges in the Scofield Reservoir Drainage Basin

There are five coal mines holding six NPDES permits in the Pleasant Valley Creek subbasin. Details concerning the permits are given in Table 1-10. Virtually all of the permits have identical requirements as given in Table 1-11.

Table 1-10. Point source inventory.

Name	NPDES #	Receiving Water
Blazon Company No. 1 Mine	UT-0023647	Pleasant Valley Creek
Coastal States Skyline Mine	UT-0023540	Eccles Creek
First Western Coal Co. Aletha # 1 Mine	UT-0023876	Scofield Reservoir
UCO, Inc. (Mine) Scofield Mine (Loadout)	UT-0023931 UT-0023990	Winter Quarters Creek Millers Creek
Valley Camp of Utah Bellina # 1 and 2 Mines	UT-0022985	Whiskey Creek to Eccles Creek

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Table 1-11. NPDES effluent requirements for Pleasant Valley Mines.

EFFLUENT CHARACTERISTIC	DISCHARGE LIMITATION			MONITORING REQUIREMENTS	
	Daily Average	7-Day Average b/	Daily Maximum	Measurement Frequency	Sample Type
Flow - M^3/Day, gpd	N/A	N/A	N/A	Monthly	Measured a/d/
Total Suspended Solids	25 mg/l	35 mg/l	70 mg/l	Monthly	Grab
Total Iron	N/A	N/A	2.0 mg/l c/	Monthly	Grab
Total Dissolved Solids	N/A	N/A	N/A e/	Monthly	Grab

Oil and Grease shall not exceed 10 mg/l and shall be monitored monthly by a grab sample.

The pH shall not be less than 6.5 standard units nor greater than 9.0 standard units and shall be monitored twice per month by grab sample.

There shall be no discharge of floating solids or visible foam in other than trace amounts.

There shall be no discharge of sanitary wastes.

See Schedule of Compliance. Samples taken in compliance with the monitoring requirements specified above shall be taken at the following location(s): At any point which is representative of each discharge prior to its mixing with the receiving stream and as indicated by the solid triangles on the current area maps submitted pursuant to Part III, A.1.

a/ See Part I, C.3.c.

b/ This limitation shall be determined by the arithmetic mean of a minimum of three (3) consecutive samples taken on separate days in a 7-day period (minimum total of three (3) samples).

c/ If any Iron analysis exceeds this limitation, the State of Utah and the permittee shall review the actions necessary to achieve compliance with the limitation and the continued appropriateness of the limitation. In no event shall the discharge exceed a daily maximum limitation for Total Iron of seven (7) milligrams per liter.

d/ For the intermittent discharges, the duration of the discharge shall be reported.

e/ The total amount of Total Dissolved Solids (TDS) discharged from all outfalls is limited to one ton (2,000 pounds) per day of TDS.

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SECTION 2

BASIN HYDROLOGY AND WATER QUALITY

Field Work

Field work for this study involved monitoring water quality and measuring flowrates at selected sampling stations in the basin. Samples were collected by Utah Division of Environmental Health personnel over a two year period beginning in September 1980, and analyzed at the Utah State Health Laboratory. Thirteen stream sampling sites were chosen. Six of these stations were established on major streams flowing directly into the reservoir; six were located along the upper reaches of Pleasant Valley Creek and its tributaries; and one station was set up on the Price River immediately downstream from Scofield Dam (see Figure 2-1). The sampling sites were selected with the objectives of acquiring information to isolate significant sources of pollutants, and monitoring their movement through the reservoir.

Determination of Flowrates

Estimates of typical monthly and annual flowrates were needed to define basin hydrology and compute pollutant loadings for nutrients and other constituents. These estimates were derived by compiling the limited study flowrate information and other available hydrologic records, delineating subbasins, and applying hydrologic principles to estimate runoff from each subbasin as described below.

Three U.S. Geological Survey (USGS) gaging stations provided longterm flow records for Price River, Fish Creek, and Gooseberry Creek, a tributary of Fish Creek. The USGS also supplied a hydrograph of daily flow during the 1981 water year for Pondtown Creek. The Division of Environmental Health personnel measured streams at sampling sites several times during the sampling period. In addition, the Utah Division of Water Resources (1978) combined USGS gaging station records, irrigation water depletions, and estimates of reservoir evaporation and precipitation to establish a water budget for the Upper Price River Basin (see Table 2-1). Their value was used as the best estimate of flow leaving the reservoir (45,066 ac ft/yr).

Scofield basin was then divided into thirteen subbasins as shown in Figure 2-2. Each subbasin was defined as the entire upstream area tributary to a stream sampling station and given the code designation of that station. The area of each subbasin was determined by planimetry.

The next step involved distributing the annual reservoir inflow among its six major tributaries. Fish Creek inflow was readily computed by subtracting diversions from Gooseberry Creek from the total flow measured for Fish Creek. Pondtown Creek flowrates were estimated by multiplying measured 1981 monthly flow rates by the ratio of average Fish Creek flows to 1981 Fish Creek flows. A similar method was used to establish Pleasant Valley Creek flowrates using flow data collected by the Division of Environmental Health during the sampling period.

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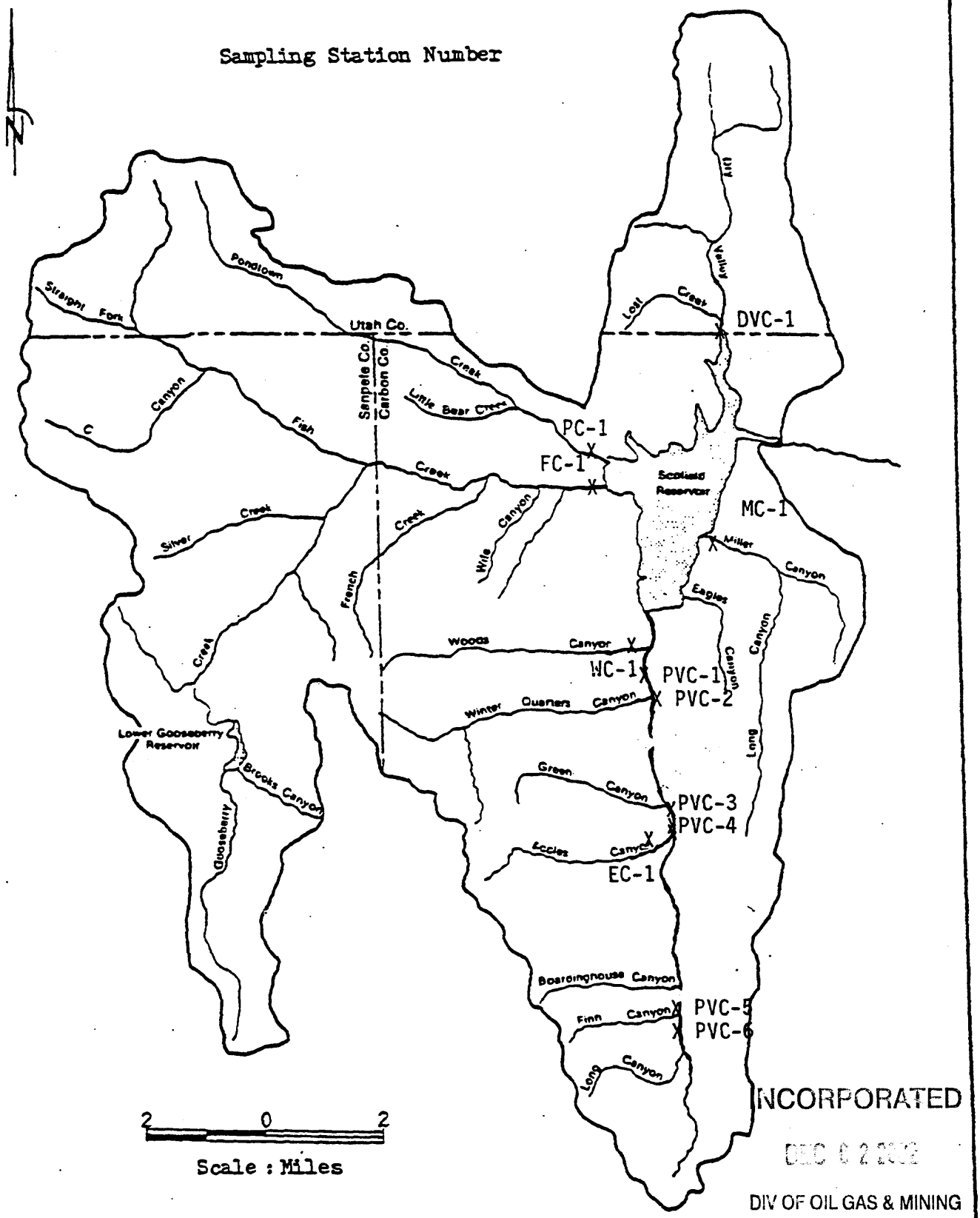

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Figure 2-1. Stream Sampling Stations in the Scofield Basin.

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Table 2-1. Water budget for the Upper Price River Basin. ac. ft / year

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANNUAL
Climatological Data													
Temperature °F	41.6	28.3	21.1	17.6	20.9	28.2	38.1	46.2	53.4	61.3	60.1	52.5	39.1
Precipitation inches	1.06	1.07	1.51	1.50	1.70	1.54	1.01	1.10	.62	1.17	1.38	1.06	14.72
Subarea Supply													
River Inflow													
Price River near Scofield	1,561	448	337	151	114	123	1,161	7,410	10,437	11,089	7,216	5,019	45,066
Tributary Inflow													
White River near Soldier Summit	243	218	200	188	198	559	3,011	7,336	2,055	679	333	246	15,266
Beaver Creek	62	54	58	57	60	103	326	1,319	723	195	69	47	3,073
Willow Creek	116	70	44	45	62	303	1,213	2,371	855	375	218	128	5,800
Ungaged	1,266	880	979	952	1,275	3,421	3,737	4,281	2,369	1,177	1,131	1,048	22,516
Exports													
Price City	260	260	240	215	215	250	260	315	350	350	350	335	3,400
Helper City	155	155	145	125	125	145	155	185	205	205	205	195	2,000
Groundwater Withdrawals													
Utah Power and Light Co. Wells	110	60						110	110	120	120	70	700
Subtotal	2,943	1,315	1,233	1,053	1,369	4,114	9,033	22,327	15,994	13,080	8,532	6,028	87,021
Cropland effective precipitation	61							64	36	68	80	61	370
Total Subarea Supply	3,004	1,315	1,233	1,053	1,369	4,114	9,033	22,391	16,030	13,148	8,612	6,089	87,391
Withdrawals (Diversions)													
Industrial													
Utah Power and Light	170	222	250	240	190	242	225	242	282	267	258	212	2,800
American Electric	35	35	35	35	35	35	35	35	35	35	35	35	420
Irrigation (@ 40% overall efficiency)	133							242	390	520	455	282	2,022
Total	338	257	285	275	225	277	260	519	707	822	748	529	5,242
Depletions (Consumptive Use)													
Industrial													
Utah Power and Light	170	222	250	240	190	242	225	242	282	267	258	212	2,800
American Electric	35	35	35	35	35	35	35	35	35	35	35	35	420
Irrigation	53							97	156	208	182	113	809
Total	258	257	285	275	225	277	260	374	473	510	475	360	4,029
Basin Outflow													
Surface													
Price river near Heiner	2,746	1,058	948	778	144	3,837	8,773	22,017	15,557	12,638	8,137	5,729	362

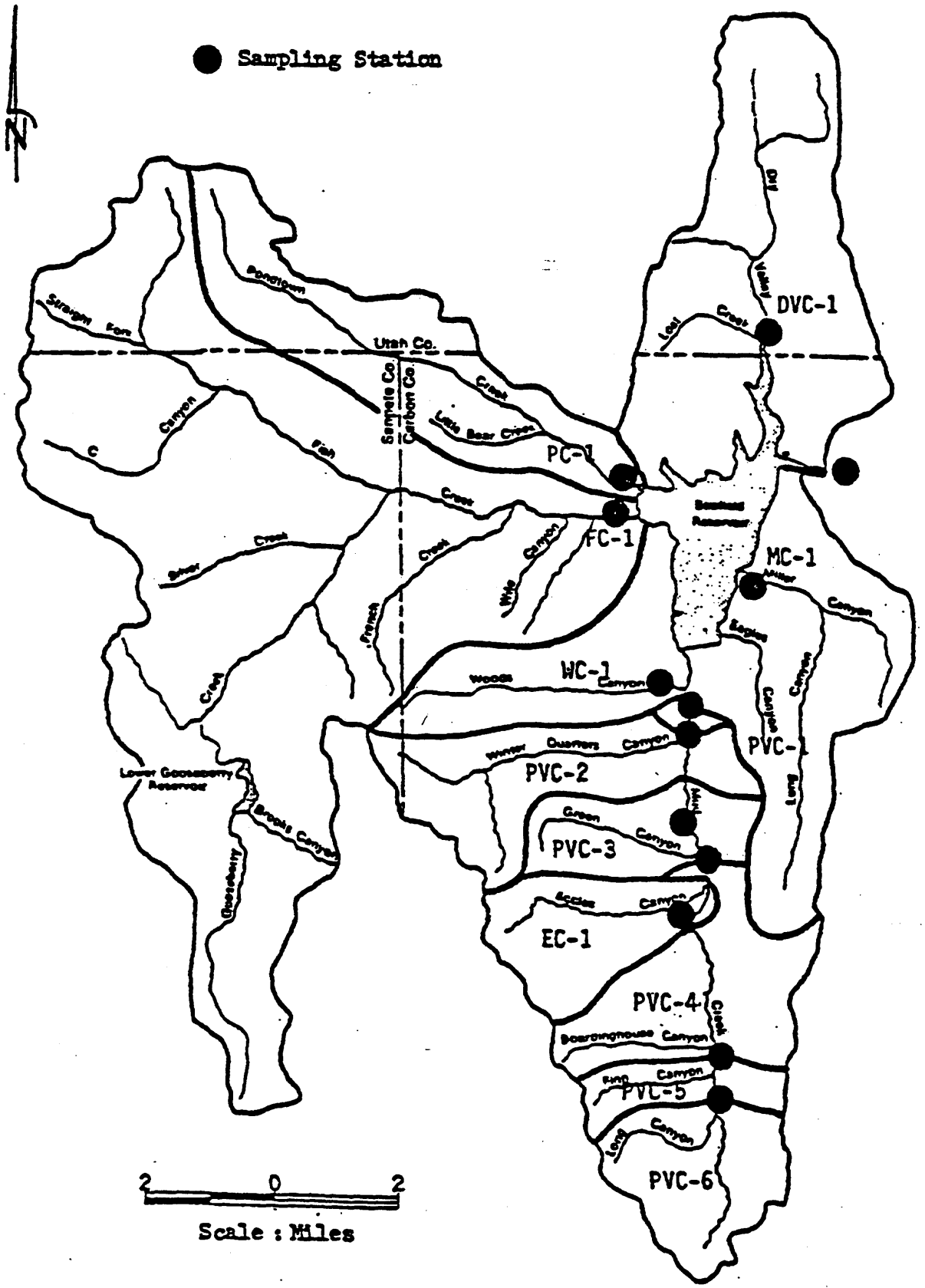

Figure 2-2. Stream sampling stations and designated subbasins in the Scofield Basin.

Dry Valley Creek and Miller Canyon Creek are located along the drier northern and eastern edge of the study basin. Both streams maintain a low, yet fairly constant, flow year-round with the exception of a moderate surge during spring run-off. Environmental Health personnel made estimates of base flows which were used to compute yearly flowrates. Annual discharge from Woods Canyon Creek was approximated using an area-flowrate correlation with Fish Creek. Estimates of average flowrates for upstream Pleasant Valley Creek sampling stations were derived using area-discharge relationships from nearby streams with known discharges and similar drainage basin topography. Resulting flowrates for all the stations are given in Table 2-2 and 2-3.

The Utah Water Research Laboratory (Clyde, et al., 1981) has estimated that groundwater enters the reservoir through alluvial deposits in Pleasant Valley (the basin's largest and most productive aquifer) at a rate of 14.7 acre-feet per year. This value is negligible compared to annual surface inflow. Seepage losses from the reservoir are unknown but thought to be small. Therefore, groundwater flow was assumed negligible in the hydrologic budget.

In a typical year the five major streams discharge 49,317 acre-feet of water into Scofield Reservoir. Direct precipitation supplies an additional 2,888 acre-feet to the reservoir giving a total annual inflow of 52,205 acre-feet. Approximately 5,728 acre-feet evaporate from the reservoir surface and 46,477 ac ft/yr are released into the Price River. The overall water budget is given in Table 2-4.

Water Quality in the Streams

Water quality concentrations for the various constituents were developed from data collected on streams in the watershed over a two year period beginning in September 1980.

Sampling points had been chosen earlier as the key points in monitoring and identifying the pollutant loadings in the subbasins. A summary of water quality in the basin streams is given in Table 2-5. A complete listing of the water quality data is available upon request from the State Division of Environmental Health.

A review of the water quality data indicates that the waters are generally of good quality. Based on flow-weighted averages and excluding the Price River we see a low Total Dissolved Solids (TDS), ranging from about 200 mg/l to 300 mg/l; moderate alkalinity ranging from about 150 mg/l to 220 mg/l; and moderate hardness, ranging from about 190 mg/l to 290 mg/l. Total Suspended Solids (TDS) values are occasionally quite high, especially during spring runoff or heavy sumer rainstorms. Total phosphorus concentrations are quite high, ranging from 0.07 mg/l to 0.34 mg/l. Nitrogen species are moderately low with Total Kjeldahl Nitrogen (TKN) below 1.0 mg/l, ammonia (NH_3) below 0.06 mg/l, and nitrate (NO_3) below 0.60 mg/l.

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Table 2-2. Average flowrates for streams in the Scofield Basin (ac/ft).

Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Total
FC-1	511	477	715	3,343	16,269	7,859	1,859	946	643	674	633	588	34,487
PC-1	44	48	91	230	1,420	688	71	60	55	51	48	45	2,851
PVC-1	282	273	337	559	5,083	597	199	142	151	240	288	290	8,441
WC-1	21	19	28	65	480	270	33	29	27	26	23	22	1,043
MC-1	25	23	31	53	149	81	42	35	31	30	28	26	554
DVC-1	33	32	36	170	321	136	41	36	35	34	34	33	941
PVC-6	63	60	76	112	1,055	176	94	76	780	69	66	65	1,982
PVC-5	81	78	97	141	1,315	217	120	97	86	84	83	84	2,483
PVC-4	182	175	216	316	2,867	462	266	217	193	191	186	187	5,458
PVC-3	188	181	173	326	2,958	477	275	223	200	198	192	193	5,633
PVC-2	287	276	342	495	4,405	698	421	344	303	313	293	295	8,473
EC-1	43	41	51	76	679	108	64	53	45	45	44	44	1,293
SW-1	Monthly distribution not estimated.												1,000
PR-1	151	114	123	1,161	7,410	10,437	11,089	7,216	5,019	1,561	448	337	46,477

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Table 2-3. Scofield Reservoir watershed subbasin areas and annual flowrates.

Station No.	Station Name	Subbasin Area[a] (Acres)	Annual Flow (ac ft/yr)	Location
1	FC-1	41,600	34,487	Fish Creek above Scofield Res.
2	PC-1	7,750	2,851	Pondtown Creek above Scofield Res.
3	PVC-1	22,690	8,441	Pleasant Valley Cr. above Scofield Res.
4	WC-1	3,370	1,043	Woods Canyon Cr. above Pleasant Cr. Confluence
5	MC-1	5,250	554	Miller Canyon Creek above Scofield Res.
6	DVC-1	8,070	941	Dry Valley Cr. above Scofield Res.
7	PVC-6	3,470	1,982	Pleasant Valley Cr. above Clear Cr.
8	PVC-5	5,110	2,483	Pleasant Valley Cr. below Clear Cr.
9	PVC-4	14,140	5,458	Pleasant Valley Cr. above Valley Camp
10	PVC-3	16,210	5,633	Pleasant Valley Cr. below Valley Camp
11	PVC-2	21,750	8,473	Pleasant Valley Cr. above Scofield Town
12	EC-1	3,460	1,293	Eccles Canyon Cr. above Pleasant Cr. Confluence
13	SW-1	6,700	1,000	Direct Runoff (ungaged) from the Lake Shoreline
14	PR-1	98,410	46,477	Price River below Scofield Res.

[a] All drainage area tributary to each station, see Figure 2-1 for locations.

Table 2-4. Annual water budget for Scofield Reservoir.

INFLOW		Ac Ft.
Tributaries:	Fish Creek	34,487
	Pleasant Valley Creek	8,441
	Pondtown Creek	2,851
	Woods Canyon Creek	1,043
	Dry Valley Creek	941
	Miller Creek	554
Shoreline Wash		1,000
Subtotal		49,317
Precipitation:	(16.1 in/yr)[a]	2,888
Total Inflow:		52,205
OUTFLOW		
Deletion[b]		1,411
Discharge:	Price River	45,066
Evaporation:	(24.5 in/yr)[c]	5,728
Total Outflow:		52,205

a Water Resources 1978

b Recent additional outflow. Used in Pleasant Valley for irrigation and mining.

c This approximate value was estimated by study personnel and should not be used as data values since detailed investigations were not made on this component.

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Table 2-5. Water quality summary for Scofield Reservoir tributaries.

STATION		Temp. °C	DO mg/l	pH units	Alk mg/l	PO_4-P mg/l	TP-P mg/l	NH_3-N mg/l	NO_3-N mg/l	TKN-N mg/l
		Water Quality Parameter								
DVC-01	A. Avg.[a]	8.8	7.8	8.0	179	0.050	0.12	0.03	0.07	0.36
	Wght. Avg.[b]	9.1	7.7	7.8	173	0.047	0.11	0.03	0.08	0.39
	Min.	5.2	5.6	7.5	66	0.020	0.05	0.03	0.00	0.20
	Max.	16.2	9.1	8.9	235	0.070	0.25	0.05	0.13	0.60
	Stnd. Dev.	4.4	1.3	0.6	66	0.019	0.08	0.01	0.05	0.15
FC-01	A. Avg.	11.3	8.5	8.3	166	0.019	0.05	0.06	0.23	0.36
	Wght. Avg.	9.2	8.5	8.2	175	0.028	0.07	0.05	0.28	0.44
	Min.	0.1	4.5	8.0	134	0.002	0.00	0.03	0.00	0.05
	Max.	22.0	12.3	8.6	200	0.100	0.15	0.20	0.95	0.90
	Stnd. Dev.	6.6	1.9	0.2	19	0.022	0.04	0.04	0.23	0.22
MC-01	A. Avg.	12.3	7.6	8.1	222	0.052	0.13	0.04	0.35	0.83
	Wght. Avg.	12.6	7.0	8.1	221	0.051	0.14	0.04	0.40	0.96
	Min.	6.8	6.0	7.9	192	0.005	0.05	0.03	0.00	0.50
	Max.	22.0	11.3	8.4	261	0.180	0.30	0.05	1.00	2.10
	Stnd. Dev.	4.3	1.6	0.2	20	0.057	0.09	0.01	0.30	0.51
PC-01	A. Avg.	11.7	8.3	8.2	201	0.028	0.08	0.06	0.26	0.34
	Wght. Avg.	10.5	7.9	8.2	194	0.046	0.08	0.06	0.43	0.37
	Min.	0.1	3.7	7.6	171	0.002	0.01	0.03	0.00	0.10
	Max.	22.2	12.5	8.5	244	0.140	0.60	0.30	1.40	0.80
	Stnd. Dev.	6.6	1.7	0.2	18	0.033	0.11	0.06	0.32	0.15

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Table 2-5. Continued

STATION		Temp. °C	DO mg/l	pH units	Alk mg/l	PO_4-P mg/l	TP-P mg/l	NH_3-N mg/l	NO_3-N mg/l	TKN-N mg/l
		Water Quality Parameter								
PVC-01	A. Avg.	10.5	8.3	8.3	191	0.044	0.13	0.05	0.26	0.38
	Wght. Avg.	8.3	8.1	8.3	177	0.074	0.24	0.05	0.41	0.58
	Min.	0.1	4.7	8.0	130	0.002	0.01	0.03	0.00	0.10
	Max.	24.3	12.4	8.6	264	0.280	1.10	0.20	2.97	1.80
	Stnd. Dev.	7.1	1.6	0.2	33	0.063	0.20	0.03	0.51	0.30
WC-01	A. Avg.	12.4	6.7	8.2	195	0.051	0.13	0.06	0.28	0.49
	Wght. Avg.	11.5	7.2	8.3	181	0.082	0.23	0.04	0.43	0.63
	Min.	4.9	2.9	7.1	146	0.002	0.00	0.03	0.00	0.05
	Max.	23.8	11.3	8.4	254	0.280	0.67	0.20	1.37	1.40
	Stnd. Dev.	6.5	2.0	0.3	30	0.074	0.17	0.04	0.33	0.36
PVC-02	A. Avg.	10.7	7.9	8.2	195	0.032	0.12	0.04	0.26	0.49
	Wght. Avg.	10.2	8.0	8.3	189	0.045	0.14	0.04	0.45	0.57
	Min.	0.1	4.8	8.0	120	0.005	0.00	0.03	0.00	0.10
	Max.	23.0	11.7	8.3	261	0.170	0.45	0.05	0.97	1.60
	Stnd. Dev.	7.3	1.6	0.1	36	0.043	0.13	0.01	0.29	0.40
PVC-03	A. Avg.	10.6	7.9	8.2	200	0.055	0.17	0.05	0.24	0.39
	Wght. Avg.	9.5	8.0	0.2	195	0.056	0.18	0.05	0.38	0.53
	Min.	0.7	4.6	8.0	151	0.002	0.00	0.03	0.00	0.10
	Max.	21.5	11.5	8.3	259	0.480	1.10	0.10	0.17	1.80
	Stnd. Dev.	6.4	1.6	0.1	31	0.105	0.25	0.02	0.31	0.34

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Table 2-5. Continued

STATION		Temp. °C	DO mg/l	pH units	Alk mg/l	PO_4-P mg/l	TP-P mg/l	NH_3-N mg/l	NO_3-N mg/l	TKN-N mg/l
		Water Quality Parameter								
PVC-04	A. Avg.	10.1	8.0	8.2	199	0.040	0.15	0.04	0.26	0.35
	Wght. Avg.	9.3	8.0	8.2	194	0.048	0.17	0.04	0.45	0.34
	Min.	1.4	4.7	8.1	151	0.002	0.00	0.03	0.00	0.05
	Max.	21.0	12.4	8.3	256	0.260	0.56	0.10	1.23	1.40
	Stnd. Dev.	5.6	1.7	0.1	32	0.063	0.17	0.02	0.33	0.28
EC-01	A. Avg.	10.1	8.1	8.2	193	0.055	0.20	0.04	0.29	0.44
	Wght. Avg.	8.7	8.4	8.2	184	0.108	0.34	0.05	0.59	0.52
	Min.	1.6	4.4	7.9	154	0.002	0.00	0.00	0.00	0.05
	Max.	21.0	12.4	8.3	238	0.370	0.87	0.10	1.40	1.30
	Stnd. Dev.	5.3	2.0	0.1	25	0.092	0.25	0.02	0.36	0.35
PVC-05	A. Avg.	8.5	7.8	8.1	208	0.053	0.12	0.08	0.34	0.38
	Wght. Avg.	8.9	7.6	8.3	198	0.075	0.13	0.05	0.41	0.48
	Min.	2.5	6.8	7.5	131	0.005	0.04	0.03	0.00	0.05
	Max.	17.6	12.0	8.3	284	0.180	0.26	0.30	1.20	1.00
	Stnd. Dev.	3.8	2.2	0.2	45	0.039	0.05	0.08	0.27	0.24
PVC-06	A. Avg.	9.0	8.2	8.3	158	0.034	0.09	0.07	0.25	0.49
	Wght. Avg.	7.3	8.2	8.3	154	0.045	0.10	0.05	0.28	0.57
	Min.	0.1	4.8	7.8	120	0.010	0.03	0.03	0.00	0.10
	Max.	19.7	12.7	8.6	194	0.140	0.30	0.60	0.85	0.90
	Stnd. Dev.	6.2	1.8	0.2	26	0.030	0.07	0.13	0.27	0.22

Table 2-5. Continued

STATION		Temp. °C	DO mg/l	pH units	Alk mg/l	PO_4-P mg/l	TP-P mg/l	NH_3-N mg/l	NO_3-N mg/l	TKN-N mg/l
				Water Quality Parameter						
	A. Avg.	11.6	7.6	8.3	155	0.018	0.05	0.08	0.27	0.53
	Wght. Avg.	11.4	8.4	8.3	145	0.016	0.05	0.06	0.29	0.52
PR-1	Min.	0.2	4.7	7.9	132	0.005	0.00	0.03	0.00	0.10
	Max.	19.4	11.7	8.5	180	0.080	0.20	0.30	1.04	1.40
	Stnd. Dev.	5.6	1.6	0.2	13	0.017	0.05	0.06	0.26	0.26

a The arithmetic average includes all data at equal weight in the average.
b The flow weighted average is calculated by using the arithmetic monthly average for all data in each month and then using these monthly values and the monthly flowrate values to calculate a flow-weighted, annual weighted value.

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Benthos

Pleasant Valley Creek and Fish Creek are the major tributaries and were selected for limited benthos studies. Stream benthos in Pleasant Valley Creek and Fish Creek indicate systems of good water quality. Taxa indicative of good water quality, such as Ephemeroptera (mayflies), Plecoptera (stoneflies) and Trichoptera (caddisflies), are well represented in benthos samples. The diversity in both streams is similar but the mean number per square meter is much greater in Pleasant Valley Creek probable due to greater amounts of organic matter. Although both systems tranport large sediment loads during runoff, they apparently are not too detrimental to the benthic biota. The taxonomic identification, mean numbers and statistical analysis of data is included in Appendix B.

Loading Rates

Water quality concentrations were plotted as shown in Figure 2-3. These plots gave a feel for the shape of the curves and yearly variations encountered in the nearly two years of data collected. A smoothed trend curve was then fit by eye to give the best estimate of the "typical" year. Curves for total phosophorus, othophosphorus, inorganic nitrogen, Total Kjeldahl nitrogen and total suspended solids were thus developed.

Pollutant loadings were then calculated by multiplying the mean monthly flowrates by the mean quality values taken from the trend curves. This approach was used to smooth out the data and thus moderate atypical data values. Monthly loadings were summed for the year for each station and each of the constituents to give annual pollutant loading rates. These are summarized in Tables C-1 through C-6 given in Appendix C. These values were also used in the assessment of nonpoint loadings which are discussed in the next section.

Stream Fisheries

The following information was supplied by the Utah Division of Wildlife Resources.

Fish Creek. Fish populations include rainbow and cutthroat trout. The stream habitat supports excellent spawning, rearing, and residency requirements for trout. Many adult reservoir trout run this stream each spring during the spawning phase.

Pondtown Creek. Fish populations include rainbow and cutthroat trout. The stream habitat supports good trout spawning and rearing requirements, but only fair requirements for residency. This stream is also used in the spring for spawning by adult trout from Scofield Reservoir.

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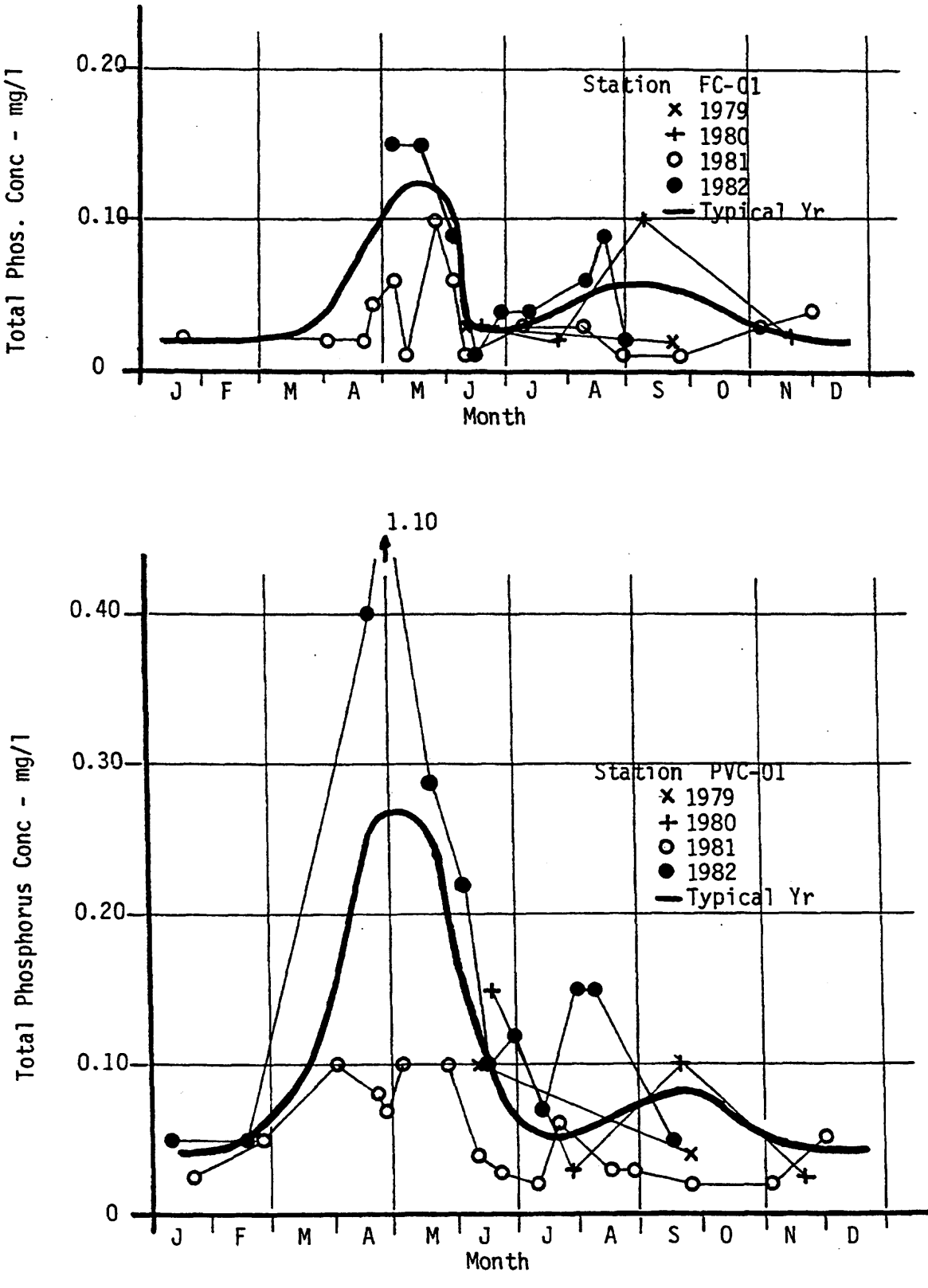

Figure 2-3. Total Phosphorus in Fish Cr. and Pleasant Valley Creek.

Dry Valley Creek. Fish populations are limited to the confluence area at the reservoir, and may include rainbow and cutthroat trout. No other data is available on habitat quality. Populations are limited mainly by minimum flow.

Miller Canyon Creek. Fish population is mainly fingerling cutthroat trout up to the road culvert only. The habitat requirements are suitable for trout rearing through the end of June. Populations are limited mainly by minimum flow.

Woods Canyon Creek. Fish populations are mainly cutthroat and rainbow trout. Both species utilize the stream for spawning in high densities during spring migration from the reservoir.

Pleasant Valley Creek. Fish populations are mainly cutthroat trout, with rainbow trout in limited numbers. Stream habitat is mainly geared to rearing and residency requirements. The stream contains natural trout populations along with spring spawners migrating from the reservoir. Several diversions on the creek, along with livestock overgarzing in the riparian zone, have proven detrimental to the trout.

Eccles Creek. The fish population is cutthroat trout. The habitat serves mainly as a spawning and rearing area for Pleasant Valley Creek. Few trout over 12 inches occur in this small stream. Recent detrimental impacts (siltation and coalfines from road construction and coal mining) have severely reduced trout populations in the creek.

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SECTION 3

LAND USE AND NONPOINT LOADINGS

Land use in the Scofield drainage basin is largely range and forest in nature. For the purposes of this study it was broken into four categories.

1. Forest: 93% of the drainage basin is in this category which includes the range areas. Both public and private lands are included.

2. Water: 3.5% of the drainage basin is covered by water. This includes Scofield reservoir, Lower Gooseberry Reservoir and streams in the basin.

3. Industrial: 2.5% of the drainage basin is owned by mining companies. Only a small fraction of these lands are being worked at the present time.

4. Residential: 1.0% of the drainage basin is used for low density dwellings. Scofield Town, Clear Creek Town and a few small recreational developments comprise this category.

Subbasin Character and Land Use

An estimation of the proportions of total phosphorus and total suspended solids originating from background and nonpoint sources requires information regarding subbasin character and land use. The following descriptions outline factors influencing water quality in each subbasin. Refer to Figure 2-1 for subbasin location.

Fish Creek Subbasin (FC-1). The Fish Creek Subbasin is the largest in the study area, enclosing 41,600 acres. Its fan-shaped, high-altitude collection basin extends fifteen miles along the San Pitch-Price River divide. It covers only 40 percent of Scofield Basin's total area but supplies 66 percent of the inflow. Slopes along the middle and lower reaches of the subbasin are very steep.

Moderate recreation activities and sheep grazing during the summer season are the predominant human influences on the subbasin. Approximately 100 campers per night use the unimproved campground beside Gooseberry Creek, and several dozen summer cabins are found nearby. Wastes are disposed of in septic tanks or privies. There are three to five miles of light duty roads in the Fish Creek drainage.

The subbasin's forests and rangelands are in fair to good condition with little evidence of overgrazing except in limited areas along the upper reaches. Stream banks are flanked with thick willows along the full length of the creek and its tributaries. Riparian vegetation is in good to excellent condition. Soils tend to be very unstable on the steep lower Gooseberry drainage resulting in slippage and landslides especially during wetter than normal years such as 1983.

Pondtown Creek Subbasin (PC-1). Pondtown Creek drains a 7,750 acre, cigar-shaped area north of the Fish Creek drainage. Its total area is evenly distributed between upper and lower elevations. Pondtown Creek contributes 5.5 percent of reservoir inflow from 2 percent of the total drainage area. Like Fish Creek, its slopes are steep and rugged.

Pondtown Creek is rough, inaccessible, and unsuitable for uses other than livestock grazing and very limited recreation. Sheep frequent the upper slopes while cattle graze the stream bottoms. Overall, slope and riparian conditions are nearly as good as those along Fish Creek. An unimproved road begins at the stream mouth and travels two and a half miles along Pondtown Creek before grading upward to the crest of the canyon's right ridge.

Dry Valley Creek Subbasin (DVC-1). The Dry Valley Creek subbasin is an 8,070 acre, semi-arid valley. Most of the water originates from spring flow within two miles of the stream's mouth. Slopes are mild and most of Dry Valley is less than 500 feet above the elevation of the reservoir. This subbasin covers 8 percent of the Scofield Basin yet produces only about 2 percent of the annual inflow.

There is almost no development and limited grazing in Dry Valley. Utah State Highway 96 cuts across its eastern edge. The rocky valley floor is covered with sagebrush, and grass. The high quality of Dry Valley Creek waters can be attributed to a short length, low gradients, and minimal cultural influences.

Miller Canyon Creek Subbasin (MC-1). Miller Canyon Creek subbasin is similar to Dry Valley Creek in that the drainage basin is semi-arid, and the stream is largely fed by springs. However, canyon walls are steeper and most of the basin is at a much higher elevation. Its 5,250 acres comprise 5 percent of the study area and contribute about 1 percent to lake inflow.

The subbasin is used for little other than sheep grazing. Periodically, the sheep are contained in a large holding pen several hundred yards upstream from the sampling site. Canyon slopes are in generally poor condition. Water quality in Miller Canyon Creek is good except during high runoff. Sagebrush and grass predominate along the stream banks.

Woods Canyon Creek Subbasin (WC-1). Woods Canyon Creek is a tributary to Pleasant Valley Creek but was treated as a separate inflow to the lake because of sampling site locations. The 3,370 acre subbasin has moderately steep slopes and is at upper elevations. This canyon forms 3 percent of total basin area and generates 2 percent of the water.

Cattle grazing is the only major human-related influence on lower water quality in Woods Canyon Creek with sheep influencing the upper drainage. The stream banks are steep and considerable sloughing is occurring along the creek, potentially a serious problem. Beavers are active along most of the stream and have built numerous beaver ponds.

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Pleasant Valley Creek Subbasin (PVC-6). During 1981, a single coal mine was in operation a short distance upstream from the PVC-6 sampling site but it was closed down in 1982. An unimproved mountain road extends a short distance up Long Canyon Creek. Its use, however, is restricted. In addition, exploratory drilling, gas wells, and cattle and sheep grazing occurs. Slopes are moderate to steep and in good condition.

Pleasant Valley Creek Subbasin (PVC-5). The PVC-5 subbasin contains PVC-6 subbasin plus the community of Clear Creek and 1,600 additional acres. Land use and basin morphology are essentially the same as those of PVC-6. Clear Creek has a permanent population of 25 which grows to nearly 100 during the summer. Septic tanks are used to dispose of household wastes. A garbage dump beside Pleasant Valley Creek created a major public concern until it was filled in early in 1982. Stream banks between PVC-5 and PVC-6 are in fair to good condition.

Eccles Canyon Creek Subbasin (EC-1). The Eccles Canyon subbasin contains 3,460 acres. It has steep slopes and is a tributary to Pleasant Valley Creek. It is also the location of several active coal mining operations. Since 1979 a tremendous amount of earthwork and construction have occurred in connection with the opening of a new mine. The road from the canyon mouth to the mine was expanded and extended westward over the divide into the Huntington Creek drainage. Road construction created numerous cut and fill areas. Revegetation efforts are currently underway, but many of the slopes are too steep for adequate erosion control particularly those between the road and creek. Construction is expected to continue for several years.

Pleasant Valley Creek Subbasin (PVC-4). In addition to PVC-5 and EC-1 subbasins, the PVC-4 subbasin encompasses 5,560 acres of forest and rangeland with moderate slopes. The riparian vegetation between PVC-5 and PVC-4 is in poor condition. Some of the areas adjoining the stream are overgrown with weeds and thistles, and overgrazing is apparent.

Pleasant Valley Creek Subbasins (PVC-3). The PVC-3 sampling station, located one-half mile downstream from the PVC-4 site, receives the discharge from another tributary--Green Canyon Creek. Green Canyon contains church recreational property and summer homes. A large coal loading area is situated upstream along Pleasant Valley Creek. Trucks and heavy machinery create large quantities of dust during the coal loading operations. Some coal is inadvertently washed into the creek.

Pleasant Valley Creek Subbasin (PVC-2). PVC-2 subbasin drains Winter Quarters Canyon in addition to the PVC-3 subbasin. Winter Quarters Canyon was the scene of heavy mining activities prior to 1920. Today, the canyon contains numerous abandoned tunnels. Stream banks along the upper portion of Winter Quarters Canyon Creek are in good condition. However, the riparian vegetation in the lower reaches is poor, and overgrazing is evident.

Pleasant Valley Creek Subbasin (PVC-1). The town of Scofield is the only portion of the PVC-1 subbasin not shared by the PVC-2 subbasin. It contains 22,6980 acres. Overgrazing by cattle occurs along Pleasant Valley Creek both above and below the sampling station. The riparian vegetation is in very poor condition, and several segments of the stream through town have been riprapped to control erosion.

Price River Subbasin (PR-1). The 98,410 acres Price River subbasin contains the other twelve subbasins, several very small stream drainages, the lake, and its surrounding shoreline drainage area. Land area unaccounted for in the previous subbasin descriptions is heavily used for grazing and recreational purposes.

Nonpoint Source Pollutant Loadings

The drainage basin was broken into the subbasins shown in Figure 2-2. The pollutant loadings given in Appendix C were used to calculate the subbasin pollutant loadings for each area. The results are given in Table 3-1. The subbasin order in Table 3-1 is from the largest to smallest total phosphorus generation rates in kg/yr/ha.

Nutrient concentrations in the Scofield watershed seem to be somewhat correlated with the sediment carried by the streams. Those subbasins where loadings/hectare are lightest are DVC-1 and MC-1, Dry Valley and Miller Creeks, both of which are lower in elevation and more arid than others. The heaviest sediment and nutrient loadings per hectare come from subbasins where either natural conditions (steep canyon walls, unstable soils/sides, and gradients as in Woods Canyon or Fish Creek) or in areas heavily used by man (PVC-1 incremental subbasin which contains Scofield Town). Eccles Canyon (EC-1) has been disturbed by road building activities in the last three years, and exhibits large sediment and nutrient loads per hectare.

The largest percentage of nutrients comes from Fish Creek (FC-1) which is in the largest subbasin with 42% of the watershed. Nutrient concentrations in Fish Creek are slightly lower than most other subbasins, but its large flow results in a large nutrient inflow to Scofield Reservoir. The Fish Creek subbasin is in fairly good condition, but reports indicate that some overgrazing occurs on upper ridges. However, a few areas are unstable particularly those areas containing steep slopes, when saturated. In 1983, many of these areas slid into Fish Creek. High spring flows eroded the slide material and much of it was deposited in the reservoir.

Phosphorus Availability

Much of the total phosphorus measured in the tributary waters is associated with the suspended solids which are largely mineral (inorganic) solids in this basin. As mentioned earlier, point sources of pollution are negligible and other sources of organic or soluble phosphorus are small. The bioavailability of the "total" phosphorus therefore becomes a pertinent question.

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Table 3-1. Watershed nonpoint source pollutant loadings from incremental subbasin areas.

Subbasin	Incremental Area (ha)	Constitutent	Incremental Subbasin Loading (kg X 10^3/yr.)	Incremental Subbasin Loading (kg/yr/ha)	
PVC-1 Pleasant Valley Creek	376	TSS	50	134	
		TKN	0.40	1.06	
		Total P	0.16	0.48	158 ✓
PVC-3 Pleasant Valley Creek	809	TSS	114	140	
		TKN	0.86	1.06	
		Total P	0.25	0.31	249 ✓
PVC-2 Pleasant Valley Creek	2,164	TSS	330	152	
		TKN	2.36	1.09	
		Total P	0.53	0.24	528 ✓
PVC-1 Cummulative (summ of PVC-6 to PVC-2 & EC-1)	8,496	TSS	1817	214	
		TKN	6.10	0.72	
		Total P	1.95	0.23	
FC-1 Fish Creek	16,520	TSS	2490.	151	
		TKN	20.5	1.24	
		Total P	3.51	0.21	350?
EC-1 Eccles Canyon Creek	1,352	TSS	411	304	
		TKN	0.58	0.43	
		Total P	0.34	0.25	337 ✓
PVC-6 Pleasant Valley Creek	1,255	TSS	299	237	
		TKN	1.14	0.91	
		Total P	0.24	0.19	[illegible] ✓
PVC-5 Pleasant Valley Creek	641	TSS	166	259	
		TKN	0.11	0.17	
		Total P	0.12	0.18	115 ✓
PC-1 Pondtown Creek	3,027	TSS	254	84	
		TKN	1.3	0.43	
		Total P	0.49	0.16	488
PVC-4 Pleasant Valley Creek	2,175	TSS	449	245	
		TKN	0.65	0.30	
		Total P	0.32	0.15	323 ✓
WC-1 Woods Canyon Creek	1,316	TSS	265	202	
		TKN	0.80	0.61	
		Total P	0.17	0.13	172
SW-1 Direct Drainage to Reservoir	2,700	Total P	0.31	0.11	308
MC-1 Miller Creek	2,051	TSS	53	26	
		TKN	0.35	0.17	
		Total P	0.07	0.03	66
DVC-1 Dry Valley Creek	3,152	TSS	15	5	
		TKN	0.44	0.12	
		Total P	0.09	0.02	89

* Loading increase between stations on the stream, it is therefore, for the entire subbasin if no upstream station exists.

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6~~28~~
308
1.5 ~~2~~ 2-10

Dr. Messer of Utah State University investigated a few soil and sediment samples taken from the Scofield drainage basin for phosphorus bioavailability. His report is included as Appendix D. He found the NaOH-extractable phosphorus is generally low in the Scofield basin as a fraction of the total phosphorus. He also investigated the reservoir sediments and found low fractions of available phosphorus as reported in Appendix H. This implies that a somewhat smaller percentage of the phosphorus entering Scofield Reservoir might be available for algae growth than in a "typical" lake.

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the sediments studied. If this P fraction originate from erosion, care should be taken in determining the potential effects of reducing phosphorus inputs from the watershed; reducing apatite-P inputs will have little effect on the trophic state of the reservoir, even though they may account for a large fraction of the total phosphorus loading. Conversely, reductions in more available forms of P may have beneficial effects far out of proportion to their contribution to the total P budget of the reservoir. Organic-P was relatively low in the Scofield sediments, while total P was the highest of any value measured in the western reservoirs. The relatively high Fe:P ratio in the sediment suggests that the iron available to bind P in the sediment is relatively high, which would tend to reduce the corresponding P release rates under anaerobic conditions.

The sediment chemistry outlined above suggests that the reservoir sediment could support moderate rates of P release under anaerobic conditions. Laboratory incubations of intact sediment cores from other Intermountain reservoirs suggest a release rate of 5-6 mg/m^2 day under anerobic conditions at 25 C. This rate must be related to the hydrologic regime of the reservoir in order for predictions to be made of the exact corresponding impact. However, it may be compared to estimated release rates of 8-12 mg/m^2 day for the lower reaches of the arms of Flaming Gorge Reservoir and Deer Creek Reservoir, or 15-50 mg/m^2 day for some eutrophic Canadian and European lakes. Because an intact core could not be collected, no actual release experiments were performed.

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SECTION 4

LIMNOLOGICAL DATA AND EVALUATION

Water Quality

Reservoir water quality data are available at the Utah Bureau of Water Pollution Control. Reservoir stations sampled are shown on Figure 4-1. Stations were sampled between 13 and 36 times over the 1978-1982 period with most times falling in 1981 and 1982.

A summary of water quality data for the reservoir is given in Table 4-1. The arithmetic average given is the average of all water samples with each sample carrying equal weight. The weighted average is based on the average for each month which was then averaged for all months for which data were available. Since no quality data were available for several of the winter months, these weighted averages still may not represent good annual weighted average values for some constituents.

The reservoir has good water quality as measured by most parameters. It is moderately high in alkalinity at about 155 mg/l and hardness at 170 mg/l. Nutrient levels are quite high, commonly at 0.01 to 0.05 mg/l T.P., as seen in the example given in Figure 4-2, and 0.1 to 0.3 mg/l for inorganic N; during the summer these levels drop as nutrients are depleted by phytoplankton growth. Secchi depths during the summer are about 2 to 5 meters which is typical for mesotrophic systems. (See the example in Figure 4-3).

Dissolved oxygen is often low in the hypolimnion as seen in Figures 4-4 and 4-5. The temperature and dissolved oxygen profiles shown in these figures are typical for mesotrophic to slightly eutrophic reservoirs in the Central Utah area. Oxygen depletion occurs near the bottom in late summer and again in late winter. Since Scofield Reservoir is shallow the percentage of its area contained in the hypolimnion (zone below the thermocline) is small. As shown in Figures 4-4 and 4-5 the thermocline is well developed by mid-June but intersects the bottom in all but the very deepest areas by mid-August. Therefore, during the summer only a small percentage of the reservoir is anoxic for a period generally less than two months.

Biological Conditions

Algae. A report on the phytoplankton is given in Appendix E. Phytoplankton types and numbers indicate Scofield Reservoir is presently a "meso-eutrophic" system. Blue-green algal genera indicative of eutrophy: Anabaena and Aphanizomenon, reached high numbers of bloom proportions in late summer and fall in both 1981 and 1982 which is a typical condition of eutrophic systems. Asterionella formosa and Melosira granulata var. angutissima, two diatom indicators of eutrophy, were found to be abundant in the phytoplankton at various times

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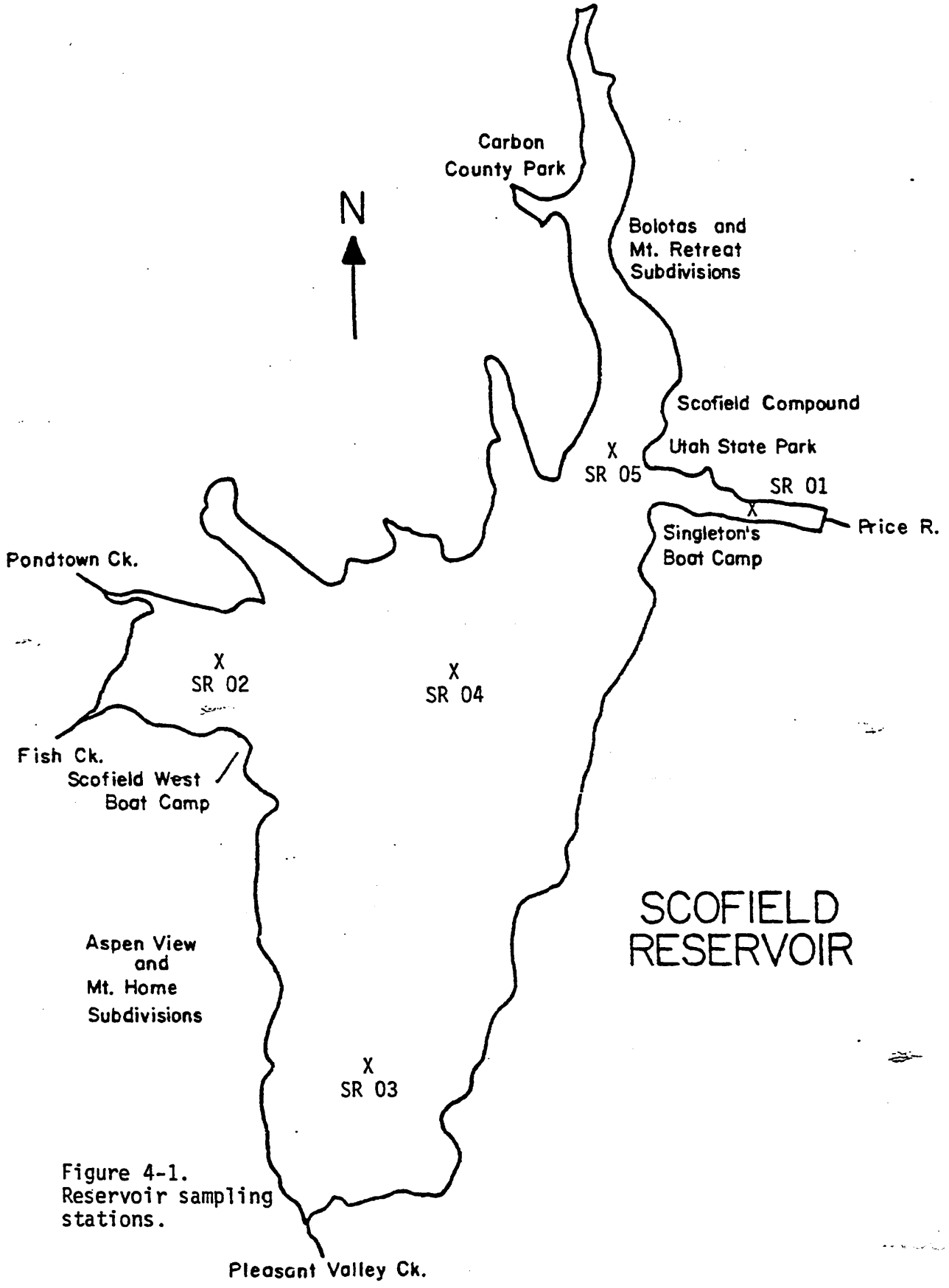

Figure 4-1.
Reservoir sampling
stations.

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Table 4-1. Water quality data summary for Scofield Reservoir.
Water quality parameter

Station		Temp. °C	S. Depth m	DO mg/l	pH units	Alk mg/l	PO_4-P mg/l	TP-P mg/l	NH_3-N mg/l	NO_3-N mg/l	TKN-N mg/l
SR-01	A. Avg.	11.7	3.7	6.3	8.3	153	0.022	0.03	0.12	0.22	0.60
	Wgt. Avg.	9.6	3.9	6.2	8.3	152	0.019	0.03	0.13	0.23	0.63
	Min.	0.2	1.2	0.0	7.5	130	0.005	0.00	0.03	0.00	0.10
	Max.	21.5	9.0	10.5	8.8	175	0.190	0.18	0.50	0.75	1.70
	Stnd. Dev.	5.3	1.9	2.8	0.3	12	0.034	0.03	0.10	0.17	0.26
SR-02	A. Avg.	13.7	3.1	7.8	8.2	152	0.015	0.04	0.07	0.19	0.49
	Wgt. Avg.	13.4	3.1	7.5	8.2	153	0.015	0.04	0.07	0.23	0.52
	Min.	3.2	1.2	1.5	7.8	102	0.005	0.00	0.03	0.00	0.10
	Max.	20.6	5.5	11.1	8.5	185	0.006	0.10	0.50	1.50	1.60
	Stnd. Dev.	5.3	1.4	2.4	0.3	20	0.014	0.03	0.09	0.28	0.26
SR-03	A. Avg.	13.0	2.8	7.9	8.3	152	0.019	0.04	0.09	0.10	0.49
	Wgt. Avg.	13.0	2.8	7.5	8.3	152	0.016	0.03	0.07	0.19	0.52
	Min.	3.5	0.2	3.9	7.8	136	0.005	0.00	0.03	0.00	0.10
	Max.	20.0	5.5	11.5	8.6	172	0.100	0.16	0.57	0.95	1.20
	Stnd. Dev.	4.8	1.7	1.7	0.2	12	0.023	0.04	0.12	0.19	0.26
SR-04	A. Avg.	12.6	3.7	6.7	8.3	155	0.022	0.06	0.08	0.16	0.46
	Wgt. Avg.	11.9	3.8	6.4	8.3	153	0.024	0.06	0.10	0.18	0.50
	Min.	0.2	1.3	0.0	7.6	97	0.002	0.00	0.01	0.00	0.00
	Max.	20.0	6.0	11.1	8.6	187	0.300	0.67	0.41	0.96	1.60
	Stnd. Dev.	5.0	1.5	2.7	0.2	16	0.044	0.10	0.09	0.19	0.23
SR-05	A. Avg.	11.8	3.9	6.0	8.3	149	0.017	0.03	0.11	0.28	0.51
	Wgt. Avg.	9.9	4.1	5.9	8.3	151	0.017	0.03	0.12	0.29	0.52
	Min.	0.1	1.2	0.1	7.8	132	0.002	0.00	0.03	0.00	0.20
	Max.	20.1	7.0	10.7	9.2	199	0.110	0.12	0.40	0.84	1.10
	Stnd. Dev.	6.2	1.8	3.0	0.2	12	0.019	0.02	0.07	0.16	0.19

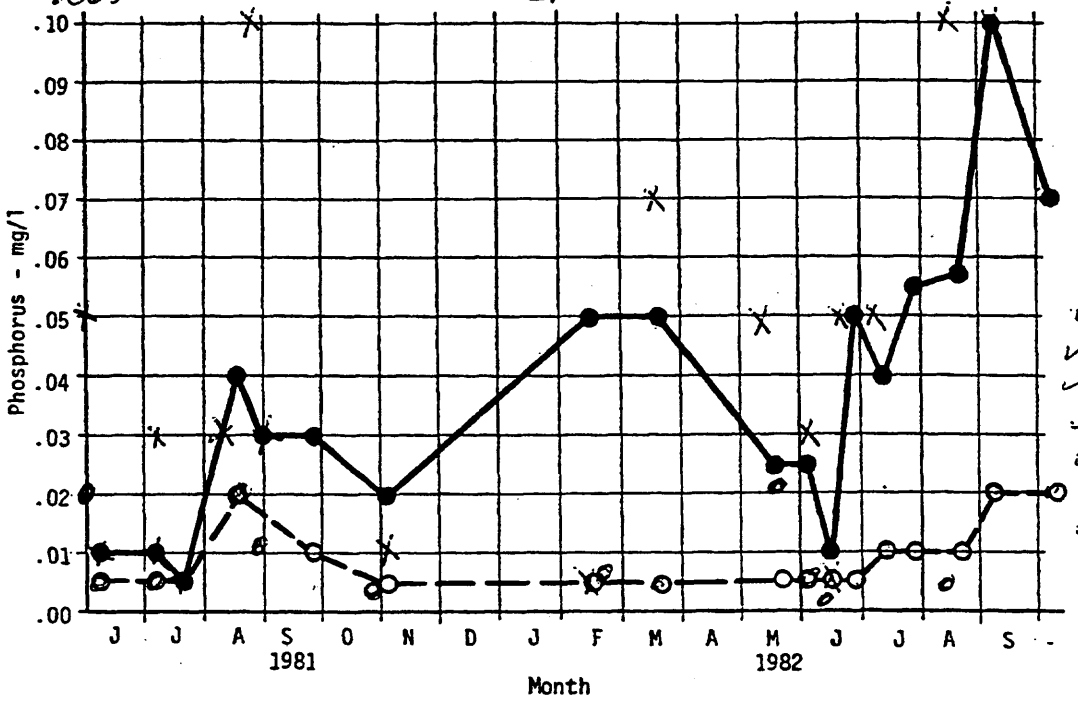

Figure 4-2. Epilimnetic phosphorus concentrations at Station SR-04 on Scofield Reservoir.

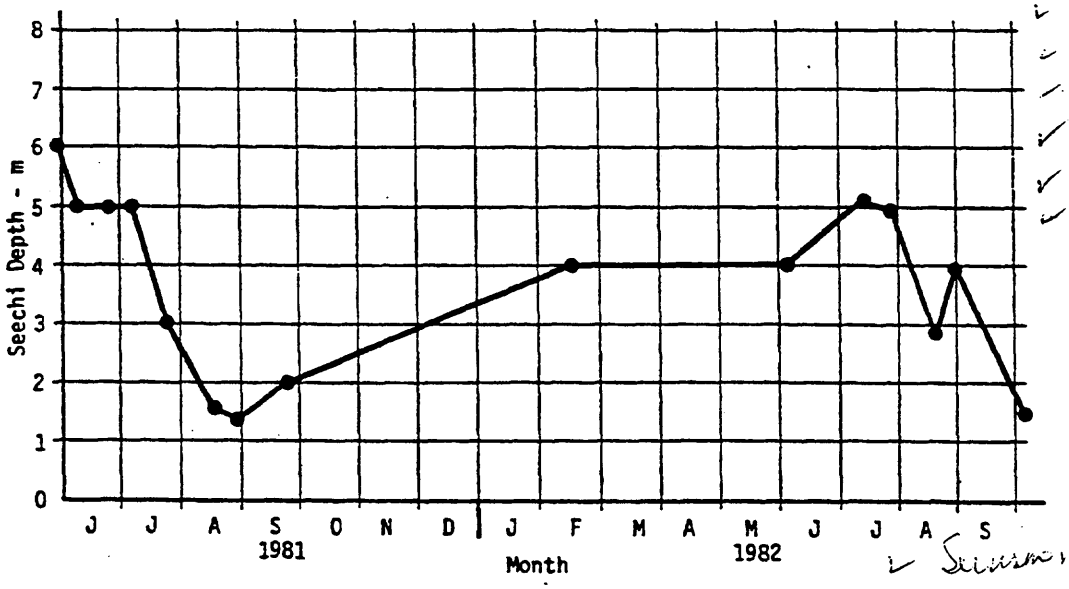

Figure 4-3. Secchi depths for Station SR-04 on Scofield Reservoir.

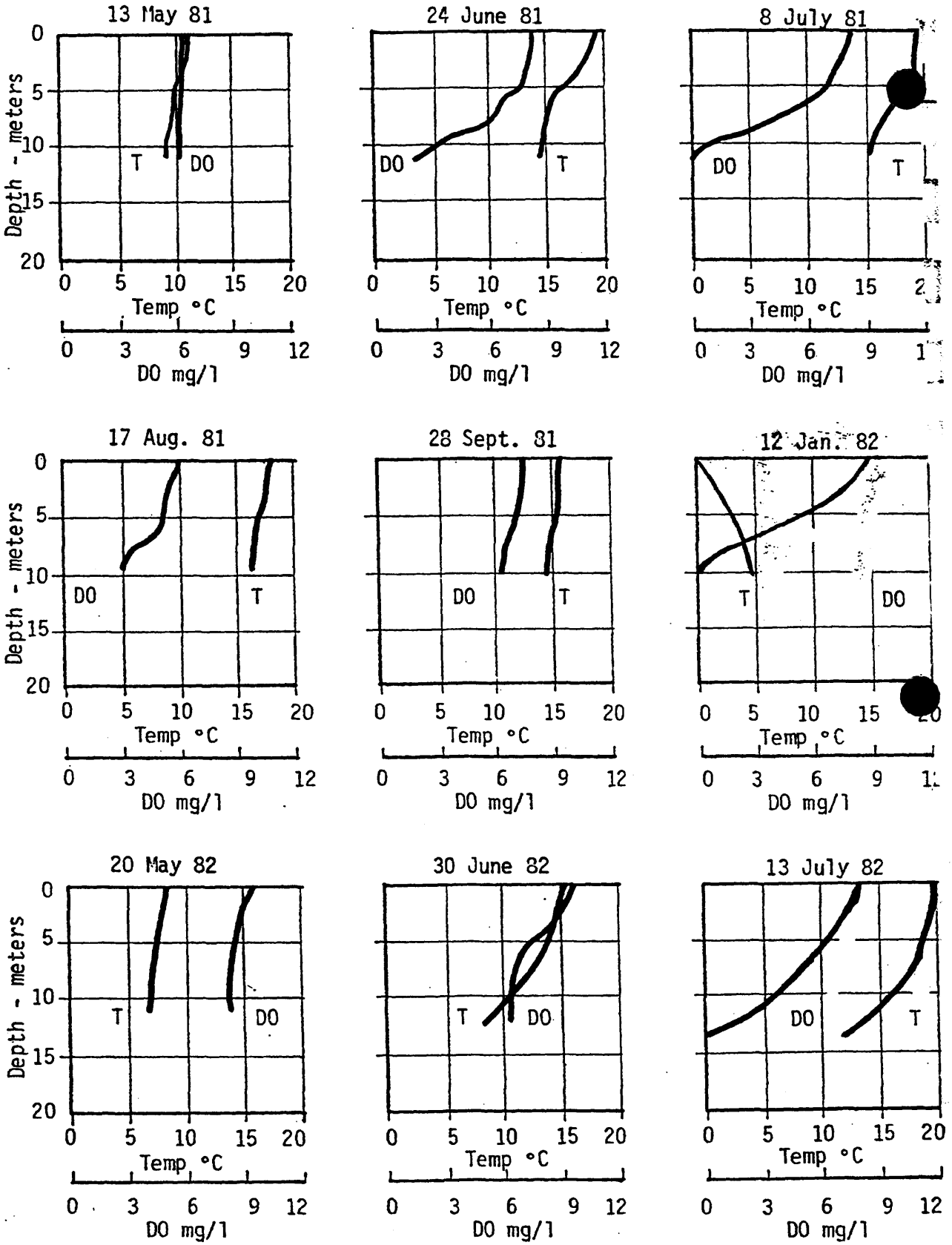

Figure 4-4. Temperature and Dissolved Oxygen Profiles at Station SR-01 on Scofield Reservoir.

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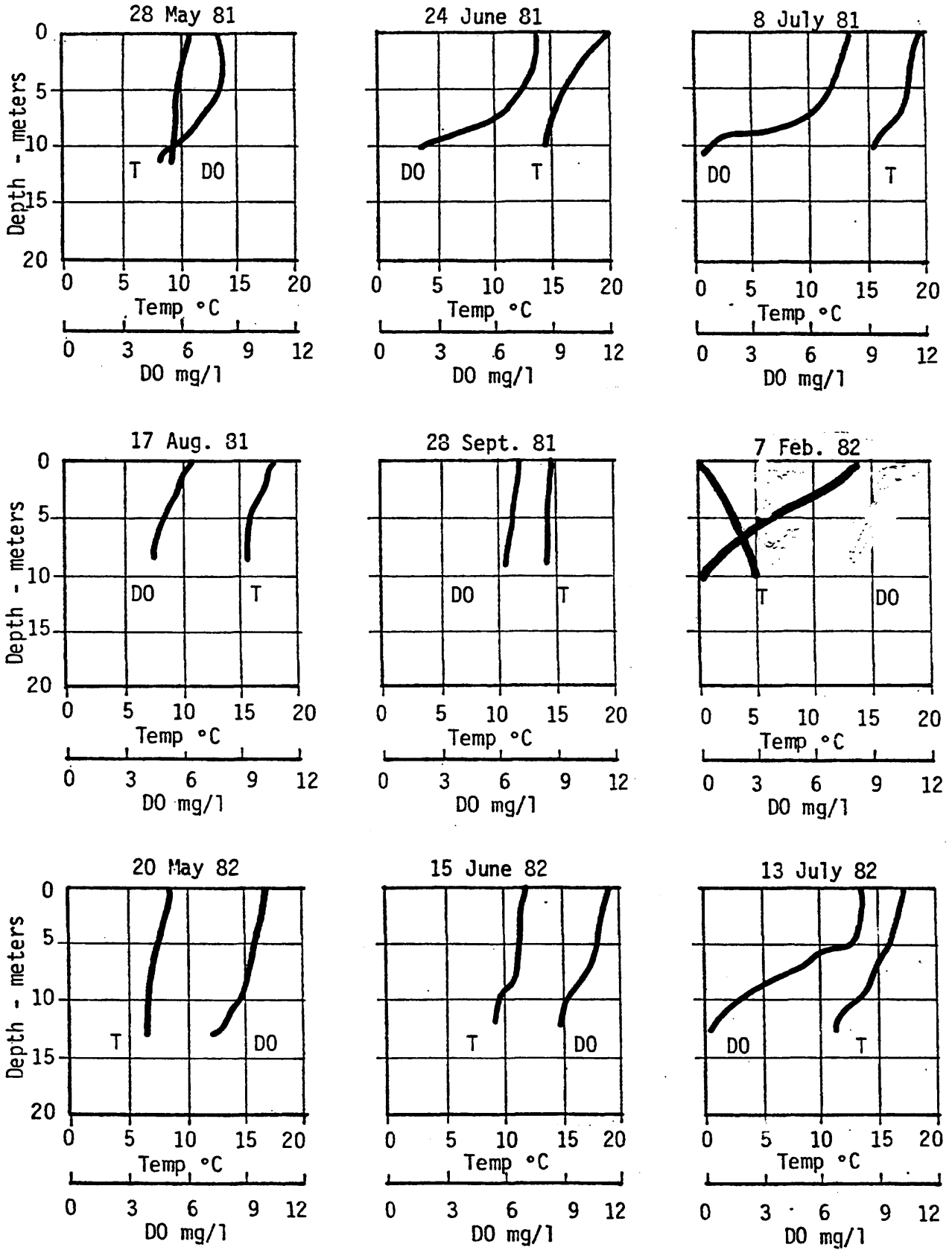

Figure 4-5. Temperature and Dissolved Oxygen Profiles at Station SR-04 on Scofield Reservoir.

both years. One of the best indicators of eutrophic conditions in the intermountain region is Stephanodiscus minutula, a centric diatom which also reached high numbers in the phytoplankton in both years. Asterionella formosa and Stephanodiscus minutula were the dominant diatoms in the bottom sediments. A comparison between samples taken in 1975 and 1981-1982 indicates increasing eutrophy in the reservoir. However, algal diversity in Scofield Reservoir was found to be moderately high and several of the taxa present are indicators of quite high water quality.

Macrophytes. The coverage of aquatic macrophytes, almost entirely of Elodea canadensis, was extensive throughout all areas of the reservoir in both 1981 and 1982. Elodea canadensis was found growing in almost all areas of less than 15 feet in depth. The summer of 1981 was a low water year and the Elodea was an emergent plant throughout most of the macrophyte plants beds. The water level in 1982 was 6 to 8 feet higher than in 1981 and the Elodea was submergent in most cases but still growing well. Healthy Elodea was sometimes collected on anchors and samplers from depths over 15 feet. In 1981 the only macrophytes seen besides Elodea were fragments of a Potamogeton species in the area of the State Park boat ramp on two occasions. The fragments could have come from another area of the reservoir on a motor or another part of a boat. Healthy appearing Elodea was collected with the water sampled at near shore stations through the ice during the winter of 1980-81.

During the summer of 1982, beds of Ranunculis aquatilis and Polygonum coccineum occupied shallow areas at the south end of the reservoir, the north arm of the reservoir, and the heads of some small coves along the north and northwest shores of the reservoir; areas that had been dry the year before. Small areas containing both Potamogeton pectinatus and P. filiformis were observed in 1982. Findings are shown in Figures 4-6 and 4-7.

Fish kills were observed in the Elodea mat areas along the southern shore, in the Fish Creek Bay area, in the head of the north arm, and at the head of small coves along the north shore in July and August 1981. Loss of oxygen due to the respiration of the Elodea and blue-green algae in the thick mat is a plausible explanation for the fish kills.

Winter access to Scofield Lake is difficult and extensive winter sampling through the ice was not possible. It appears, however, that the debris from heavy growths of summer algae and macrophytes in the shallows could cause oxygen depletions under the winter ice, particularly when the reservoir is severely drawn down late in the year. Such drawdown concentrates the biomass in shallower water hence setting up the potential oxygen loss problem.

Fish Tissue. Two cutthroat trout samples, one a large trout over two pounds and the other a collection of 3 to 4 small fish less than 0.25 pounds each, were tested for 6 metals and 86 organic pesticides. Three rainbow trout samples, one a large trout over 2 pounds, one a medium trout about 0.75 pounds and one of 3 or 4 fish below 0.25 pounds, were also tested for the same parameters. The central section of the

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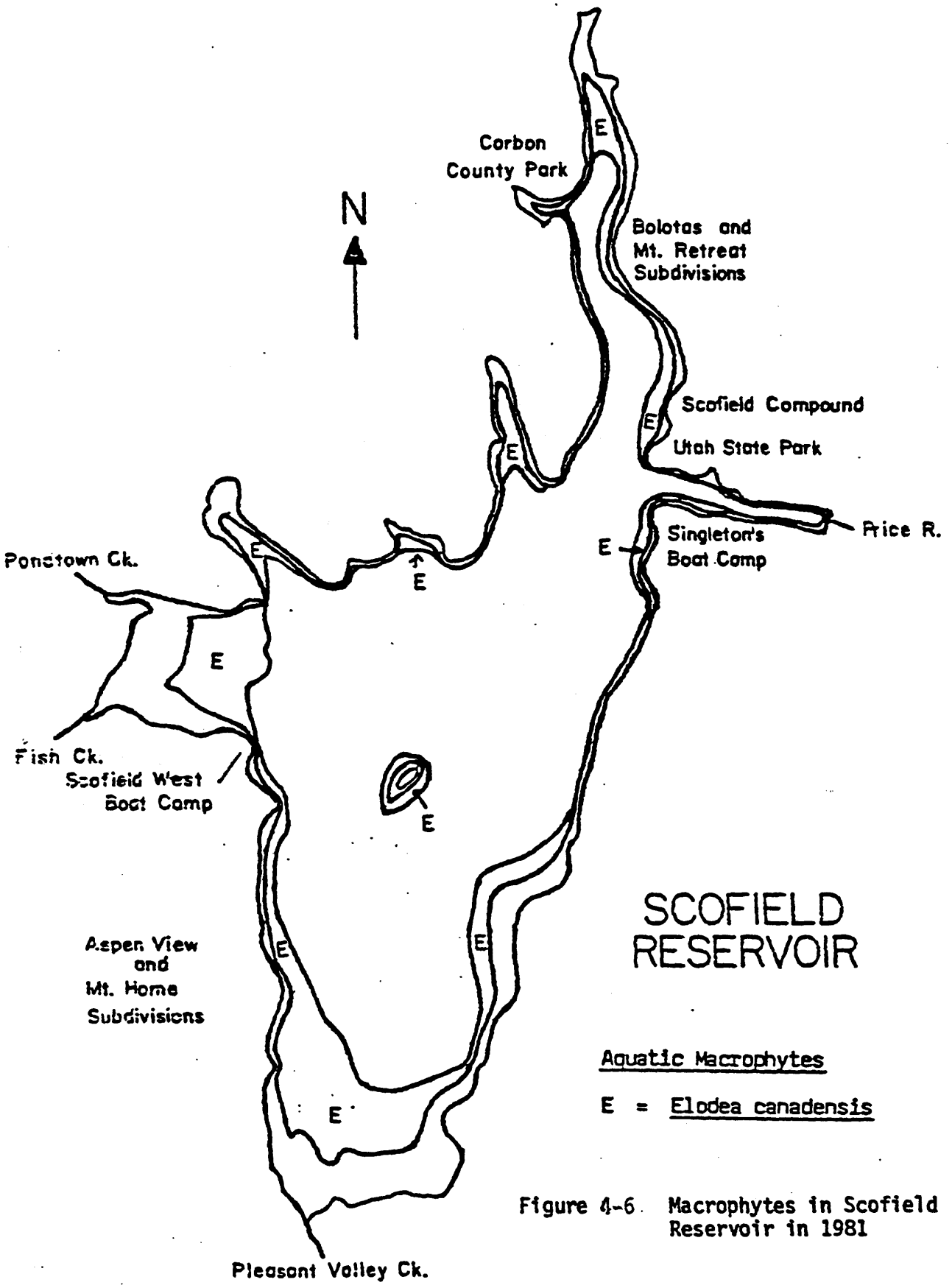

SCOFIELD RESERVOIR

Aquatic Macrophytes

E = Elodea canadensis

Figure 4-6. Macrophytes in Scofield Reservoir in 1981

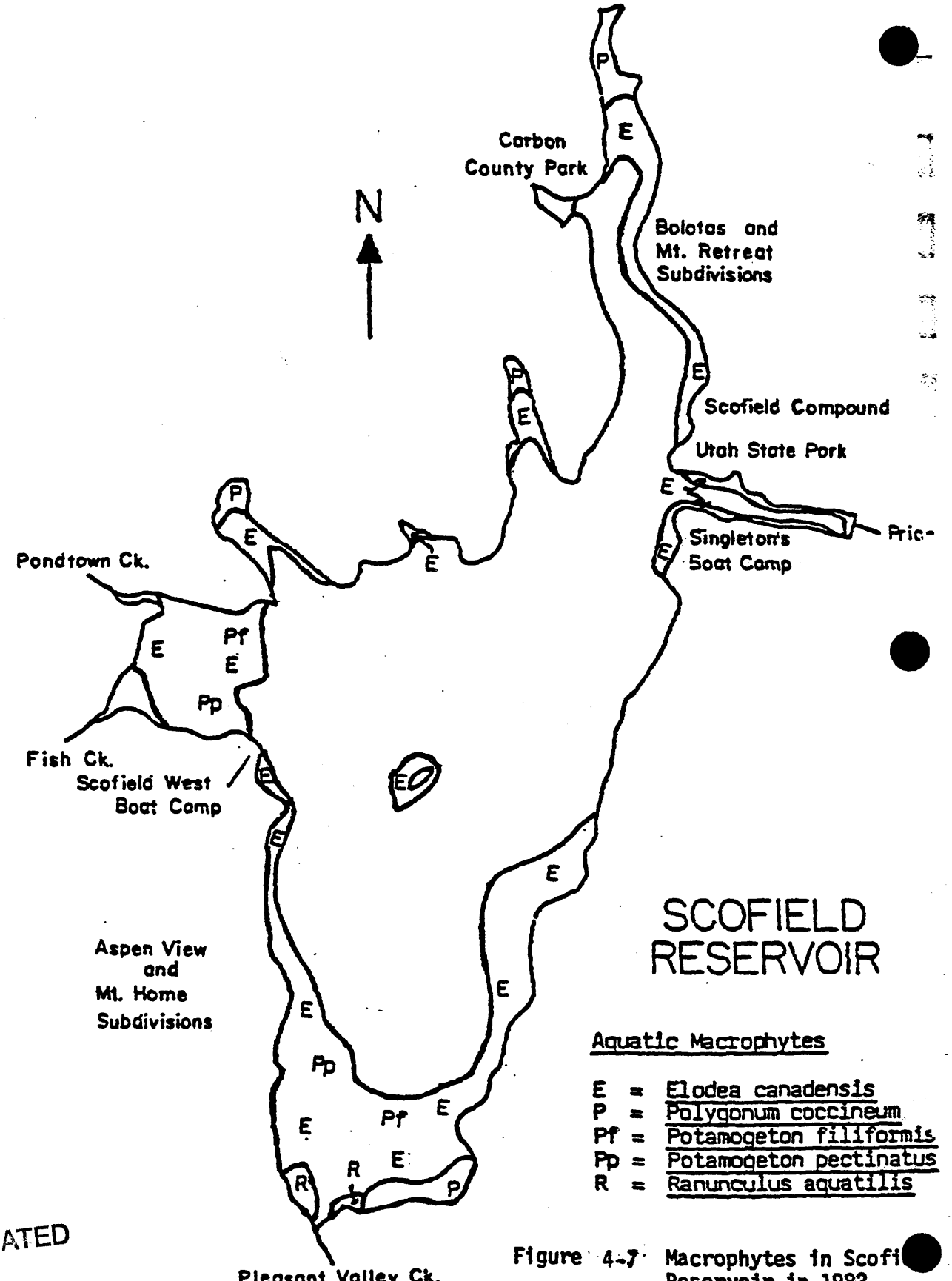

Figure 4-7 Macrophytes in Scofield Reservoir in 1982

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fishes comprised of visceral organs and main muscle mass tissues of the fishes were removed and blended in a Waring blender. The resulting liquid material was tested for each parameter.

A detectable, but very low, concentration of DDE, a derivative of DDT was found in each sample. Only DDE was detected of 19 chlorinated hydrocarbons tested. None of the 21 organophosphates tested were detected and none of the 46 herbicides were isolated from the fish tissues.

No metals concentrations were found which would be of concern. Arsenic concentrations were all low, ranging from 0.016 ug/g to 0.04 ug/g. All samples contained less than the minimum detectable limit (M.D.L.) of cadmium of less than 0.05 ug/ma. Lead was low ranging from 0.43 ug/ma to 0.50 ug/ma. Only one sample had a detectable limit of chromium (0.51 ug/g compared to an M.D.L. of 0.50 ug/g). Detectable amounts of mercury were found. They ranged from 0.11 ug/g to 0.24 ug/g, still well below the FDA established guideline for mercury in edible fish of 1.0 ug/mg, (F.D.A., 1982). The selenium concentrations were low and ranged from 0.31 ug/g to 0.44 ug/g.

DDE concentrations ranged from the low of 0.4 to the high of 3.0 ug/l (ppb). These concentrations are well below the F.D.A. guideline for DDE of 5.0 ppm (5,000 ppb) for fish (F.D.A., 1980).

There would appear to be no findings of public health concern in the fish tissue analyses. A summary of data is contained in Table 4-2.

Fish Populations. Scofield Lake is an excellent trout fishery as was indicated in the catch data given in Appendix G. "Trash" species tend to be a problem and fish eradication and sports fish restocking will likely be necessary into the future. Appendix G contains information on the fishery.

Trophic Index

The Carlson Trophic State Index (1977) was used to evaluate the reservoir (See Appendix G). Overall TSI values were 49 in 1981 and 53 in 1982. These values are on the border between mesotrophic and eutrophic zones. In 1981, nitrogen/phosphorus ratios were predominately above 15 which indicates phosphorus limitation. In 1982 more of the mid to late summer values were less than 15 indicating nitrogen limitation under late summer bloom conditions. This helps explain the late summer increase in blue-green algae, some of which are nitrogen-fixing.

Nutrient Balances

Nutrient balances for Scofield Reservoir are given in Table 4-3. These nutrient balances result from using the average-year, trend-curve nutrient concentrations and average year flowrates described earlier. They are somewhat different than what would result from using the "weighted average" values from Table 2-5 since those values were for

Table 4-4. Comparison of P fractions and CDB-Fe in some Intermountain reservoir sediments based on the extraction procedure of Hieltjes and Lijklema.

P fraction	Deer Creek	Panguitch	Scofield	Flaming Gorge	Strawberry
Exchangable-P	35	128	63	48	108
Available Fe-P	295	248	177	271	172
E-P	330	376	240	319	280
Unavailable Fe-P	140	76	143	75	74
NAI-P	470	452	383	394	354
Apatite-P	394	146	423	487	267
Organic-P	123	246	284	81	228
Total P	987	864	1,090	962	848
CDB-Fe	8,800	4,800	10,400	5,700	5,200
CDB-Fe:NAI-P[1]	10	6	15	8	8

1 Mole basis

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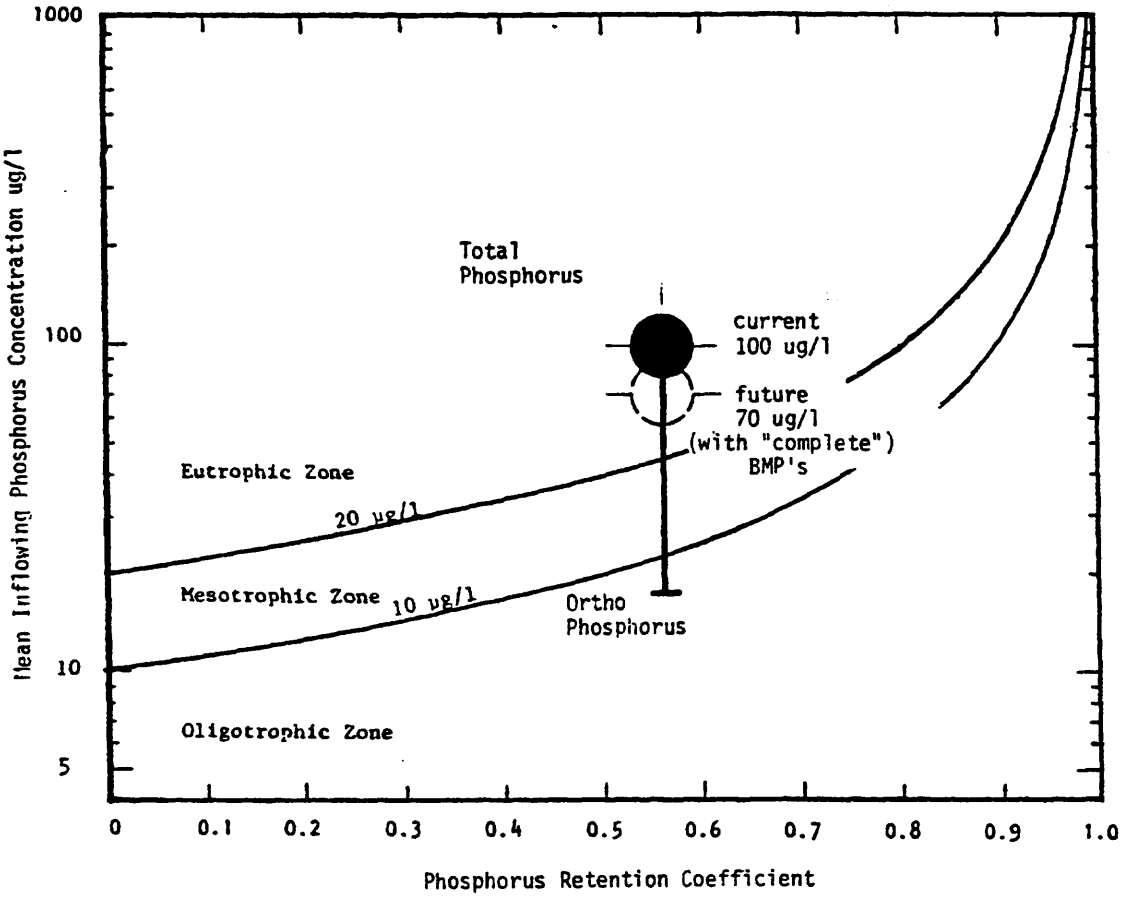

Figure 4-8. Trophic Level Plot for Scofield Reservoir - Larsen/Mercier Model.

Table 4-5. Scofield Reservoir characteristics & Larsen-Mercier Model Retention Coefficient.

Scofield Reservoir

Lake Data:

Volume:	$8.326(10^7)$ m^3
Area:	$1.133(10^7)$ m^2
Mean Depth:	7.4 m
Mean Inflow:	$6.4(10^7)$ $m^3/yr.$
Washout Coeff (p_w):	1.3/yr.
Areal Hyd Load (q_s):	5.7 m/yr.
Mean Phosphorus Load:	6,652.0 kg/yr.
Mean Inflow Phosphorus:	0.10 mg/l

Larsen-Mercier Model

Phosphorus retention coefficient from correlation equations.

1. $Rexp = 10/(10 + q_s)$ = .65
2. $Rexp = 1/(1 + p_w^{1/2})$ = .47
3. $Rexp = 854 - .142 \ln q_s$ = .61

Average: .57

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Table 4-6. Results of Vollenweiders Model[a] for Scofield Reservoir.

Reservoir Data:

Area: $1.133\ (10^7)\ m^2$

Mean Depth (H): 7.4 m

Inorganic N Loading: 24,600 Kg/yr.

Total Phosphorus Loading: 6,652 kg/yr.

Allowable Loading:

$\log N_A = 0.6 \log H - .42$ @ H = 7.4, $N_A =$ 1.26 g/m^2/yr.

$\log P_A = 0.6 \log H - 1.6$ @ H = 7.4, $P_A =$ 0.08 g/m^2/yr.

Dangerous Loading:

$\log N_D = 0.6 \log H - .13$ @ H = 7.4, $N_D =$ 2.46 g/m^2/yr.

$\log P_D = 0.6 \log H - 1.3$ @ H = 7.4, $P_D =$ 0.17 g/m^2/yr.

Present Loading:

Nitrogen: $N_P =$ 2.17 g/m^2/yr.

Allowable		Dangerous
1.26	2.17	2.46

Therefore, the current loading is mesotrophic near the eutrophic boundary.

Phosphorus: $P_P =$ 0.59 g/m^2/yr.

Dangerous	
0.17	0.59

Therefore, the current loading is hypereutrophic.

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[a] Equations are based on Schinder, et. al. (1971) who made modifications to the Vollenweider Model (1968).

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Table 4-7. Phosphorus contributions from subbasin areas and estimated controllability.

Phosphorus Subbasin Designation	Incremental[a] Annual Total Phosphorus Load (Kg/Yr)	Estimated Background Proportion (%)	Estimated Nonpoint Proportion (%)	Loading Reduction (Kg/Yr)
FC-1	3,508	80	20	701
PC-1	488	90	10	49
PVC-1	158	40	60	95
WC-1	172	70	30	52
MC-1	66	95	5	3
DVC-1	89	95	5	4
PVC-6	240	85	15	36
PVC-5	115	75	25	29
PVC-4	323	70	30	97
PVC-3	249	60	40	100
PVC-2	528	40	60	317
EC-1	337	35	65	219
SW-1[b]	308	25	75	230
Precipitation	142	100	0	0
TOTAL	6,651			1,932

a This is the annual loading generated from the drainage area added between stations. Therefore, for all but the Pleasant Valley Cr. stations it is for the entire subbasin drainage area.

b Shoreline Wash. One-third from PVC-1 to shoreline and South Shore area, and two-thirds from the remaining reservoir shoreline. Estimated.

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Nutrient Loading and Trophic Level Summary

Scofield Reservoir is presently slightly eutrophic and appears to be experiencing increased eutrophy over time. Lake algae are about equally limited by nitrogen and phosphorus. Since phosphorus is more readily controllable, phosphorus control is the recommended course of action. Much of the very high total phosphorus loading appears to be unavailable since it is minerally bound. Control strategies need to also use orthophosphorus levels as an indicator of those waters carrying larger or smaller fractions of bioavailable phosphorus.

Sewage, animal manure, and other organic debris contains much larger fractions of bioavailable phosphorus in their total phosphorus as compared to most sediments hence their control should always carry some priority.

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SECTION 5

LAKE RESTORATION PLAN

Introduction

Scofield Reservoir is a valuable freshwater resource in Utah. Recreation, wildlife and water supply, both agricultural and municipal, are key beneficial uses served by the reservoir. The areas' value as a recreational resource is highlighted by the 122,500 user days in the area in 1979 and by the reservoir's excellent trout fishery. In addition the excellent fishery, the reservoir and its environment serve as a focal point for the ecosystem of the area, particularly for the wildlife component. Most of the water from the basin is used for irrigation on downstream lands along the Price River or for municipal and industrial uses after treatment in facilities serving Price City and the Price River Water Improvement District.

Unfortunately, the water quality in the drainage basin has been deteriorating and is now to the point where some of the beneficial uses are threatened. Study findings show progressive eutrophication is occurring in the reservoir. The reservoir is currently mildly eutrophic and most likely rapidly approaching a fully eutrophic state wherein serious impairment of wildlife and recreation uses would result. The increased levels of taste and odor causing compounds would also render the waters more difficult and costly to treat for the domestic uses downstream.

Beneficial Uses to be Protected

More specific than indicated above, all of the waters on the Price River drainage upstream from the Price City Water Treatment plant are classified as 1C - culinary water source, 2B - recreation, 3A - cold water fishery, and 4 - agricultural use. All of these waters are also designated as anti-degradation segments which means that no additional pollution is permitted in addition to the need to remove any existing specific violations of water quality standards for the designated beneficial use classes. Parameters occassionally exceeding water quality standards on the Price River are manganese, mercury, and total phosphorus. Phenol and high coliform bacteria counts have also been detected on Pleasant Valley Creek above the reservoir; fortunately, these are largely degraded or altered in passing through the reservoir. Reductions in reservoir algae growth which is largely dependent on lowering phosphorus inputs would also likely reduce the manganese and mercury in the Price River downstream since both are likely associated with releases from reservoir bottom sediments during oxygen depletion episodes.

Feasibility of Lake Restoration

The key question addressed in the Clean Lakes Program is that of reservoir water quality. Although tributary waters and areas are normally the crux of any reservoir quality improvement, downstream water quality is improved with better reservoir water quality.

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Findings reported in previous sections indicate that large total phosphorus loadings and moderately large nitrogen loadings are currently entering the reservoir when viewed as to the resulting reservoir trophic level. Evidence indicates that current phosphorus and nitrogen loadings are sufficient to support a mildly eutrophic algae and other aquatic plant growth and are about equally limiting to these growths. Since nitrogen is more difficult to control, not to mention that often an earlier onset of noxious blue-green algae occurs as it becomes more limiting, phosphorus seems the best choice for control in Scofield Reservoir.

Although total phosphorus loadings to the reservoir are very large, findings indicate that an unusually large fraction is in chemically-bound forms that render it unavailable to algae growth in the reservoir. Again, our findings indicate that current loadings of "available" phosphorus are such that the reservoir is on the boundary between mesotrophic and eutrophic conditions and is moving over time into the eutrophic zone. Hence, one would expect a favorable response to reductions in "available" phosphorus loadings. Of the data collected during the Clean Lakes Study, orthophosphorus is the best indicator of available phosphorus when used in conjunction with the associated total phosphorus values. Where a tradeoff is to be made one should first reduce the phosphorus sources having a higher fraction of orthphosphorus since more is likely to be available for algae-growth in the reservoir.

Table 4-6 in Section 4 lists our best estimate of phosphorus controllability in the various subbasins upstream of the reservoir at 1,932 kg/yr. As is discussed later most of the phosphorus is naturally occurring and would be difficult to control. The reduction values given in Table 4-6 would result from mainly from a longer term program of low cost, nonintensive practices for erosion control and rangeland stabilization. This approach would be coupled with a few more intensive restoration projects which are discussed in the following pages.

Overall, it appears that the probability of markedly reducing the trophic level in the reservoir is small. However, a program of slight reduction and then limiting future nutrient increases is critical to the existence of Scofield Reservoir as a prime recreational and water supply resource.

The relatively low cost Phase II lake restoration program outlined below has several elements not directly linked to reservoir water quality but they are important in moving forward an overall program in the area of public awareness as well as public pride and action to improve the area from environmental, public health, general sanitation and reservoir quality points of view.

Current Control Plans and Projects

Several efforts are currently in the development stages for the control of pollution in the Scofield Watershed. Projects in various stages of completion are underway for livestock management, recreational facilities development, human waste disposal system improvements, control of surface disturbance activities and solid waste disposal.

Recreation Facilities

An effort to improve recreational facilities and minimize campe sprawl and improper waste disposal, a cooperative effort among responsible agencies, is proceeding. The Scofield Lake State Park is currently in the process of upgrading their sewage treatment facilities. The County operates the only other public recreation area. This facility is in need of repair and a proposal has been made for the State to operate this facility. Carbon County, the State, and local agencies are presently developing plans to improve recreation facilities and provide for the increasing usage of the reservoir.

Sewage Disposal

The recreation subdivisions, which have been in existence for many years, are almost without exception in violation of local and State Health codes. A plan is being prepared to bring these cabins into compliance in the most cost-effective manner. The plan contains a variety of options including holding tanks, centrally located septics tanks with drain fields and variations on the above. Currently, the Price River Water Improvement District is being petitioned to annex this area and thus expedite local water and sewer needs.

Three main areas of concern over high coliform counts are Scofield Town, Clear Creek Town, and recreation subdivisions on the lakeshore. The Town of Scofield has retained an engineer to design a sewage treatment facility and water system. Funding is the primary inhibitor to completing the system. The Community Impact Account, which provide grants to energy impacted communities is expected to be the main funding source with other funding to come from the Division of Water Resources, the Town, user fees and coal mines. The engineer's proposal will include costs and a proposed funding package.

Coliform counts dramatically increase in Pleasant Valley Creek below Clear Creek Town in comparison to counts above town. The total sewage system in Clear Creek is suspect and needs to be investigated. A dye study is recommended to confirm or deny Clear Creek as the source.

Construction Activities

The major construction activities in the Scofield area are coal mine development and road construction. The roads become necessary due to coal mine development. The Regional Coal Team for Utah is in the process of preparing an EIS to determine the impacts of future leasing in this and other areas. During the scoping and tract-ranking process, local governments and the water quality agency prepared comments on lease tracts located in municipal watershed. It was determined by these entities that such leases create the potential for damage to water supplies and should not be leased unless a need could be demonstrated. Large demand for the coal from this area does not currently exist and is not expected to develop in the foreseeable future.

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The road construction in Eccles Canyon has had a detrimental effect on water qualitity and the aquatic biota. The Utah Department of Transportation (UDOT) has recently initiated revegetation programs to reduce siltation, but preliminary work was not adequate to prevent erosion. Studies by the Division of Wildlife Resources (Donaldson 1983, personnel communications) clearly indicate a reduction in the fishery population, trout biomass, and fish condition. Fish populations were estimated at about 900/2.5 miles in 1981 but had dropped to an all time low of less than 100/2.5 miles in 1983. Part of this reduction was probably due to an unreported pollution spill below the Coastal States Mine in May 1982. Invertebrate samples on Eccles Creek substantiate the spill which would have resulted in a major fish kill. (Winget 1983, personnel communication).

Future mining activities and road construction must be monitored (with proper permits approved). Revegetation and erosion control methods must be utilized by UDOT, Coastal States Energy, and the U.S. Forest Service.

Solid Waste Disposal

Solid waste disposal for the Town of Scofield has been a persistent problem. The remoteness of the area makes collection by ordinary means difficult. The Town has operated a landfill, however, it has not been up to standards due to a lack of local funding. The Town recently received a $25,000 Community Development Block Grant and these funds will be used to improve the existing landfill to meet State Standards. User fees and equipment loaned from the mines will be used for operation and maintenance of the site. This project is expected to provide a sanitary solid waste disposal site for all residents of Pleasant Valley.

Restoration Alternatives

First, the primary restoration alternative consisting of four techniques is discussed. Second, the recommendations and actions of the Pleasant Valley Citizens Advisory Committee are discussed. A separate section on unacceptable or nonselected alternatives is discussed in Appendix K.

Lake Restoration Alternatives Originating from the Clean Lakes Study

About 53% of the phosphorus loading to the reservoir enters from Fish Creek. Examination of the Fish Creek watershed indicates that the source of most of the phosphorus is naturally-occurring, phosphorus-laden soils in the upper watershed. Riparian vegetation is of high quality in most reaches and the range land is for the most part not over-grazed. The watershed in general appears to be in good to excellent conditon. The soils are quite unstable, however, and when saturated with moisture as in 1982-83, steep slopes have a tendency to slide. Many of these slide areas are adjacent to or directly into streams which can result in heavy siltation. High spring runoff periods in conjunction with unstable slopes and slides contribute a large and significant amount of phosphorus laden sediment into Scofield Reservoir.

The area is roadless on the National Forest and the terrain is steep, rugged, and geologically unstable. The large number of land slides in the spring of 1983 alone would be infeasible to stabilize. Perhaps some reseeding of slide areas should be undertaken by the Forest Service, but this action is at best a "bandaid" approach to the problem. If the present above normal wet cycle of 1983 continues, it is fairly safe to predict continued slippage which stimulates erosion.

In the final analysis, although a large reduction in Fish Creek sediment load would be very beneficial, it is not feasible at this time to consider a restoration program beyond some reseeding of slide areas and continued Best Management Practices by the Forest Service.

Phosphorus loadings and the nutrient budget indicates about 31% (2,050 kg) of the loading to the reservoir enters from the Pleasant Valley Creek (Mud Creek on some maps). Examination of the Pleasant Valley Watershed indicates that the source of most of the phosphorus is naturally-occurring, phosphorus-laden soils in the watershed related to erosion.

Riparian vegetation is poor to nonexistant from the reservoir up to PVC-4. Above PVC-4, the riparian vegetation is poor to fair. The soil load from erosion is severe from PVC-4 to the reservoir. Although Dr. Messer's report indicates the phosphorus associated with soil loss is not very readily available for algae production, the soil loss is extremely high which results in a significant amount of readily available phosphorus being deposited in the reservoir. Field observations during 1981-1982 indicated bank erosion up to 10 feet on many meanders and sections of the creek. The direct cause of this excelerated erosion has been overgrazing which eliminated riparian vegetation. The amount of phosphorus from livestock droppings has slightly declined over the years due to some reduced herd sizes in the area including the national forest.

The South Shore wetlands project would remove the livestock sources of phosphorus from the South Shore while halting phosphorus tied to erosion. A twofold benefit will occur from a reduction in phosphorus loadings. First, instream fisheries will be greatly enhanced. Currently, the stream is utilized by reservoir fisheries as spawning habitat. However, siltation and unstable substrate greatly reduce the hatching and rearing potential. The stabilization of the stream would correct this situation plus provide habitat for the residential population. Second, a reduction of about 500 kg of phosphorus will have a beneficial impact on the reservoir especially the south end. Benefits include enhanced fishery, water quality, aesthetics, culinary supply and recreation. This reduction would help hold the meso-eutrophic state in the south arm.

In reviewing all the phosphorus sources, loadings, and the feasibility of restoration techniques, the South Shore project is the most feasible. Since no feasible alternatives are available for the major source (Fish Creek), working on the second highest loading source (Pleasant Valley Creek) is feasible and thus proposed.

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The following four restoration techniques compose the primary feasible alternative for the Scofield Reservoirs 314 Clean Lakes study (see Table 5-1): Figure 5-1 provides the implementation schedule.

1. South Shore Wetlands Project.
2. Continuance of Pleasant Valley Citizen Advisory Committee.
3. Public Education Campaign.
4. Reservoir Water Management and Operation Plan.

These are the primary techniques for consideration of Phase II awards. Discussions of their costs, benefits, public acceptance, and feasibililty follows.

PRIMARY FEASIBLE ALTERNATIVE

Restoration Technique #1 - South Shore Wetlands Project

The proposed program for Phase II funding includes three components. The objectives include removal of livestock from direct contact with the reservoir, the creation of a wetland, and a buffer zone along the south shore of the reservoir. The buffer zone would be fenced to prevent livestock access. Other elements of the project include revegetation of the riparian zone along Pleasant Valley Creek, improvement of range management practices and improvement of irrigated pastures as mitigation for loss of direct access to the reservoir (see Figure 5-2).

The first component includes purchase and control of 60 acres of land adjacent to the south shore of Scofield Reservoir. At the time the reservoir was constructed it was not the policy of the U.S. Bureau of Reclamation (USBR) to purchase adjacent property. The land in the valley remained in private hands and the USBR purchased only a flowage easement. When water is not covering the land the owner may use it for any purpose. Current county zoning prohibits all uses except agriculture. Extensive grazing is taking place in close promixity to the south shore of the reservoir and livestock use the reservoir as a main watering point.

The entire south shore of the reservoir would be purchased and fenced to prohibit livestock access. The purchase of 60 acres of land and construction of one mile of fence is required. Within this area the riparian zone of Pleasant Valley Creek will be replanted with native willow slips. The entire area will be power seeded with either Garrison Creeping Meadow Foxtail or Reeds Canary Grass. These species have proven high nutrient uptake capability. An agreement will be made with a local rancher to harvest this area annually during the fall months.

Water will be provided to the area through two routes. The natural groundwater table flow in Pleasant Valley moves from south to north. The water table in the buffer zone is at the surface level for most of the year, except during the late summer months. Much of the acquired sixty acres is actually lower in elevation than the high water line of the reservoir. Return flow water will also be made available from the irrigated pastures to the south.

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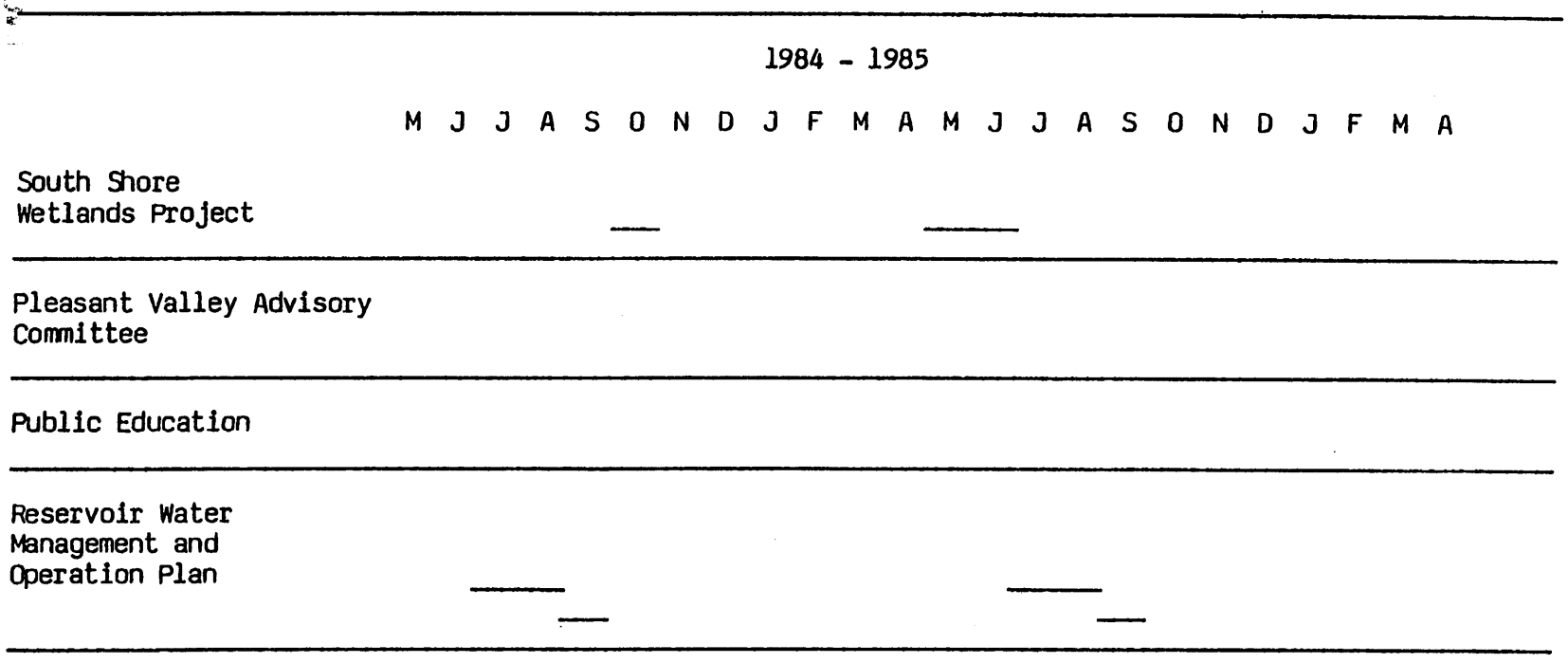

Figure 5-1. Phase II implementation schedule 1984-85.

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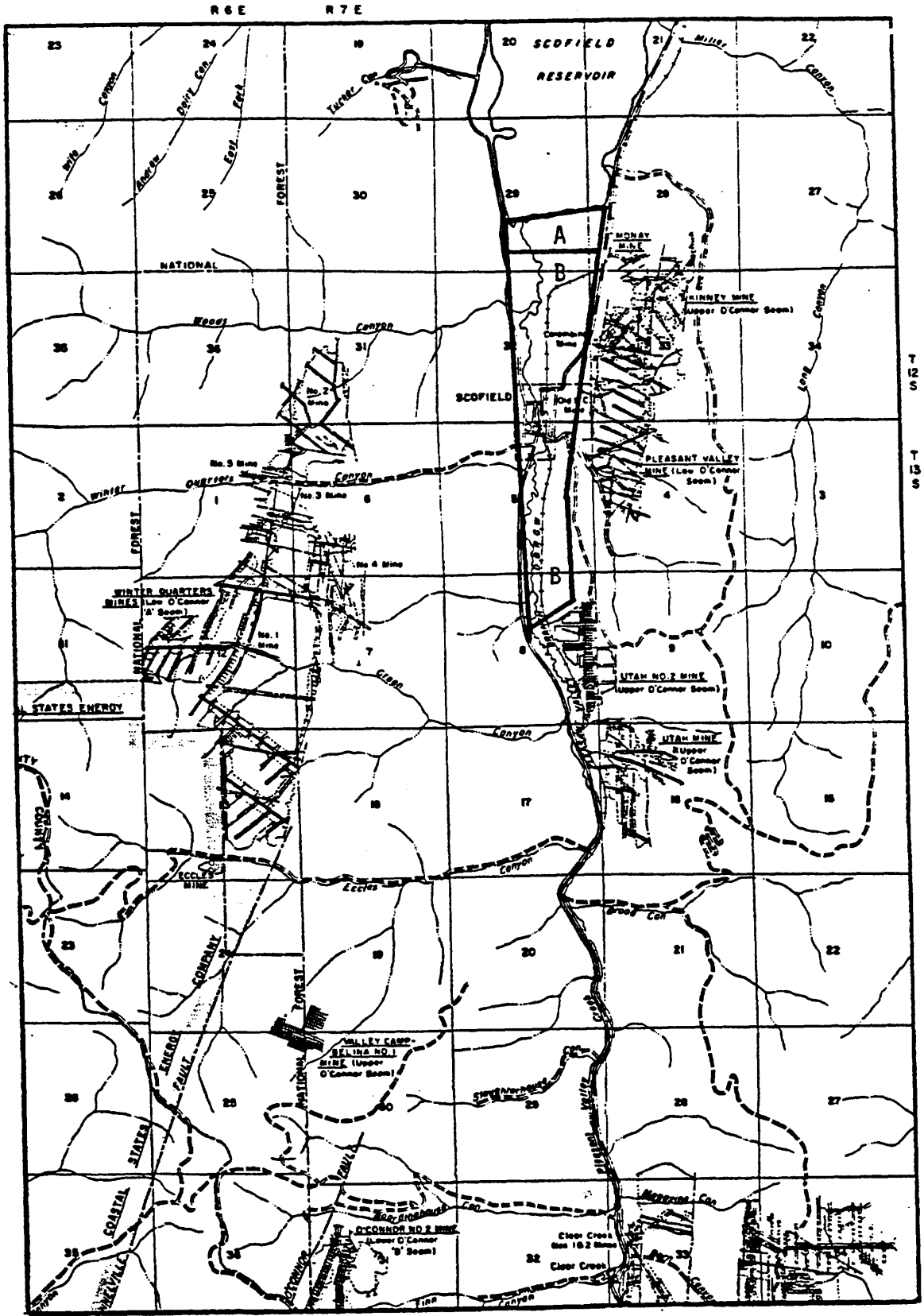

Figure 5-2. Approximate project boundries.
A. Buffer zone. B. Riparian and watershed restoration.

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The second component of the project includes restoration of the riparian zone along one section of Pleasant Valley Creek. The riparian zone of this creek from Scofield Town south to the Jensen-Radakovich property line has been entirely denuded of vegetation. It is unknown why the native willows were removed, however overgrazing is suspected. The current landowner has expressed an interest in restoring this vegetation. This activity should help stabilize the stream banks and reduce erosion.

This component will require cutting and seeding of native willows along approximately a one and one-half mile stretch of Pleasant Valley Creek. A stock management plan will be developed with the landowner to insure grazing does not take place during critical plant growth periods.

The final component of the project consists of improvement of irrigated pastures south of Scofield Reservoir and development of livestock management plans for each rancher in the area. There are approximately 270 acres of irrigated pasture lands within the project area. The condition of these lands indicate overgrazing is occurring in most sections.

This component of the project includes working with the three ranchers in the area to improve the pasture, stock watering and irrigation systems. The entire 270 acres would be power seeded with either Garrison Creeping Meadow Foxtail or Reed's Canary grass. Approximately two miles of fence will be installed to facilitate pasture rotation in the stock management plan rest-rotation system.

Water management is an important element in maintaining pasture lands. In the past, water was transported from a diversion through a canal on the east side of Pleasant Valley. Currently, irrigation water is diverted at different points from Pleasant Valley Creek. The current system provided inadequate water to the pasture northeast of Scofield Town. Re-establishment of the diversion on Radakovich property will provide irrigation water to pastures on the east side of the valley. Tail water from these pastures will flow into the buffer zone. Improved vegetation on these pastures will act as a nutrient trap and slow runoff from storm events. A rock gabion structure with drop board flexibility and a control headgate for the top of the irrigation canal will be installed in the location of the former diversion which washed out.

Creation of the buffer zone will prohibit livestock use of the reservoir for watering. Two alternative stock watering ponds will be developed to replace this loss.

Program Benefits

This project will have a positive benefit to the ranchers by increasing the carrying capacity of these pastures. Livestock management plans will be developed to insure that carrying capacities are not exceeded and that proper rest-rotation systems are implemented. Irrigation during the spring runoff will be encouraged. This will also remove considerable quantities of phosphorus contained in these sediments.

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The water quality benefits of this program are difficult to quantify, however several expected improvements should accrue. The most obvious benefit will be from a reduction in nutrient loading due to removal of livestock access to the reservoir. Further nutrient reduction will be realized from improved vegetation in the project area. Sediment levels will also be reduced by improvement of riparian vegetation.

Other spin-off benefits are also anticipated. Many private land-owners are hesitant to make improvements due to a fear the reservoir is in a declining state. If these landowners perceive positive actions are being taken to improve the area, they will be more inclined to improve their own properties. A general improvement of properties is expected to result from this effort. In addition, recreation values will be enhanced and other State and local agencies encouraged to improve public facilities.

Implementation Schedule

Component	Estimated Date of Completion
Land Purchase	September 1984
Stock Management Plan Developed to Protect Willow Plantings.	1984
Placement of Willow Slips along Pleasant Valley Creek.	October 1984
Fence Construction around Buffer Zone.	October 1984
Power Seeding of Pastures.	May 1985
Development of Livestock Management Plans.	May 1984
Development of Livestock Watering Ponds.	May 1985
Rest-Rotation Field Fence Construction.	May 1985
Installation of Diversion Structure.	June 1985

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Public Participation Program

Activities undertaken at Scofield Reservoir have been under the close scrutiny of the Pleasant Valley Committee. This committee has been involved in problem identification and development of alternative solutions. The committee will provide input on all restoration activities. Members will be closely involved in all stages of project development, implementation and evaluation. The committee will be the lead agency in the public participation program.

The general public will be informed of activities and have input opportunities at a number of key points, e.g. at a public meeting which will be advertised in the state and local media and held prior to project implementation. This initial meeting will allow public input into the plan before construction commences.

A second public meeting will be held during the implementation phase to inform the public of progress on the project.

A final public meeting will be held at the conclusion of the implementation phase to inform the public of project completion and to receive input on the monitoring and evaluation plan. This will also inform individuals of how they may become involved in other projects in the future.

These three public meetings will be duplicated in Price City and Scofield Town.

Meetings will be held with key individuals not involved in the Pleasant Valley Committee to inform them of developments and to receive input. The contact point for public involvement will be through the Secretary of the Pleasant Valley Committee.

Post Project Operation and Maintenance Plan

Several aspects of the proposed project will require long-term maintenance for the project to continue to be effective in pollution removal. Operation and maintenance costs have not been included in the proposed project. Those costs will be borne by users and management agencies.

The buffer zone fence will require periodic maintenance over time. This buffer area will fall under the control of the Carbon County Water Conservancy District. All maintenance aspects for the buffer strip will be the responsibility of the District. A management agency agreement for continued maintenance will be entered into between the Southeastern Utah Association of Local Governments and the District.

Typically, stock management plans and range improvements cost-shared with the Agricultural Stabilization and Conservation Service (ASCS) carry a ten year maintenance requirement. The landowner is required to maintain all improvements for this period. All remaining aspects of this project relate to private land improvements. Therefore, a similar agreement will be entered into between the local ASCS Committee and the landowner to maintain improvements for the ten-year period.

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Program Budget:

Component:	Estimated Cost
Land purchases 60 acres @ $500.00 per acre.	$ 30,000.00
Placement of Willow Slips along Pleasant Valley Creek. 32 man hours @ $5.00 per hours.	$ 160.00
Fence construction around Buffer Zone. One mile	$ 4,000.00
Power seeding of pastures. 270 acres.	$ 10,800.00
Installation of diversion.	$ 15,000.00
Livestock watering ponds 2 @ $750.00 each.	$ 1,500.00
Rest-Rotation field fence 2 miles @ $4,000.00 per mile.	$ 8,000.00
Monitoring and evaluation.	$ 49,528.00
Administration SEUAOG.	$ 10,000.00
TOTAL	$128,988.00

Non-Federal Funding Sources:

The following agencies and individuals will provide funding for this project.

1. Carbon County Water Conservancy District - 40 acres of land valued at $500.00 per acre - total - $20,000.00
2. Pleasant Valley Committee - Cash and Labor valued at $4,500.00.
3. Utah Department of Health - Labor, Equipment and Services valued at $24,764.00.
4. Carbon County - Labor and Equipment valued at $5,000.00.
5. Utah Department of Natural Resources - Supplies, Labor, and Equipment Valued at $7,310.00.
6. Southeastern Utah Association of Local Governments Administration - $2,920.00.

Total non-federal funding - $64,494.00

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Public Benefit:	Excellent.
Water Quality Benefits:	Great.
Public Acceptance:	Good.
Feasibility:	Feasible.

Benefits Expected from Restoration

The proposed watershed management plan for Scofield Reservoir is expected to reduce total phosphorus loadings by about 30 percent. This will help to maintain total phosphorus concentrations below 0.025 mg/l in the south arm and about .03 mg/l in the overall reservoir. The limiting nutrient is nitrogen during most of the late summer-fall period when severe blue-green algal blooms are common. Reduced phosphorus loads should lead to reduced numbers of blue-green algae and decrease the length of time that blue-green algal blooms occur in Panguitch Lake. Reduced phosphorus levels should also decrease the severity of the winter blooms of eutrophic indicating diatoms. The severity and extent of summer and winter oxygen depletions due to decomposition of the large algal biomass should be reduced by lowered phosphorus levels in the lake.

The productive fishery in Scofield Reservoir should be preserved and perhaps even enhanced by the lowered phosphorus levels. The incidence of future fish kills should be reduced or illuminated. The aesthetic appeal of the lake would be enhanced by the reduction of the unappealing blue-green algal blooms.

Scofield Reservoir is the focal point of an important recreational area. The area is experiencing an annual increase in use of at least 3.5 percent in spite of a downturned economy the past few years. Recreational use at the lake was estimated at 122,199 user-days in 1980 with a value of approximately $2,443,986 (Table 5-2). The preservation of present water quality is essential for continuation of the present recreational use value of the lake and surrounding summer homes and campgrounds. Enhancement of lake water quality would help to ensure an annual increase in recreation that is valued at over $100,341 annually. If the present rate of increased recreational use continues over the next 10 years, use would increase to 172,370 user-days worth $2,443,986 in 1990. Increased recreational use would be 50,171 user-days valued at $1,003,420. This increased use would further impact the lake if not properly planned for in the design and construction of waste disposal facilities, roads, cabins, and other facilities.

Further degration of lake water quality would reduce the lake's appeal and its recreational use and value. The Carbon County area would be economically impacted proportionately to the reduction in recreational use.

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Table 5-2. Projection of benefits from lake restoration project.

Use Category	Benefit Type[a]	Baseline Usage 1980	Projected Usage 1990[b]	Change in Use	Value of Annual Baseline Usage[c]	Value of Annual Projected Usage	Value of Benefit 1980-1990
Sightseeing		6,594	9,300	2,606	$131,880	$186,000	$54,120
Picnicking		3,923	5,530	1,607	78,466	110,600	32,134
Camping		18,892	26,650	7,758	377,840	533,000	155,160
Waterskiing	3,032	4,280	1,248	60,640	85,600	24,960	
Boating		5,720	8,070	2,350	114,400	161,400	47,000
Fishing		78,296	110,440	32,144	1,565,920	2,208,800	642,880
Hunting		5,742	8,100	2,358	114,840	162,000	47,160
		122,199	172,370	50,171	$2,443,986	$3,447,400	$1,003,414

[a] 1. Existing use protected.
2. Existing use improved.
3. Increase in usage of existing uses.

[b] 3.5% estimated increase/year.
[c] Used day value $20.00.

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Adverse Impacts and Mitigative Measures Statement

The impacts of all four restoration techniques will have a beneficial impact on the environment and the recreational capacity of the Scofield Reservoir watershed. No adverse effects will be realized, but during construction, minor turbidity may be realized. Some earth moving and bank stabilization will be necessary which will cause some short term turbidity. The turbidity will be significantly less than that experienced during spring runoff. Minimal to no effect will be felt on the fishery. Utah Division of Wildlife Resources will be in constant awareness of construction activities and their concerns will dictate quality control.

It is evident that any phosphorus reduction associated with erosion or other projects will have beneficial impact on the lakes trophic state therefore controlling blue-green algae populations. If Scofield Reservoir is to remain a viable fishery which is responsible for hundreds of thousands of recreational dollars added to the depressed and recreational dependent economy of Southeastern Utah, the lake's integrity must be maintained or improved. The Phase II project is a beginning.

Pleasant Valley Citizen Advisory Committee

The Pleasant Valley Citizen Advisory Committee was organized under the direction of Southeastern Utah Association of Governments and consists of citizens and groups that have a vital interest in the future of Scofield Reservoir (see membership Table 5-3). The Committee assists the Water Quality Management Agency in developing and implementing solutions to water quality problems. The Committee has been instrumental in helping to identify problems, educate the public and implement control measures in the watershed.

The Pleasant Valley Committee has established priorities which they feel are potentially economically and politically feasible. All items require the cooperative efforts of public and private entities.

In addition to representatives from the Carbon County Commission and Price-Helper Cities, there were members from water users, commercial owners, landowners, resport owners/operators, wildlife interests, livestock, and citizens at large. Additionally, technical and coordinating assistance was obtained from the Southeastern Utah Health Department, Forest Service, State Wildlife Resources, Soil Conservation Service, and the State of Utah. The Citizens Advisory Group meets in session on a monthly basis.

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Table 5-3. Composition of the Pleasant Valley Citizens Advisory Committee.

INTEREST	NAME	INTEREST	NAME
USFS	Leland Matheson	Carbon Commission	Quido Rachiele
	Dennis Kelly		
State Parks	Pat Walsh	Div. of Wildlife	John Livesay
		Resources	Walt Donaldson
District Health	Gerald Story		
Private Citizen	Quint Gardner	Price City	Amel Denison
Private Citizen	Mrs. Paul Mancina	Mayor of Scofield	Doug Trease
Recreation	Garth Frandsen	Private Citizen	Mrs. John Lamb
Private Citizen	Bertie Knox	Carbon County	Richard Walker
Agriculture	Lyle Bryner	St. Dept. of Health	Richard Denton
		Southeast AOG	Nancy Ingold
Clear Ck-Livestock	Shefton Gordon	Soil Conservation	Gary Moreau
Valley Camp Coal	Trevor Whiteside	BLM	Jessie Purvis
Coal Industry	John Garr	Private Citizen	Roy Nikas

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Advisory Group Actions. The Pleasant Valley Advisory Group reviewed the study results presented by the staff of the State Bureau of Water Pollution Control and addressed alternatives for reducing the reservoir pollution. The Advisory group drafted several recommendations targeted at problem areas. Since the Advisory Group has no implementing authority or statutory power, recommendations must be acted on by agencies and private entities who have direct responsibility and authority.

Department of Health Action. State personnel presented the study data, conclusions, and a list of possible restoration measures to the Carbon County Commission and the Pleasant Valley Citizens Advisory Group. With the aid of Southeastern Utah Association of Governments staff, a public awareness program has been initiated as well as public meetings held. A detailed account of this process can be found in the Scofield Reservoir Report Public Participation Section in the Appendixes.

The State reviewed the Advisory Groups recommendations for costs and feasibility. Additional restoration alternatives as formulated by the State were also reviewed for cost and feasibility. Feasibility was determined by costs, available funding, public acceptance, and benefits to the Scofield Reservoir ecosystem and watershed.

Recommendations. The Pleasant Valley Citizens Advisory Group and the Utah Department of Health recognized the far reaching and broad areas that must be considered in drafting recommendations. The general consensus was that no one reservoir user, operator, private individual or agency causes all of the reservoir pollution. The intent of the process was not to single out any particular group, individual user, or agency as having the prime responsibility for correcting the problem unless clearly warranted. They are trying to initiate a cooperative and continuing effort to accomplish the objective of retaining Scofield Reservoir as a good quality reservoir. Solutions involve public awareness and education, regulatory action, physical or mechanical action. Some parts require substantial funds and some longer term follow-through. The Advisory Group and the state supports the concept of cooperative funding for such actions either under the auspices of county, state, or federal agencies, or private action groups.

Pleasant Valley Citizen Advisory Committee Program Elements

The Committee has prepared a set of general recommendations many of which relate directly to the protection of Scofield Reservoir.

1. Funding needs to be identified to complete a 201 sewage treatment facilities plan for Scofield Town.

2. Funding needs to be identified to upgrade the culinary water supply for Scofield Town.

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3. A valley-wide landfill is needed to serve the mines, Town and cabins. $25,000 has been approved from the Block Grant Program. The mines have expressed a willingness to participate in financing this project.

4. Camping facilities in the Scofield area need to be upgraded and expanded. This may be accomplished through public and private cooperation. The State Park system, County facilities and private developers need to provide and /or improve facilities. Necessary facilities include: adequate solid waste disposal points, increased number of sanitary restrooms, more overnight campsites and more trailer dump stations.

5. A fee system should be established by the County at its campground. The fees will generate funds for the operation, maintenance and construction of facilities used.

6. Utah Department of Transportation is currently preparing to upgrade U-96. This highway should be designed to minimize conflicts between recreation users and mine traffic. Adequate parking should be included to provide areas for recreation users to pull off the highway. Early public involvement in the design and construction of this highway is mandatory.

7. The Town and the County should develop a fire protection and ambulance service agreement. The Town of Scofield is able to provide these services to the unincorporated areas of the valley, via a formal agreement.

8. A livestock-free buffer zone should be established around the reservoir. This zone should also be considered for the tributaries in heavily grazed areas. Other uses such as cabins and overnight camping should be restricted in this zone.

9. The local Health Department should be required to enforce existing health regulations in the recreation subdivisions and the entire valley. Cabin owners must find suitable systems for waste disposal and all new developments must comply with existing regulations.

10. Law enforcement by all agencies is critical. The Town of Scofield, Carbon County, State Parks, Division of Wildlife Resources and the Highway Patrol should all increase their enforcement efforts in Pleasant Valley. Many of the existing problems are the result of lax enforcement of laws and regulations pertaining to health and safety.

11. Additional coal leases in this valley should be carefully scrutinized as to need and potential to degrade water quality. Coal development presents potential impacts directly through erosion and ground water interception and indirectly through growth pressures.

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12. Cooperative agreements are needed to solve the cross-jurisdictional problems between Utah and Carbon Counties. An alternative would be to create a watershed management district with control at the State level for health issues.

13. A blanket user fee could be established for all recreation users. The fees could be used to finance improvements around the reservoir.

Implementation of many of these recommendations is taking place through coordination with local, State and federal agencies, and private landowners. This activity will continue with aggressive efforts to implement all committee recommendations.

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APPENDIX A

GEOLOGICAL AND SOILS DESCRIPTION OF DRAINAGE BASIN

Geological Description

The Scofield Reservoir drainage occupies part of the Northern Wasatch Plateau in parts of Carbon, Utah, and Sanpete Counties in Central Utah. The majority of the drainage lies in the economically important Wasatch Plateau coal field with most coal being mined from the Blackhawk Formation of late Cretaceous age. The Wasatch Plateau, which is commonly called the Manti or Manti Mountain, is in the northwestern part of the Colorado Plateau physiographic province. The western edge of the Wasatch Plateau is in the transition zone between the Colorado Plateau physiographic province located to the east and the basin and range physiographic province located to the west.

The entire plateau is composed of Cretaceous and Tertiary sedimentary rocks with a few intrusive igneous rocks in dikes being found in Pleasant Valley with metamorphosed coal and rock along the dike contacts (Spieker, 1931).

The stratigraphy of the Pleasant Valley Creek area is shown in Figure A-1. The Star Point Sandstone is the bottom structure exposed at the south end of Scofield Reservoir (Hansen, 1980) and also at the mouth of Eccles Creek (Full, 1979 and Valley Camp of Utah, 1980). The Star Point Sandstone is the lowest formation in the Mesaverde Group as shown in Table A-1. The formation is a massive sandstone that is cliff forming and consists of tan, light gray, and white sandstones that may be separated by tongues of Mancos Shale (Masuk Shale) (Davis and Doelling, 1977).

The contact of the Star Point Sandstone with the overlying Blackhawk Formation is sharp (Davis and Doelling, 1977) and is used as a principal marker horizon throughout the Wasatch Plateau and the western end of the neighboring Book Cliffs located to the east of the Wasatch Plateau (Full, 1979).

The Blackhawk Formation is Utah's chief coal producer (Stokes, 1964) and is the middle formation of the Mesaverde group with most of the thick and important coal beds located in the lower half of the formation (Davis and Doelling, 1977).

The Blackhawk Formation consists of light to medium gray sandstones which are mostly fine-grained and weather to shades of tan, yellow brown, yellow gray, and occasionally white. The sandstones form ledges and cliffs. The shales in the formation are light gray to black in color and the siltstones underlie covered slopes. Leaf imprints of sequoias, ferns, and willows may be found in carbonaceous siltstones and darker shales (Davis and Doelling, 1977).

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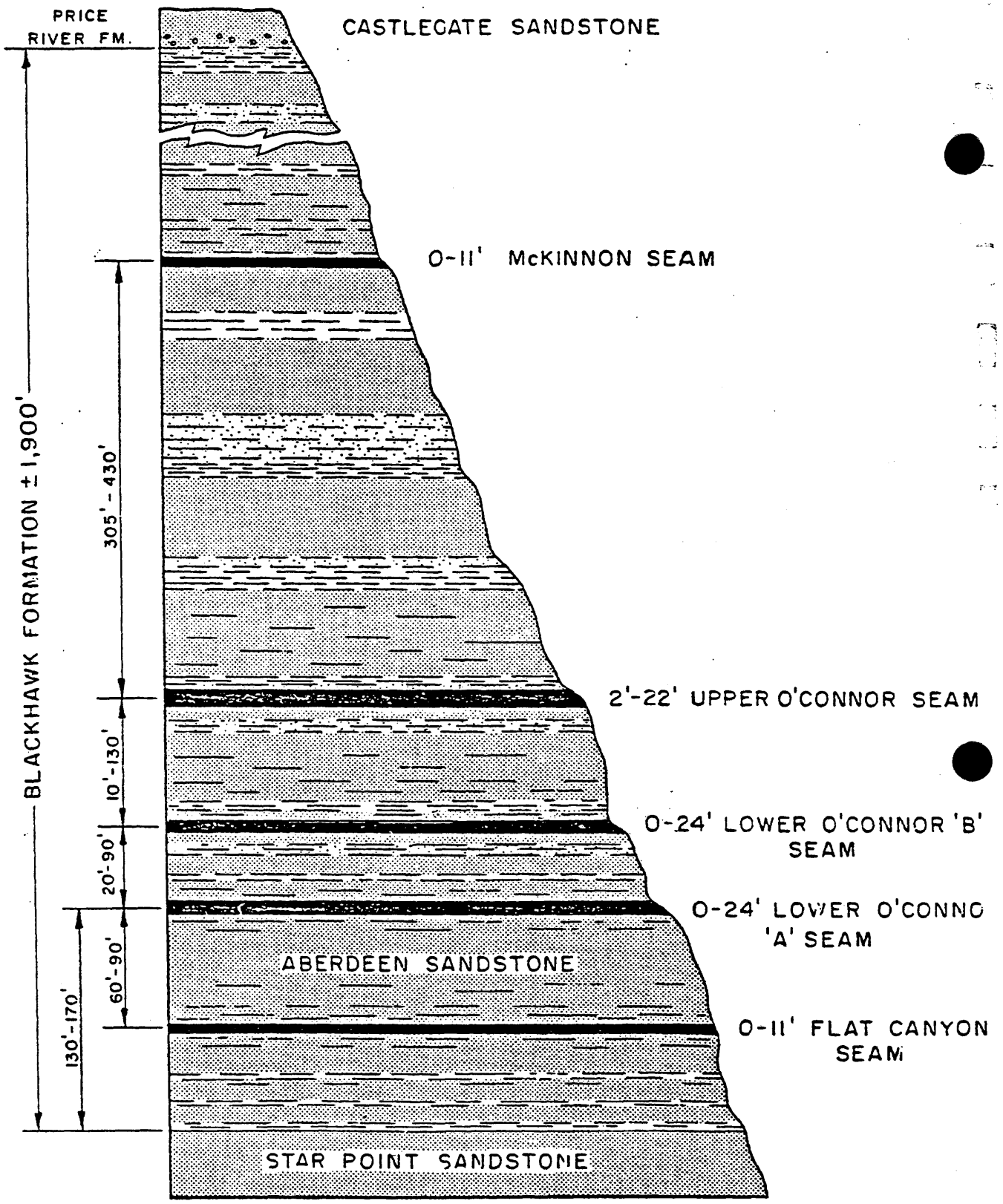

Figure A-1 Generalized Columnar Section
Eccles Canyon Area
(from Full, 1979)

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After Doelling

System	Series	Stratigraphic Unit		Thickness (feet)	Description
TERTIARY	Eocene	Green River Formation		–	Chiefly greenish lacustrine shale and siltstone.
		Wasatch Group	Colton Formation	300-1,500	Varicolored shale with sandstone and limestone lenses, thickest to the north.
	Paleocene		Flagstaff Limestone	200-1,500	Dark yellow-gray to cream limestone, evenly bedded with minor amounts of sandstone, shale and volcanic ash, ledge former.
			North Horn Formation (Lower Wasatch)	500-2,500	Variegated shales with subordinate sandstone, conglomerate and freshwater limestone, thickens to north, slope former.
CRETACEOUS	?				
	Maestrichthian	Mesaverde Group	Price River Formation	600-1,000	Gray to white gritty sandstone interbedded with subordinate shale and conglomerate, ledge and slope former.
			Castlegate Sandstone	150- 500	White to gray, coarse-grained often conglomeratic sandstone, cliff former, weathers to shades of brown.
	Campanian		Blackhawk Formation *MAJOR COAL SEAMS*	700-1,000	Yellow to gray, fine- to medium-grained sandstone, interbedded with subordinate gray and carbonaceous shale, several thick *coal* seams.
			Star Point Sandstone	90-1,000	Yellow-gray massive cliff-forming sandstone, often in several tongues separated by Masuk Shale, thickens westward.
	Santonian	Mancos Shale	Masuk Shale	300-1,300	Yellow to blue-gray sandy shale, slope former, thick in north and central plateau area, thins southward.
			Emery Sandstone *COAL (?)*	50- 800	Yellow-gray friable sandstone tongue or tongues, cliff former, may contain *coal* (?) in south part of plateau if mapping is correct, thickens to west and south. *Coal* may be present in subsurface to west.
	Coniacian		Blue Gate Member	1,500-2,400	Pale blue-gray, nodular and irregularly bedded marine mudstone and siltstone with several arenaceous beds, weathers into low rolling hills and badlands, thickens northerly.
	Turonian		Ferron Sandstone Member *MAJOR COAL SEAMS*	50- 950	Alternating yellow-gray sandstone, sandy shale and gray shale with important *coal* beds of Emery coal field, resistant cliff former, thickens to the south.
	Cenomanian		Tununk Shale Member	400- 650	Blue-gray to black sandy marine slope forming mudstone.
	Albian	Dakota Sandstone *MINOR COAL*		0- 60	Variable assemblages of yellow-gray sandstone, conglomerate shale and *coal*. Beds lenticular and discontinuous.

Table A-1 Generalized Section of Rock Formations, Wasatch Plateau Coal Field (from Full, 1979)

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Davis and Doelling (1977) examined 7 cores from the Blackhawk formation in the Trail Mountain area located south of the study area and found that the cores showed numerous and rapid vertical lithological changes. They said that "it appears that the sediments of the Blackhawk Formation were deposited in littoral marine, floodplain (fluvial), deltaic, and coastal lagoonal-paludal environments".

The Blackhawk Formation extends west and is exposed into the neighboring upper Huntington Creek and lower Gooseberry Creek areas (Spieker and Billings, 1940). The formation also extends along the east shore of Scofield Reservoir north of Miller Canyon, past the dam and including the east side of the north arm of the reservoir (Moussa, 1965). Moussa also mapped the Blackhawk Formation along the southwestern shoreline of the reservoir and the valley floors of Fish and Pondtown Creeks.

The upper most stratum in the Pleasant Valley area is the Castlegate Sandstone member, the lowest member of the Price River Formation. The Price River Formation is the uppermost of the three formations in the Mesaverde group and is separated from the Blackhawk Formation by a discomformity (Davis and Doelling, 1977). The Castlegate member is a series of prominent near-vertical cliffs above the less resistant underlying Blackhawk Formation and caps the ridges between the Pleasant Valley Creek and Huntington Creek drainages (Full, 1979). Smaller, narrow exposures of the Castlegate member are found on the west side of the Huntington Creek drainage where it underlies the larger and more exposed Price River member (Spieker and Billings, 1940).

The Castlegate member forms most of the north shoreline of Scofield Reservoir from Pondtown Creek east and north to the County Park which is situated on the Price River Member. The Castlegate member is found between the underlying Blackhawk Formation and the overlying Price River Member from Miller Canyon North to the north end of the reservoir and also along the slopes of Fish and Pondtown Creeks (Moussa, 1965).

The Price River Member of the Price River Formation forms the cap on the plateau south of the Scofield Reservoir Dam and overlies the Castlegate member and underlies the North Horn on the North side of the Price River below the Dam and also northwest throughout Dry Valley. It caps the ridges north of Pondtown Creek and also south of Upper Pondtown Creek (Moussa, 1965). It occupies the same stratigraphic position along the west side of Upper Huntington Creek, Flat Canyon, and into Brooks Creek and the lower east side of Gooseberry Valley (Spieker and Billings, 1940). Davis and Doelling (1977) describe the Price River member as forming "a steep receding slope above the Castlegate Sandstone cliff". The strata are predominently fluvial sandstones, but there are a few thin interbedded pebble conglomerates and gray shales. The sandstones are gray, grayish tan, tan, and brown; most are medium to coarse grained, but some are fine grained.

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The Wasatch formation was originally divided by Spieker (1931) into three members; 1. the lower member, 2. the Flagstaff Limestone Member and, 3. the upper member. The lower member has since been given formation status and named the North Horn Formation. The Flagstaff Limestone has been given formational status also. The North Horn Formation covers much of Dry Valley (Moussa, 1965) and Gooseberry Valley (Spieker and Billings, 1940). The lower North Horn is described as late Cretaceous with late Cretaceous fossils while Tertiary fossils have been found in the upper part of the formation.

The North Horn primarily contains shales with small amounts of sandstone and thin beds of freshwater limestone. It primarily forms slopes with its upper contact with the overlying, more resistant Flagstaff limestone often being a pronounced break in slope (Davis and Doelling, 1977).

The Flagstaff Limestone forms white cliffs along the western and northern areas of Dry Valley and in the upper areas of Gooseberry Valley and is the uppermost formation found in the Scofield Reservoir drainage. The formation is Paleocene in age and "consists of white and light gray, thin-bedded lacustrine limestone with some thin beds of gray shale and dense white volcanic ash" (Davis and Doelling, 1977).

The upper Gooseberry Valley was subjected to glaciation that was unmistakenly Wisconsin in age according to Spieker and Billings (1940). They followed the course of the glacier from a small cirque northwest of Spring Canyon where Gooseberry Creek heads northward through the broad Gooseberry Valley to the terminal moraine north of Gooseberry Reservoir. The stream had cut its way through the terminal moraine but a dam has been built in the outlet forming Lower Gooseberry Reservoir.

The most important aquifer in the Scofield Reservoir Drainage is the Star Point Sandstone Formation with a much higher yield of groundwater than the sandstones in the Blackhawk Formation (Hansen, 1979). Hansen reported that the Star Point, which covers approximately 25% of the surface of Eccles Canyon, is nearly full to the upper reaches of the outcrop and yielding water through seeps and springs to that point. By comparison, the Blackhawk Formation in neighboring Huntington Creek has a very low yield of water with approximately 19% of the total annual flow attributed to annual ground water yield compared to 64% for the Eccles Creek flow.

The shales in the Price River drainage have important effects on the surface and ground water qualities in the Price River Basin (Hansen, 1979). Shales and siltstones tend to contain soluble minerals in abundance and afford more surface contact to water flowing through than would be expected in coarse-textured rocks (Bentley et al., 1978).

Springs having low dissolved solids concentrations of 17 to 64 mg/l are found issuing from the Castlegate Sandstone which lack shaley layers (Hansen, 1979). Springs issuing from the Blackhawk Formation which has an abundance of shales and siltstones in the Eccles Creek drainage have

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dissolved solid concentrations of normally greater than 300 mg/l according to Hansen (1979). Surface water in Pleasant Valley Creek has been found to have average total dissolved solids mg/l concentrations in samples collected as part of the Clean Lakes study although storm runoff examples were as high as 978 mg/l on August 10, 1981. Surface waters sampled during this study were found to have average total dissolved solids concentration as low as 183 mg/l and as high as 292 mg/l. The low value found was 98 mg/l, in Dry Valley Creek during snow melt in May and during storm runoff on August 10, 1981.

The contribution of the Blackhawk in the salinity load to the Price River is not as great, however, as that by the Mancos Shales and other formations in Castle Valley. Dissolved solids in both surface and ground water are both near 3,000 mg/l in and near the Price River near its confluence with the Green River (Price and Waddell, 1973) with the major portion of the dissolved solids being contributed by the saline shales in the watershed. The flow-weighted mean for total dissolved solids is 272 mg/l in the Price River at the monitoring station at Heiner where the Price River enters the Mancos Shale Formation and increases to 2,016 mg/l at the Woodside monitoring station.

Ground Water Hydrology

The south end of Scofield Reservoir sits on alluvium covering the Star Point Sandstone Formation, the most important aquifer in the drainage (Hansen, 1980). Groundwater enters the reservoir through the alluvial deposits at a rate of 14.7 acre-feet per year according to estimates of the Utah Water Research Laboratory (1981). The strata in the southeast corner of the reservoir are dipping toward the northeast in the area of the Aletha Mine and studies by Hansen (1980) show that the ground water movement in the mine area is toward the northeast which would be away from the reservoir area. The ground water moving out of the Scofield Reservoir drainage area in the southeast corner of the reservoir in the areas of Eagle Creek which is intermittent and Miller Canyon Creek which has very low flows, might be an explanation for the low surface water yield of those watersheds in relation to their areas. At this time, it is not known if the ground water that may be leaving the Scofield Reservoir drainage is balanced by the ground water coming into the reservoir.

The ground water in the basin is recharged by only about 5% or less of the precipitation with low specific yields of rocks in the order of 0.2 to 0.7% with low hydraulic conductivities as well (Price and Wadell, 1973). There is only an average of less than 600 acre feet of recoverable water per square mile in the upper 100 feet of saturated rock in the drainage area (Price and Arnow, 1974).

The explanation for the low ground water yield lies in the interbedded shales and sandstones of continental and marine origin according to Price and Waddell (1973). They indicated that the impermeable shale layers prevented the downward movement of water so that

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the sandstones were prevented from achieving the potential aquifer capabilities. After percolating down through the sandstone layer to an impermeable shale layer, the water moves horizontally until it reaches the surface or another drain such as another sandstone finger or a fault (Hansen, 1979). Spieker (1931) identified three types of shale of continental origin in the Blackhawk formation; namely, (1) a common clay shale which is soft and granular, (2) a carbonaceous shale, and (3) a smoke gray shale usually associated with the coal.

Vertical movement of water through the impermeable shale layers can be accomplished through the numerous faults in the basin. The faults can act as major passages in the Star Point Sandstone but may be of only local importance in the Blackhawk Formation (Hansen, 1979 and 1980). The United States Geological Survey (1979) stated that the shale layers of the Blackhawk formation tend to swell when wet and become an impervious clay. This bentonitic characteristic of the clay therefore helps the fractures in the formation to seal and prevent water movement down through the formation.

The sandstones in the Blackhawk Fomation are not always a continuous sandstone layer throughout the region but are discontinuous with shales forming the remainder of the horizontal layer (Hansen 1979).

The discontinuity of sandstone within the layers and the interbedding of shale and sandstone layers makes the Blackhawk sandstone important only locally as aquifers as compared to the underlying Star Point which is a regional aquifer.

Hansen (1979) made five observations concerning ground water characteristics on the Skyline Mine area:

1. A majority of seeps and springs issue from west facing slopes (which would be into the Huntington Creek drainage), probably because of the westerly dip of the strata.

2. Many springs issue from the base of a sandstone lens at the contact with the underlying shale layer from a few feet to tens of feet above the adjacent stream bed. The stream bed would normally be the drain in a perennial watershed.

3. A number of springs are located at high elevations in the upper Blackhawk formation where the sandstone lenses are very discontinuous. This indicates that most, if not all of the water from the spring comes from the small recharge area in the small surface depression or basin around the spring indicating a local and not a regional ground water system.

4. Very few seeps or springs appear to be fault-related. Bentonitic shale material in the Blackhawk shales decompose into an imprevious clay, fill the fractures, swell, and provide a seal to water movement through the fault zones.

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5. Travertine deposits, which are often an indication of a deep water source, are often associated with springs in the area. Rather than being a deep source, the travertine deposits probably come from the high calcium bicarbonate content of the water which can also cause travertine (Hem, 1970).

Groundwater in the region exist under the following conditions according to the U.S. Geological Survey (1979):

1. Water table conditions in relatively flat lying sedimentary rocks and in shallow alluvial deposits along larger perennial streams. (The deposits of the valley floors along Pleasant Valley, Fish, Gooseberry, and Pondtown Creek would be of most significance).

2. Artesian conditions exist at greater depths where a confining layer overlies a more permeable layer. Pressures in the watershed are usually not sufficant to produce flowing wells.

3. Perched or impeded conditions exist where the confining layer lies beneath the water bearing strata. (This condition applies to most seeps and springs in the upper part of the watershed).

Topography

The Scofield Reservoir watershed is in the northern Wasatch Plateau area. The plateau area consists of relatively flat lying strata that has been deeply dissected by streams into larger canyons and smaller side canyons causing large areas of great local relief in much of the watershed. The reservoir occupies the northern end of Pleasant Valley. Elevations in the watershed range from 7,618 feet above sea level at the reservoir to 10,452 at Monument Peak which is located at the south end of the Pleasant Valley Creek watershed.

Dry Valley Creek entering at the northern end of the north arm of Scofield Reservoir drains the area of the watershed which is relatively lower in elevation and consists mainly of rolling hills and knolls. Pondtown (Bear) Creek enters at the northwest corner of Scofield Reservoir and drains a long, narrow, steep canyon.

The Fish Creek drainage is the largest sub-basin on the watershed. There are over a dozen small tributaries from small side canyons that enter Fish Creek and its main tributary, Gooseberry Creek, that drains the southwest part of the watesrshed and enters Fish Creek approximately 4 miles upstream from the reservoir. Lower Gooseberry Reservoir, Beaver Dam Reservoir, and Fairview Lakes are on the Gooseberry Creek drainage. Most of the water from Fairview Lakes is diverted from the Colorado River basin of which the Price River is a part, into the Great Basin to be used for irrigation in the Fairview area.

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Millers Creek, which was a tributary to Pleasant Valley Creek before the construction of the dam, enters the reservoir along the southeast shore. Streams from a series of narrow steep canyons enter Pleasant Valley Creek south of Scofield Reservoir and Pleasant Valley becomes a narrow Canyon with steep walls south of Valley Camp.

Structure

The Clear Creek Anticline occupies the area between the Pleasant Valley Creek and Huntington Creek drainages and the strike extends north through the mountain west of Scofield Town and Reservoir and then, according to Moussa (1963), trends northeast through Dry Valley and Soldiers Summit. The beds in the west limb generally dip west into the Huntington Creek drainage and the beds in the east limb generally dip east into the Pleasant Valley Creek drainage (Full, 1979).

Numerous faults extend throughout the Scofield Reservoir drainage with most faults trending northeast - southwest. Pleasant Valley Creek trends north and south and lies in the bottom of a graben bordered on the east and west by fault blocks. The fault on the east side of Pleasant Valley and Scofield Reservoir extends north to the Soldiers Summit area as does the Pleasant Valley Fault Zone that borders the west side of Pleasant Valley. Gooseberry Valley in the south part of the Gooseberry Creek drainage occupies a north - south trending graben. The Fish Creek Graben extends the length of the creek trending from northwest to southeast and includes the southern fourth of the reservoir. The lower part of Millers Canyon Creek occupies a fault that is an extension of the Fish Creek Graben while Pondtown Creek follows a fault north and parallel to the Fish Creek Graben system (Moussa, 1965). Dry Valley Creek occupies the bottom of the Dry Valley Graben.

Slopes

Pondtown Creek occupies a narrow step-sided canyon with side slopes ranging from 50% to 65% with an average stream gradient of 3.4%. Slopes in the Fish Creek Drainage ranging between 24% and 65% on sides of canyons while the average stream gradient is 3%. Slopes on lower Gooseberry Creek may be as steep as 50% while areas in the bottom of Gooseberry Valley have slopes of less that 1%. The average stream gradient in Gooseberry Creek is 3%. Slopes on the Dry Valley Creek drainage range from 2% to 37% with an average stream gradient of 1%. The average stream gradient in the Miller Canyon Creek is 3% while slopes range up to 44%. The average stream gradient in Pleasant Valley Creek is 5% while slopes range up to 72%.

Soils

A detailed soils survey of the soils around Scofield Reservoir and throughout Pleasant Valley south of the Town of Scofield to the mouth of Ecles Canyon include nine groups of soil types as mapped and described in

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(Figure A-2 and Table A-2). The soils were interpreted as to limitations for septic tank installations, sewage lagoons, sanitary landfills and types of building. All of the soils were classed as moderate to severe, most were severe, for installation of sanitary facilities because of excessive ground water problems, steep slopes, shallow soil over bedrock or other reasons.

Collins (1981) described the soils of the Aletha Mine tract at the southeastern corner of the reservoir. The soils were classified as being Type A-5 35% Typic Argiborolls, 20% Lithic Argiborolls, and 20% Typic Haploborolls with the remaining 25% being mainly Pachic Argiborolls, Argic Cryoborolls and rock as described by Wilson et. al. (1975). The soils in the mine area by the lake were also grouped into subdivisions similar to the vegetation of:

1. dry sagebrush community soils;
2. moist meadow/pasture soils and;
3. disturbed soils on which primarily noxious weeds were growing.

The soils in the upland areas of the mine lease were classed as Type A-1 Argic Cryoborolls, Pachic Cryoborolls, and Cryic Paleoborolls association, as described by Wilson et al., (1975).

Detailed soil surveys of the Bellina and Skyline Coal Mine properties between Pleasant Valley Creek and Huntington Creek were conducted by Welsh et al., (1979 and 1980) in areas that are probably representative of the upland or type 1 soils of the Scofield Reservoir Drainage. They described ten soils on the Skyline mine property with the vegetation associated with each soil association (Table A-3) and eleven soils on the Belina Mine property with the vegetation associated with each soil association (Table A-4).

Sediment production on the lower Type 5 soil association is low (Wilson et al., 1975 and Collins, 1981) except in areas of disturbed soils. The uplands type 1 soils can have higher sediment yields of slight to moderate in undisturbed soils but can have severe sediment yields in disturbed soils because of the steepness of the slopes (Wilson et al., 1975). The average sediment yield was calculated as 0.52 acre-foot per square mile per year on the Skyline Mine property using the Universal soil loss equation according to Hansen (1979).

Waddell, et al. (1983) estimated that 3,000 acre-foot of sediment had accumulated in Scofield Reservoir between 1943 and 1980, which reduced the storage capacity of the reservoir by 4 percent. The average annual sediment yield of the Scofield Reservoir drainage basin was estimated to range from 0.2 to 0.5 acre-foot per square mile.

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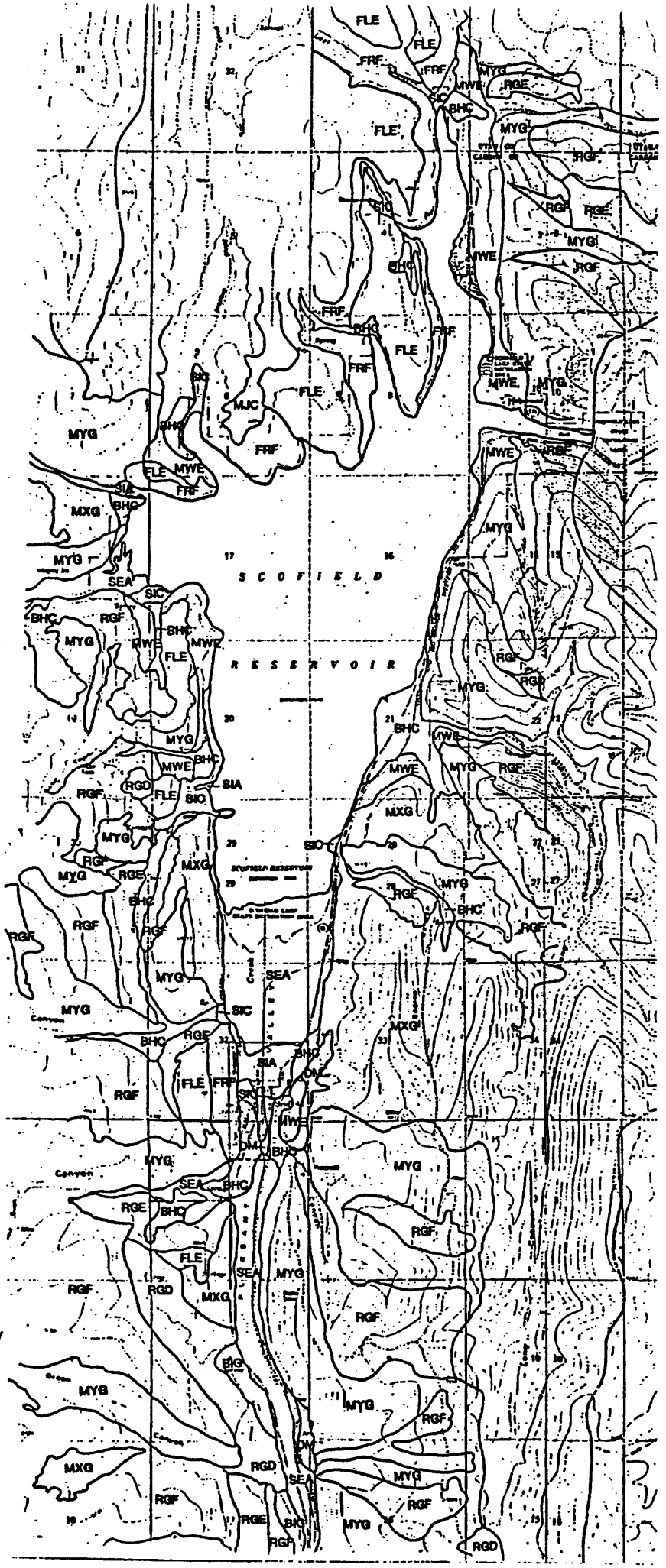

Figure A-2.
Pleasant Valley
soils.
See key on
Table A-2.

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Pleasant Valley Soil Interpretations and Limitations

Use — Soil Type

	BIG Beardall	MJC Moreno	BHC Brycan	RGD, RGE, RGF Ercan	MWE, MXG, MYG Kuhnz-Trog-Ercan	SIA, SIC, SEA Silas	FLE, FRF Falcon	TKA	DM - Mine Dumps
Septic tank	Severe-slope, depth to rock	2-15% Severe-percs slowly +15% Severe-percs slowly, slope	Severe-percs slowly	8-15% Severe-percs slowly +15% Severe-percs slowly, slope	8-15% Severe-percs slowly; +15% Severe-percs slowly slope	Severe-wetness	8-15% Severe-depth to rock; +15% Severe-depth to rock, slope	Uninterpreted; Sulfur springs cause high concentrations of calcium carbonate.	Uninterpreted: waste rocks and coal from abandoned mines.
Sewage Lagoon	Severe-slope, depth to rock	2-7% Moderate - slope +7% Severe-slope	0-2% Moderate-seepage 2-7% Mod.-seepage, slope; +7% Severe-slope	+8% Severe-slope	Severe-slope	Severe-wetness	Severe-seepage, depth to rock, slope	-	-
Sanitary Landfill	Severe-depth to rock, slope	2-15% Severe-too clayey; +15% Severe-too clayey, slope	0-8% Moderate-too clayey 8-15% Mod.-slope, too clayey	8-15% Mod.- too clayey, slope; +15% Severe-slope	8-15% Mod.-slope, too clayey; +15% Severe-slope	Severe-wetness	8-13% Severe-depth to rock, seepage; +15% Severe-depth to rock, slope, seepage	-	-
Shallow Excavation	Severe-depth to rock, slope	2-8% Slight 8-15% Moderate-slope; +15% Severe-slope	0-8% Slight 8-15% Moderate - slope	8-15% Mod.-slope +15% Severe-slope	8-15% Mod.-slope +15% Severe-slope	Severe-wetness	8-15% Severe-depth to rock; +15% Severe-depth to rock, slope	-	-
Dwelling without Basement	Severe-slope	2-8% Mod.-too clayey; 8-15% Mod. too clayey,.slope; +15% Severe-slope	0-1% Slight 8-15% Moderate - slope	8-15% Mod.-slope, shrink swell, frost action +15% Severe-slope	8-15% Mod.-shrink swell, slope; +15% Severe-slope	Severe-floods, wetness	8-15% Severe-depth to rock, slope; +15% Severe-depth to rock, slope	-	-
Dwelling with Basement	Severe-slope, depth to rock	2-8% Mod.-Shrink, swell; 8-15% Mod. Shrink swell,slope +15% Severe-slope	0-8% Slight 8-15% Moderate - slope	8-15% Mod.-slope, shrink swell; +15% Severe-slope	8-15% Mod.-shrink swell, slope; +15% Severe-slope	Severe-floods, wetness	8-15% Severe-depth to rock, slope; +15% Severe-depth to rock,slope	-	-
Small Commercial	Severe-slope	2-4% Mod. Shrink swell; 4-8% Mod. Shrink swell, slope; +8% Severe-slope	0-4% Slight; 4-8% Mod.-slope; +8% Severe-slope	+8% Severe-slope	Severe-slope	Severe-floods, wetness	Severe-depth to rock, slope	-	-
Roads/Streets	Severe-slope	2-15% Severe-low strength; +15% Severe-low strengt slope	0-8% Mod.-frost action 8-15% Mod.-slope, frost action	8-15% Mod.-slope, low strength, frost action; +15% Severe-slope	Severe-slope,low strength	Severe-frost action	8-15% Severe-depth to rock; +15% Severe-depth to rock,slope	-	-

TABLE A-2
(from Land Designs, 1982)

Table A-3. Soils in the Bellina Mine area.

Taxonomic Classification	Vegetation
Loamy-Skeletal, mixed Mollic Cryoboralfs	Spruce/Fir/Grass/Forbs
Fine-loamy, mixed Argic Pachic Cryoborolls	Aspen
Loamy-skeletal, mixed Argic Cryoborolls	Grass/Forb/Elderberry
Coarse-loamy, mixed Pachic Cryoborolls	Aspen
Loamy-skeletal, mixed Typic Cryoborolls	Aspen/Grass
Coarse-loamy, mixed Cumulic Cryoborolls	Aspen/Snowberry/Elderberry
Loamy-skeletal, mixed Typic Cryoboralfs	Sagebrush/Grass/Snowberry
Coarse-loamy, mixed Mollic Cryofluvent	Grass/Forb
Coarse-loamy, mixed frigid Typic Argiborolls	Stinging Nettle
Coarse-loamy, mixed frigid Typic Haploborolls	Aspen
Loamy-skeletal, mixed Lithic Cryocrepts	Sagebrush/Grass
Rock Outcrops	

Source: Welsh and Murdock, 1980. Underground Mining Permit Application, Valley Camp of Utah, Inc.

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Table A-4. Soils in the Skyline Mine area.

Reference Area	Soil	Texture	Vegetation
1	Typic Cryoborolls	Fine Loamy	Grass/Forbs/Elderberry
1	Lithic Cryoborolls	Loamy-skeletal, mixed	Aspen
1	Argic Cryoborolls	Loamy-skeletal, mixed	Spruce/Fir
2	Typic Cryoborolls	Coarse Loamy, mixed	Grass/Forb/Elderberry
2	Argic Lithic Cryoborolls	Course Loamy	Aspen
2	Mollic Paleboralf	Loamy Skeletal	Spruce/Fir
3	Argic Lithic Cryoboralf	Coarse Loamy	Aspen
3	Lithic Cryochrepts		Sagebrush
3	Typic Cryoborolls	Loamy Skeletal, mixed	Spruce/Fir
3	Aquic Cryofluvent	Coarse Loamy	Riparion Ca /Grass
4	Lithic Cryoborolls	Loamy-skeletal, mixed	Aspen
4	Typic Cryofluvent	Loamy-skeletal, mixed	Riparian
4	Typic Cryoboroll	Loamy-skeletal, mixed	Spruce/Fir
A	Argic Cryoboroll	Loamy-skeletal, mixed	Aspen
B	Typic Cryofluvent	Loamy-skeletal, mixed	Riparian Shrub/Grass/Forb
C	Typic Cryorboralfs	Loamy-skeletal, mixed	Spruce/Fir
D	Cumulic Cryroborolls	Coarse Loamy	Aspen/Grass/Forbs

Source: Welch, et al., 1979. Underground Mining Application. Coastal States Energy Company. Skyline Mine.

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APPENDIX B

BENTHOS SAMPLE RESULTS

This section contains the data from macroinvertebrate samples taken in the Scofield Reservoir drainage basin as a part of the Cleans Lakes studies.

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Table B-1. Macroinvertebrate populations for Pleasant Valley Creek.

SPECIES ANALYSES

STATION: 255 PVC ASR PLEASANT VALLEY CK ABOVE SCOFIELD RES DATE: 14 11 81

CLASS	ORDER	FAMILY	GENUS	SPECIES	MEAN NO/SQM	LOG10 NO/SQM	TOLERANCE QUOTIENT	LOG10 X TQ	MEAN WT GM/SQM
NEMATODA					322.80	2.509	108.	271.	
GASTROPODA		LYMNAEIDAE	LYMNAEA		301.28	2.479	108.	268.	
PELECYPODA					21.52	1.333	108.	144.	
OLIGOCHAETA					150.64	2.178	108.	235.	
ARACHNIDA	HYDRACARINA				688.64	2.838	98.	278.	
CRUSTACEA	OSTRACODA				43.04	1.634	108.	176.	
INSECTA	EPHEMEROPTERA	BAETIDAE	BAETIS		1570.96	3.196	72.	230.	
INSECTA	EPHEMEROPTERA	EPHEMERELLIDAE	EPHEMERELLA	GRANDIS	43.04	1.634	24.	39.	
INSECTA	EPHEMEROPTERA	EPHEMERELLIDAE	EPHEMERELLA	INERMIS	2259.60	3.354	48.	161.	
INSECTA	PLECOPTERA	PTERONARCYIDAE	PTERONARCELLA	BADIA	29.59	1.471	24.	35.	
INSECTA	PLECOPTERA	PERLODIDAE	ISOGENOIDES		21.52	1.333	24.	32.	
INSECTA	PLECOPTERA	PERLODIDAE	ISOGENOIDES	ZIONENSIS	2.69	.430	24.	10.	
INSECTA	PLECOPTERA	PERLODIDAE	ISOPERLA		67.25	1.828	48.	88.	
INSECTA	TRICHOPTERA	HYDROPSYCHIDAE	HYDROPSYCHE		3357.12	3.526	108.	381.	
INSECTA	TRICHOPTERA	LIMNEPHILIDAE	OLIGOPHLEBODES		43.04	1.634	24.	39.	
INSECTA	TRICHOPTERA	BRACHYCENTRIDAE	BRACHYCENTRUS		64.56	1.810	24.	43.	
INSECTA	COLEOPTERA	ELMIDAE			18141.36	4.259	104.	443.	
INSECTA	DIPTERA	TIPULIDAE	ANTOCHA	MONTICOLA	279.76	2.447	24.	59.	
INSECTA	DIPTERA	TIPULIDAE	HEXATOMA		86.08	1.935	36.	70.	
INSECTA	DIPTERA	TIPULIDAE	HOLORUSIA	GRANDIS	2.69	.430	72.	31.	
INSECTA	DIPTERA	TIPULIDAE	HOLORUSIA		21.52	1.333	72.	96.	
INSECTA	DIPTERA	TIPULIDAE	ERIOCERA		24.21	1.384	72.	100.	
INSECTA	DIPTERA	CHIRONOMIDAE			4325.52	3.636	108.	393.	
INSECTA	DIPTERA	CERATOPOGONIDAE			322.80	2.509	108.	271.	
INSECTA	DIPTERA	EMPIDIDAE	HEMERODROMIA		322.80	2.509	95.	238.	
				TOTALS	32514.03	4.512			9.33

TOTAL SAMPLE STATISTICS

STATION: 255 PVC ASR PLEASANT VALLEY CK ABOVE SCOFIELD RES DATE: 14 11 81

REPL.	TOTAL NO. SPECIES	MEAN /SQM	CONFIDENCE LIMITS (80 PERCENT) LL	UL	STANDARD DEVIATION	PERCENT SE OF MEAN	COEFF. OF VARIATION	DBAR	R	CTQA	CTQD
* NUMBERS DATA											
4	25	32514.	23543.	41485.	10953.09	16.84	33.69	2.2842	0.5084	[illegible]	77.

Table B-2. Macroinvertebrate populations for Fish Creek.

SPECIES ANALYSES

STATION: 275 UFC ASR UPPER FISH CK ABOVE SCOFIELD RES, UT CNTY DATE: 14 11 81

CLASS	ORDER	FAMILY	GENUS	SPECIES	MEAN NO/SQM	LOG10 NO/SQM	TOLERANCE QUOTIENT	LOG10 X TQ	MEAN WT GM/SQM
HIRUDINEA					21.52	1.333	108.	144.	
OLIGOCHAETA					64.56	1.810	108.	195.	
INSECTA	EPHEMEROPTERA	BAETIDAE	BAETIS		925.36	2.966	72.	214.	
INSECTA	EPHEMEROPTERA	HEPTAGENIIDAE	CINYGMULA		1743.12	3.241	30.	97.	
INSECTA	EPHEMEROPTERA	HEPTAGENIIDAE	EPEORUS		21.52	1.333	21.	28.	
INSECTA	EPHEMEROPTERA	LEPTOPHLEBIIDAE	PARALEPTOPHLEBIA		893.08	2.951	24.	71.	
INSECTA	EPHEMEROPTERA	EPHEMERELLIDAE	EPHEMERELLA	INERMIS	608.64	2.838	48.	136.	
INSECTA	PLECOPTERA	PTERONARCYIDAE	PTERONARCELLA	BADIA	936.12	2.971	24.	71.	
INSECTA	PLECOPTERA	PERLODIDAE	ISOPERLA		269.00	2.430	48.	117.	
INSECTA	PLECOPTERA	CHLOROPERLIDAE			559.52	2.748	24.	66.	
INSECTA	TRICHOPTERA	HYDROPSYCHIDAE	HYDROPSYCHE		2980.52	3.474	108.	375.	
INSECTA	TRICHOPTERA	HYDROPSYCHIDAE	ARCTOPSYCHE		21.52	1.333	18.	24.	
INSECTA	TRICHOPTERA	LIMNEPHILIDAE			150.64	2.178	108.	235.	
INSECTA	TRICHOPTERA	LEPIDOSTOMATIDAE	LEPIDOSTOMA		21.52	1.333	18.	24.	
INSECTA	TRICHOPTERA	BRACHYCENTRIDAE	BRACHYCENTRUS		21.52	1.333	24.	32.	
INSECTA	COLEOPTERA	ELMIDAE			2329.54	3.367	104.	350.	
INSECTA	DIPTERA	TIPULIDAE	ANTOCHA	MONTICOLA	21.52	1.333	24.	32.	
INSECTA	DIPTERA	TIPULIDAE	HEXATOMA		43.04	1.634	36.	59.	
INSECTA	DIPTERA	TIPULIDAE	ERIOCERA		2.69	.430	72.	31.	
INSECTA	DIPTERA	CHIRONOMIDAE			720.92	2.858	30.	86.	
INSECTA	DIPTERA	CERATOPOGONIDAE			32.28	1.509	108.	163.	
INSECTA	DIPTERA	RHAGIONIDAE	ATHERIX		2.69	.430	24.	10.	
				TOTALS	12470.84	4.096			4.94

TOTAL SAMPLE STATISTICS

STATION: 275 UFC ASR UPPER FISH CK ABOVE SCOFIELD RES, UT CNTY DATE: 14 11 81

REPL	TOTAL NO. SPECIES	MEAN /SQM	CONFIDENCE LIMITS (80 PERCENT) LL	UL	STANDARD DEVIATION	PERCENT SE OF MEAN	COEFF. OF VARIATION	DBAR	R	CTQA	CTQD
# NUMBERS DATA											
4	22	12471.	6720.	18222.	7021.83	28.15	56.31	3.2295	0.2761	54.	56.

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APPENDIX C

WATER QUALITY LOADING TABLES

The tables in this section give the loading tabulations for the major tributaries in Scofield Reservoir drainage basin. These values are for average (typical) year. This means that flow rates are the estimated long term average flow rates, and quality constituent concentrations are the estimated long-term average values. The flow rates and concentrations were determined as explained in Section 2 of this report. See Figure 2-1 and Table 2-3 for orientation and identification of the various stream sampling sites used herein.

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Table C-1. Total phosphorus loadings for streams in the Scofield drainage basin.

Month	FC-1 Flow (ac-ft)	FC-1 Conc. (mg/l)	FC-1 Total (kg)	PC-1 Flow (ac-ft)	PC-1 Conc. (mg/l)	PC-1 Total (kg)	PVC-1 Flow (ac-ft)	PVC-1 Conc. (mg/l)	PVC-1 Total (kg)
Jan	511	.025	16	44	0.04	2	282	0.04	14
Feb	477	.025	15	48	0.03	2	273	0.05	17
Mar	715	.030	26	91	0.04	5	337	0.10	42
Apr	3,343	.070	289	230	0.10	28	559	0.22	152
May	16,269	.130	2,609	1,420	0.18	315	5,083	0.24	1,567
Jun	7,859	.030	291	688	0.13	110	597	0.10	74
Jul	1,859	.035	80	71	0.06	5	199	0.05	12
Aug	946	.055	64	60	0.07	5	142	0.06	11
Sep	643	.060	48	55	0.08	5	151	0.08	15
Oct	674	.040	33	51	0.07	4	240	0.06	18
Nov	633	.025	20	48	0.06	4	288	0.04	14
Dec	558	.025	17	45	0.05	3	290	0.04	14
	34,487		3,508	2,851		488	8,441		1,950

55.9 %0

Month	WC-1 Flow (ac-ft)	WC-1 Conc. (mg/l)	WC-1 Total (kg)	MC-1 Flow (ac-ft)	MC-1 Conc. (mg/l)	MC-1 Total (kg)	DVC-1 Flow (ac-ft)	DVC-1 Conc. (mg/l)	DVC-1 Total (kg)
Jan	21	0.04	1	25	0.03	1	33	0.04	2
Feb	19	0.07	2	23	0.05	1	32	0.05	2
Mar	28	0.12	4	31	0.08	3	36	0.10	4
Apr	65	0.14	4	53	0.12	8	170	0.14	29
May	480	0.18	107	149	0.16	29	321	0.08	32
Jun	270	0.11	37	81	0.13	13	136	0.05	8
Jul	33	0.06	2	42	0.07	4	41	0.04	2
Aug	29	0.04	1	35	0.05	2	36	0.04	2
Sep	27	0.04	1	31	0.04	2	35	0.04	2
Oct	26	0.03	1	30	0.04	1	34	0.04	2
Nov	23	0.03	1	28	0.03	1	34	0.04	2
Dec	22	0.03	1	26	0.03	1	33	0.04	2
	1,043		172	554		66	941		89

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6273 Kg/yr

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Table C-1. (Cont.) Total phosphorus loadings for streams in the Scofield drainage basin.

Month	PVC-6			PVC-5			PVC-4		
	Flow (ac-ft)	Conc. (mg/l)	Total (kg)	Flow (ac-ft)	Conc. (mg/l)	Total (kg)	Flow (ac-ft)	Conc. (mg/l)	Total (kg)
Jan	11	.03	2	81	0.04	4	182	0.04	9
Feb	60	.02	2	78	0.05	5	175	0.05	11
Mar	76	.03	3	97	0.05	6	216	0.06	16
Apr	112	.09	12	141	0.14	24	316	0.16	62
May	1,055	.14	182	1,315	0.15	243	2,867	0.28	743
Jun	176	.08	17	217	0.11	29	462	0.13	74
Jul	94	.05	6	120	0.09	13	266	0.10	33
Aug	76	.04	4	97	0.08	10	217	0.07	19
Sep	70	.05	4	86	0.06	6	193	0.06	14
Oct	69	.04	3	84	0.06	6	191	0.06	14
Nov	66	.04	3	83	0.05	5	186	0.05	11
Dec	65	.03	2	84	0.04	4	187	0.04	9
	1,982		240	2,483		355	5,458		1,015

Month	PVC-3			PVC-2			EC-1		
	Flow (ac-ft)	Conc. (mg/l)	Total (kg)	Flow (ac-ft)	Conc. (mg/l)	Total (kg)	Flow (ac-ft)	Conc. (mg/l)	Total (kg)
Jan	188	0.04	9	287	0.04	14	43	0.05	3
Feb	181	0.05	11	276	0.05	17	41	0.06	3
Mar	173	0.09	19	342	0.09	38	51	0.07	4
Apr	326	0.17	68	495	0.17	104	76	0.19	18
May	2,958	0.26	949	4,405	0.25	1,358	679	0.31	260
Jun	477	0.13	76	698	0.14	121	108	0.17	23
Jul	275	0.11	37	421	0.09	47	64	0.12	9
Aug	223	0.11	30	344	0.05	21	53	0.07	5
Sep	200	0.09	22	303	0.06	22	45	0.06	3
Oct	198	0.07	17	313	0.06	23	45	0.05	3
Nov	192	0.06	14	293	0.05	18	44	0.05	3
Dec	193	0.05	12	295	0.04	15	44	0.05	3
	5,633		1,264	8,473		1,792	1,293		337

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Table C-2. Ortho phosphorus loadings Scofield Reservoir.

Month	FC-1 Flow (ac-ft)	FC-1 Conc. (mg/l)	FC-1 Total (kg)	PC-1 Flow (ac-ft)	PC-1 Conc. (mg/l)	PC-1 Total (kg)	PVC-1 Flow (ac-ft)	PVC-1 Conc. (mg/l)	PVC-1 Total (kg)
Jan	511	0.01	6	44	0.01	1	282	0.01	3
Feb	477	0.01	6	48	0.01	1	273	0.01	3
Mar	715	0.02	18	91	0.02	2	337	0.01	4
Apr	3,343	0.01	41	230	0.01	3	559	0.03	21
May	16,269	0.01	201	1,420	0.01	18	5,083	0.05	313
Jun	7,859	0.02	194	688	0.02	17	597	0.03	22
Jul	1,859	0.01	23	71	0.01	1	199	0.01	2
Aug	946	0.02	23	60	0.02	1	142	0.02	4
Sep	643	0.02	16	55	0.02	1	151	0.02	4
Oct	674	0.02	17	51	0.02	1	240	0.01	3
Nov	633	0.01	8	48	0.01	1	288	0.01	4
Dec	558	0.01	7	45	0.01	1	290	0.01	4
	34,487		560	2,851		48	8,441		387

Month	WC-1 Flow (ac-ft)	WC-1 Conc. (mg/l)	WC-1 Total (kg)	MC-1 Flow (ac-ft)	MC-1 Conc. (mg/l)	MC-1 Total (kg)	DVC-1 Flow (ac-ft)	DVC-1 Conc. (mg/l)	DVC-1 Total (kg)
Jan	21	0.01	0	25	0.01	0	33	0.01	0
Feb	19	0.01	0	23	0.01	0	32	0.01	0
Mar	28	0.01	0	31	0.01	0	36	0.01	0
Apr	65	0.02	2	53	0.01	1	170	0.01	2
May	480	0.03	18	149	0.01	2	321	0.02	2
Jun	270	0.04	13	81	0.02	2	136	0.03	5
Jul	33	0.03	1	42	0.01	1	41	0.02	1
Aug	29	0.02	1	35	0.01	0	36	0.01	0
Sep	27	0.01	0	31	0.01	0	35	0.01	0
Oct	26	0.01	0	30	0.01	0	34	0.01	0
Nov	23	0.01	0	28	0.01	0	34	0.01	0
Dec	22	0.01	0	26	0.01	0	33	0.01	0
	1,043		35	554		6	941		10

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Table C-2. (Cont.) Ortho phosphorus loadings Scofield Reservoir.

Month	PVC-6			PVC-5			PVC-4		
	Flow (ac-ft)	Conc. (mg/l)	Total (kg)	Flow (ac-ft)	Conc. (mg/l)	Total (kg)	Flow (ac-ft)	Conc. (mg/l)	Total (kg)
Jan	63	0.01	1	81	0.01	1	182	0.01	2
Feb	60	0.01	1	78	0.01	1	175	0.01	2
Mar	76	0.01	1	97	0.01	1	216	0.01	3
Apr	112	0.01	1	141	0.02	3	316	0.03	12
May	1,055	0.02	26	1,315	0.04	65	2,867	0.06	212
Jun	176	0.05	11	217	0.04	11	462	0.05	28
Jul	94	0.03	3	120	0.02	3	266	0.03	10
Aug	76	0.03	3	97	0.02	2	217	0.02	5
Sep	70	0.02	2	86	0.03	3	193	0.02	5
Oct	69	0.01	1	84	0.02	2	191	0.01	2
Nov	66	0.01	1	83	0.01	1	186	0.01	2
Dec	65	0.01	1	84	0.01	1	187	0.01	2
	1,982		52	2,483		94	5,458		285

Month	PVC-3			PVC-2			EC-1		
	Flow (ac-ft)	Conc. (mg/l)	Total (kg)	Flow (ac-ft)	Conc. (mg/l)	Total (kg)	Flow (ac-ft)	Conc. (mg/l)	Total (kg)
Jan	188	0.01	2	287	0.01	4	43	0.01	1
Feb	181	0.01	2	276	0.01	3	41	0.01	1
Mar	173	0.01	2	342	0.01	4	51	0.03	2
Apr	326	0.03	12	495	0.03	18	76	0.04	4
May	2,958	0.07	255	4,405	0.05	271	679	0.07	58
Jun	477	0.05	29	698	0.04	34	108	0.05	7
Jul	275	0.03	10	421	0.02	10	64	0.04	3
Aug	223	0.02	5	344	0.01	4	53	0.04	3
Sep	200	0.02	5	303	0.01	4	45	0.03	2
Oct	198	0.01	2	313	0.01	4	45	0.01	1
Nov	192	0.01	2	293	0.01	4	44	0.01	1
Dec	193	0.01	2	295	0.01	4	44	0.01	1
	5,633		328	8,473		364	1,293		84

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Table C-3. Inorganic nitrogen loadings Scofield Reservoir.

Month	FC-1			PC-1			PVC-1		
	Flow (ac-ft)	Conc. (mg/l)	Total (kg)	Flow (ac-ft)	Conc. (mg/l)	Total (kg)	Flow (ac-ft)	Conc. (mg/l)	Total (kg)
Jan	511	0.11	69	44	0.15	8	282	0.16	56
Feb	477	0.14	82	48	0.20	12	273	0.19	64
Mar	715	0.19	168	91	0.25	28	337	0.26	108
Apr	3,343	0.32	1,320	230	0.30	85	559	0.32	221
May	16,269	0.55	11,037	1,420	0.65	1,139	5,083	0.74	4,640
Jun	7,859	0.22	2,132	688	0.31	263	597	0.30	221
Jul	1,859	0.12	275	71	0.25	22	199	0.18	44
Aug	946	0.25	292	60	0.09	7	142	0.14	25
Sep	643	0.27	214	55	0.22	15	151	0.19	35
Oct	674	0.17	141	51	0.19	12	240	0.10	30
Nov	633	0.12	94	48	0.12	7	288	0.07	25
Dec	558	0.11	76	45	0.13	7	290	0.07	25
	34,487		15,900	2,851		1,605	8,441		5,494

Month	WC-1			MC-1			DVC-1		
	Flow (ac-ft)	Conc. (mg/l)	Total (kg)	Flow (ac-ft)	Conc. (mg/l)	Total (kg)	Flow (ac-ft)	Conc. (mg/l)	Total (kg)
Jan	21	0.10	3	25	0.09	3	33	0.09	4
Feb	19	0.16	4	23	0.10	3	32	0.11	4
Mar	28	0.18	6	31	0.17	7	36	0.17	8
Apr	65	0.27	22	53	0.26	17	170	0.21	44
May	480	0.59	349	149	0.44	81	321	0.26	103
Jun	270	0.24	80	81	0.19	19	136	0.13	22
Jul	33	0.32	13	42	0.23	12	41	0.18	9
Aug	29	0.29	10	35	0.21	9	36	0.16	7
Sep	27	0.24	8	31	0.17	7	35	0.12	5
Oct	26	0.13	4	30	0.14	5	34	0.10	4
Nov	23	0.10	3	28	0.10	3	34	0.09	4
Dec	22	0.09	2	26	0.09	3	33	0.09	4
	1,043		504	554		169	941		216

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Table C-3. (Cont.) Inorganic nitrogen loadings Scofield Reservoir.

Month	PVC-6 Flow (ac-ft)	PVC-6 Conc. (mg/l)	PVC-6 Total (kg)	PVC-5 Flow (ac-ft)	PVC-5 Conc. (mg/l)	PVC-5 Total (kg)	PVC-4 Flow (ac-ft)	PVC-4 Conc. (mg/l)	PVC-4 Total (kg)
Jan	63	0.09	7	81	0.14	14	182	0.08	18
Feb	60	0.11	8	78	0.16	15	175	0.12	26
Mar	76	0.19	18	97	0.27	32	216	0.17	45
Apr	112	0.34	47	141	0.54	94	316	0.26	101
May	1,055	0.63	817	1,315	0.70	1,132	2,867	0.62	2,186
Jun	176	0.32	69	217	0.35	93	462	0.27	153
Jul	94	0.12	14	120	0.52	77	266	0.20	65
Aug	76	0.18	17	97	0.41	49	217	0.46	123
Sep	70	0.11	9	86	0.33	35	193	0.24	57
Oct	69	0.10	8	84	0.22	23	191	0.11	26
Nov	66	0.10	8	83	0.18	18	186	0.09	21
Dec	65	0.19	7	84	0.14	14	187	0.08	18
	1,982		1,029	2,483		1,596	5,458		2,839

Month	PVC-3 Flow (ac-ft)	PVC-3 Conc. (mg/l)	PVC-3 Total (kg)	PVC-2 Flow (ac-ft)	PVC-2 Conc. (mg/l)	PVC-2 Total (kg)	EC-1 Flow (ac-ft)	EC-1 Conc. (mg/l)	EC-1 Total (kg)
Jan	188	0.09	20	287	0.09	32	43	0.10	5
Feb	181	0.18	40	276	0.16	54	41	0.15	8
Mar	123	0.22	33	342	0.16	67	51	0.27	17
Apr	326	0.27	108	495	0.28	170	76	0.39	36
May	2,958	0.63	2,299	4,405	0.72	3,901	679	0.65	543
Jun	477	0.31	182	698	0.23	197	108	0.24	32
Jul	275	0.22	75	421	0.11	57	64	0.13	10
Aug	223	0.32	88	344	0.13	55	53	0.31	20
Sep	200	0.19	47	303	0.10	37	45	0.12	7
Oct	198	0.09	22	313	0.09	35	45	0.10	6
Nov	192	0.08	19	293	0.09	32	44	0.10	5
Dec	193	0.09	21	295	0.09	33	44	0.10	5
	1,043		504	554		169	941		216

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Table C-4. Total Kjeldahl nitrogen loadings Scofield Reservoir.

Month	FC-1			PC-1			PVC-1		
	Flow (ac-ft)	Conc. (mg/l)	Total (kg)	Flow (ac-ft)	Conc. (mg/l)	Total (kg)	Flow (ac-ft)	Conc. (mg/l)	Total (kg)
Jan	511	0.35	220	44	0.18	10	282	0.22	62
Feb	477	0.52	305	48	0.20	12	273	0.18	60
Mar	715	0.48	299	91	0.28	31	337	0.16	66
Apr	3,343	0.60	2,467	230	0.43	122	559	0.55	378
May	16,269	0.57	11,439	1,420	0.40	701	5,083	0.78	4,891
Jun	7,859	0.36	3,490	688	0.34	289	597	0.30	220
Jul	1,859	0.44	1,009	71	0.32	28	199	0.34	83
Aug	946	0.42	490	60	0.40	29	142	0.35	61
Sep	643	0.22	174	55	0.50	34	151	0.29	54
Oct	674	0.24	199	51	0.30	19	240	0.20	59
Nov	633	0.26	202	48	0.26	12	288	0.20	71
Dec	558	0.24	165	45	0.21	12	290	0.22	78
	1,982		1,029	2,483		1,596	5,458		2,839

Month	WC-1			MC-1			DVC-1		
	Flow (ac-ft)	Conc. (mg/l)	Total (kg)	Flow (ac-ft)	Conc. (mg/l)	Total (kg)	Flow (ac-ft)	Conc. (mg/l)	Total (kg)
Jan	21	0.20	5	25	0.25	8	33	0.20	8
Feb	19	0.20	5	23	0.25	7	32	0.20	8
Mar	28	0.23	8	31	0.33	12	36	0.28	12
Apr	65	0.50	40	53	0.72	47	170	0.34	71
May	480	1.00	592	149	0.64	117	321	0.50	197
Jun	270	0.34	113	81	0.56	56	136	0.40	67
Jul	33	0.24	9	42	0.58	30	41	0.40	20
Aug	29	0.25	9	35	0.66	28	36	0.45	20
Sep	27	0.17	5	31	0.46	17	35	0.35	15
Oct	26	0.18	6	30	0.34	12	34	0.25	10
Nov	23	0.20	6	28	0.25	9	34	0.20	8
Dec	22	0.20	5	26	0.25	8	33	0.20	8
	1,043		803	554		351	941		444

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Table C-5. (Cont.) Total suspended solids Scofield Reservoir.

Month	PVC-6			PVC-5			PVC-4		
	Flow (ac-ft)	Conc. (mg/l)	Total (kg)	Flow (ac-ft)	Conc. (mg/l)	Total (kg)	Flow (ac-ft)	Conc. (mg/l)	Total (kg)
Jan	63	20	1,555	81	25	2,498	182	25	5,614
Feb	60	20	1,481	78	25	2,406	175	25	5,398
Mar	76	28	2,626	97	27	3,231	216	49	13,059
Apr	112	68	9,397	141	62	10,786	316	77	30,021
May	1,055	95	253,828	1,315	249	403,997	2,867	321	1,135,496
Jun	176	75	16,286	217	78	20,884	462	113	67,263
Jul	94	27	3,131	120	35	5,182	266	62	20,348
Aug	76	21	1,969	97	29	3,471	217	56	14,993
Sep	70	20	1,727	86	25	2,653	193	50	11,906
Oct	69	20	1,703	84	25	2,591	191	32	7,541
Nov	66	20	1,629	83	25	2,560	186	25	5,737
Dec	65	20	1,604	84	25	2,591	187	25	5,768
	1,982		296,936	2,483		462,850	5,458		1,323,144

Month	PVC-3			PVC-2			EC-1		
	Flow (ac-ft)	Conc. (mg/l)	Total (kg)	Flow (ac-ft)	Conc. (mg/l)	Total (kg)	Flow (ac-ft)	Conc. (mg/l)	Total (kg)
Jan	188	25	5,781	287	25	8,825	43	30	1,587
Feb	181	25	5,566	276	25	8,487	41	30	1,513
Mar	123	50	7,564	342	69	29,026	51	42	2,635
Apr	326	101	40,499	495	103	62,712	76	106	9,909
May	2,958	345	1,258,799	4,405	275	1,494,231	679	435	363,299
Jun	477	105	61,780	698	74	63,532	108	136	18,066
Jul	275	49	16,574	421	66	34,177	64	51	4,015
Aug	223	45	12,378	344	50	21,156	53	48	3,129
Sep	200	35	8,735	303	42	15,653	45	34	1,937
Oct	198	30	7,327	313	27	10,395	45	31	1,716
Nov	192	25	5,904	293	25	9,010	44	30	1,624
Dec	193	25	5,935	295	25	9,071	44	30	1,624
	5,633		1,436,736	8,473		1,766,275	1,293		411,054

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Table C-6. Nutrient loadings in Price River (PR-1).

Month	Total Phosphorous			Ortho Phosphorous			Inorganic Nitrogen		
	Flow (ac-ft)	Conc. (mg/l)	Total (kg)	Flow (ac-ft)	Conc. (mg/l)	Total (kg)	Flow (ac-ft)	Conc. (mg/l)	Total (kg)
Jan	151	0.05	9	151	0.01	2	151	0.32	60
Feb	114	0.06	8	114	0.01	1	114	0.70	98
Mar	123	0.06	9	123	0.01	2	123	0.58	88
Apr	1,161	0.12	172	1,161	0.02	29	1,161	0.39	559
May	7,410	0.10	914	7,410	0.03	274	7,410	0.26	2,376
Jun	10,437	0.07	901	10,437	0.01	129	10,437	0.20	2,575
Jul	11,089	0.07	957	11,089	0.01	137	11,089	0.23	3,146
Aug	7,216	0.09	801	7,216	0.01	89	7,216	0.21	1,869
Sep	5,019	0.13	805	5,019	0.02	124	5,019	0.41	2,538
Oct	1,561	0.11	212	1,561	0.02	39	1,561	0.47	905
Nov	448	0.08	44	448	0.01	6	448	0.64	354
Dec	337	0.06	25	337	0.01	4	448	0.45	187
	45,066		4,857	45,066		836	45,066		14,755

Month	Total Suspended Solids		
	Flow (ac-ft)	Conc. (mg/l)	Total (kg)
Jan	151	0	
Feb	114	0	
Mar	123	0	
Apr	1,161	0	
May	7,410	0	
Jun	10,437	0	
Jul	11,089	0	
Aug	7,216	0	
Sep	5,019	0	
Oct	1,561	0	
Nov	448	0	
Dec	337	0	
	45,066	0	

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BIOAVAILABILITY OF PHOSPHORUS IN SOILS AND SEDIMENTS IN THE WATERSHED OF SCOFIELD RESERVOIR

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Introduction

The quantity of phosphorus entering a lake or reservoir that is actually available to the phytoplankton is actually some value between the quantity of soluble reactive P (SRP) and total P entering the system. Because monitoring data usually include only SRP and total P, however, the true value of available P is seldom known. Most input-output trophic state models inherently assume an empirical value for the ratio of available to toal P in the inputs, either through the choice of locations for the "permissible" or "dangerous" P loading rate curves, or through universal formulas for the conversion of lake phosphorus concentrations to standing group chlorophyll concentrations (e.g. Reckhow 1979). It has been shown that similar models that employ measured available P loadings, rather than the more usual total P values, perform even better than the more general class of models (Schaffner and Oglesby 1978). Data on available P concentrations also are useful in distinguishing between the P loadings from different tributaries in a watershed that originate from sources of P characterized by widely different ratios of available to total P (e.g. wastewater versus eroding streambanks composed primarily of apatite).

A great deal of research has been done during the past decade on the bioavailability of various forms of P to lake phytoplankton. The primary impetus for this research was elucidating the probable effectiveness of reducing wastewater inputs of P (including banning P detergents) to the North American Great Lakes. The results of these studies have been reviewed recently by Lee et al. (1980), Williams et al. (1980), and Sonzogni et al. (1982). The results of the studies performed on midwestern lake and river sediments have indicated that the P extracted by the NaOH/NaCl procedure of Williams et al. (197la) is highly effective in representing the P in sediments that is potentially available to algae.

Williams et al. (1980) found that the amount of P taken up by Scenedesmus in a 14-day incubation period corresponded almost exactly with the amount of NaOH-P added to the culture medium, in the form of lacustrine and fluvial sediments or clastics collected from erosional bluffs on the north shore of Lake Erie. NAI-P (the sum of NaOH- and citrate-dithionite-bicarbonate-extractable P) over-estimated the amount of available P by an average of 43 percent, and in no case was all of the NAI-P available. Apatite-P, i.e. the phosphorus extractable in dilute HCl, was found to be virtually unavailable to the test alga. Messer and Mok (in preparation) have found very close agreement between NaOH-P and algal available P as determined by the AAP procedure (Miller et al. 1978)

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on turbid water collected during the winter from the White River in eastern Colorado. Although other P fractionation techniques, such as NTA extraction (Golterman 1977) or weak anion exchangable P (Cowen and Lee 1976, Sagher 1976, Huettl et al. 1979), have also been used to predict algal-available P, these techniques have tended to over-predict availability of P for some waters. The overprediction may result in part from the ability of chelators and ion-exchange resins to solubilize calcium associated with apatite.

The results of bioavailability studies conducted using either NaOH/NaCl extraction or actual bioassays on midwestern waters generally indicate that less than 40 percent of the particulate P in tributary streams is in the available form (Sonzogni et al. 1982). These authors summarize the Great Lakes data collected by a variety of researchers and conclude that:

1. Of the total P load in tributaries, generally 50% is available to phytoplankton;

2. Particulate P from agricultural land and urban runoff has been found to average 20-40% available P;

3. Particulate P in tributaries draining upstream lakes is in the range of 40%;

4. Some soils may have very low (10%) availability of particulate P;

5. Availability of wastewater total P is on the order of 70%;

6. The end result is that availability of total P loads may range from 40 to 80% in midwestern tributaries.

Although less work has been done in western watersheds, some of the data presently available indicate relatively lower ratios of available to toal P. Evans and Paulson (1983) report that an average of 11% of the particulate P inputs to Lake Mead on the Colorado River were available, to give an average of 10-30% of the total P loading as being available. Messer and Mok (in preparation) found 1-6 percent of the total P load in the upper White River (Colorado) to be available, and Messer et al. (1983) found 20% of the toal P in the upper arms of Flaming Gorge Reservoir to be available. If this generally lower availability of particulate P is found to extend to other western rivers, it may offer a partial explanation for the fact that western reservoirs appear to produce a lower average concentration of P in the water column than do water bodies with similar morphometry, and hydraulic and phosphorus loadings in the eastern part of the country (e.g. Mueller 1982).

Lee et al. (1980) emphasize that bioavailability studies should be interpreted in light of their intended application. For example, the availability of P in a sediment sample that is in intimate contact with algal cells during a 14-day bioassay would be of little interest if the sediment particles were removed from the photic zone in situ in one to

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Table D-2. Total and available (NaOH-extractable) phosphorus in stream bank soils collected in Scofield Reservoir watershed.

Sampling Site	Total P		NaOH-P		NaOH/Total P	SS*
	ug/l	mg/kg	mg/l	mg/kg	%	mg/l
Fish Ck. above French Ck.	1,010	320	674	214	67	3,150
Silver Ck. above Gooseberry Ck.	470	951	217	439	46	494
Mill Ck. above Gooseberry Ck.	767	730	38	37	5	1,050
Gooseberry Ck 1/2 mi. below reservoir	1,100	679	137	85	13	1,620
Fish Ck. above Gooseberry Ck.	724	793	194	213	27	912
Fish Ck. above "C" Canyon Ck.	775	601	68	53	9	1,290

* Suspended solids.

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Table D-3. Comparisons of available phosphorus in some streambank soils and sediments from Intermountain Reservoir watersheds.

Reservoir	NaOH-P		NaOH/Total P
	ug/l	ug/kg	%
Panguitch	109 ± 82	254 ± 156	23 ± 9
Scofield	184 ± 63	212 ± 14	34 ± 19
Strawberry [1]	271 ± 299	338 ± 294	31 ± 23
Co-op Ck.	287 ± 317	435 ± 366	43 ± 26
Strawberry Ck.	298 ± 245	309 ± 231	25 ± 17
Indian Ck.	99 ± 64	138 ± 94	11 ± 5

[1] Including Mud Dk. and Cow Hollow

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To obtain water from the subsurface depths, a Van Dorn water sampler was used. The device was lowered to the desired depth and a messenger sent down the rope to trip the device which traps the sample. Upon retrieval to the surface, prelabeled sample bottles were filled. Surface samples were obtained by emersion of the bottles in the water, using care not to overfill bottles containing preservatives. Coliform samples were iced and shipped to the lab in ice chests via the fastest practical carrier.

In some cases, water was obtained by the use of a pump, especially in areas where dense macrophyte growth occurs where it was difficult to use a Van Dorn sampler in the heavy growth. A hose was lowered to the desired depth, the hose was purged to avoid contamination, and a sample obtained. Parameters analyzed are listed in Table F-2.

Physical Parameters

Temperature, dissolved oxygen, pH and conductivity were generally measured at 1 meter intervals from surface to bottom. A Hydrolab water quality measurement unit was used to measure these parameters.

Transparency

A Secchi Disk was lowered until no longer visible and raised until again visible; the average depth was recorded.

Chlorophyll^{a}

Chlorophyll^{a} samples were taken at the upper three depths described in the phytoplankton section. Samples were iced and kept dark during transport to the state laboratory where they were filtered and analyzed.

Phytoplankton

Phytoplankton for quantitative study were taken from four different depths at main lake stations. The "euphotic zone" was defined as three times the Secchi disk reading depth. Generally, four one quart samples were taken: surface, one-third the photic zone, two-thirds the photic zone, and the bottom of the photic zone (three times the Secchi disk reading). If the photic zone reached the bottom, samples were taken from the surface, bottom and one-third and two-third depths. The four samples were placed into a two (2) liter containers, the composite sample iced and taken to the laboratory for analysis.

Samples for qualitative work on periphyton were collected from 10 sites around the shoreline in the early fall. Rocks and other objects were scraped for periphyton. Algal sample processing and evaluation was done by Dr. Samuel Rushforth at Brigham Young University. Dr. Rushforth's analysis appears in Appendix E.

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Table F-2. Scofield Reservoir parameters sampled

STORET Code

Total Chemistry	Total Metals	Nutrients	Oil and Grease
Bicarbonate - 00440	Arsenic - 01002	Ammonia as N-00619	Oil and Grease - 00557
Carbon Dioxide - 00405	Barium - 01007	Nitrate as N-00618	
Carbonate - 00445	Cadmium - 01027	Nitrite as N-00613	
Chloride - 00940	Chromium - 01034	Phosphorus Ortho as P-00671	
Hydroxide - 71830	Copper - 01042	T.K.N. - 00627	
Sulfate - 00946	Iron - 01045	Total Phosphorus - 0665	
Total Alkalinity as $CaCO_3$-00431	Lead - 01051		
Total Hardness as $CaCO_3$-00900	Manganese - 01055	Bacteriological	
Turbidity as NTU - 00076	Mercury - 71900		
Sp. Cond. - 00094	Nickel - 01067	MPN Total Coliform - 31506	
TDS - 70304	Selenium - 01147	MPN Fecal Coliform - 31614	
TSS - 00515	Silver - 01077	Fecal Streptococci - 31679	
Calcium - 00915	Zinc - 01092	M.F. Total Coliform - 31504	
Magnesium - 00925		M.F. Fecal Coliform - 31613	
Potassium - 00935			
Sodium - 00930			

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APPENDIX G

CARLSON TROPHIC STATE INDEX

Index Results

Carlson (1977) proposed a trophic state index based on summer values of Secchi disk depth (SD, in meters), summer total phosphorus concentrations (TP, in mg/m^3), or summer chlorophyll a concentrations (CA, in mg/m^3), or a combination of all three. He used a TSI scale of 0-100 where TSI values of less than 40 indicated a lake with oligotrophic conditions. TSI values between 40 and 50 indicated a lake with mesotrophic conditions and TSI values over 50 indicated eutrophic conditions. The overall TSI is obtained by adding the individual TSI's for chlorophyll a, total phosphorus, and Secchi disk depth, and dividing by three. Carlson TSI values for Scofield Reservoir are given in the accompanying Table G-1.

There was a slight difference in the overall TSI between the two years. The overall TSI of 49.3 in 1981 was on the border between high mesotrophic and low eutrophic conditions while the overall TSI of 53.0 in 1982 indicated low eutrophic conditions. The two years were quite different in chlorophyll a and total phophorus concentrations found in surface samples. The chlorophyll a mean of 12.3 mg/m^3 in 1981 was three times the chlorophyll a mean of 4.0 mg/m^3 in 1982. Based upon Carlson TSI values for chlorophyll a, the TSI of 55.2 in 1981 would indicate eutrophic conditions and the TSI of 44.2 in 1982 would indicate mesotrophic conditions in terms of chlorophyll a concentrations and the causal phytoplankton production. The chlorophyll a values appear to correlate well with the plankton data obtained by Dr. Samuel Rushforth. The total phosphorus mean of 106.9 mg/m^3 in 1982 was 4.6 times the total phosphorus mean of 23.0 in 1981. The Carlson TSI of 49.4 for total phosphorus in 1981 would indicate borderline mesotrophic-eutrophic conditions while the Carlson TSI of 71.5 for total phosphorus in 1982 would indicate hyper-eutrophic conditions. 1981 was a year of lower water levels and warmer temperatures in the reservoir and higher phytoplankton production and higher chlorophyll a concentrations when compared to 1982. (Refer to Table G-1).

Reference:

Carlson, Robert E. 1977. A trophic state index for lakes. Limnol. and Oceanogr. 22(2): 361-369.

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Table G-1. Carlson Trophic State Index
Scofield Reservoir, 1981-1982

Parameter	Year	Parameter Mean	TSI	
CA (mg/m^3)	1981	12.3	55.2	54.04
	1982	4.0	44.2	43.90
TP (mg/m^3)	1981	23.0	49.4	49.98
	1982	106.9	71.5	61.40
SD (m)	1981	3.2	43.2	42.41
	1982	3.2	43.2	42.37
Overall TSI	1981		49.3	48.81
	1982		53.0	49.22

$TSI = 9.81 \ln CA + 36 = XCA$
$TSI = 14.42 \ln TP + 4.25 = XTP$
$TSI = 60 - 14.41 \ln SD = XSD$

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(relative to the standard hydrogen electrode), which is not in the range in which Fe(II) oxidation would be expected (e.g. Stumm and Morgan 1981). It is possible that the higher extractable Fe content in the Scofield sediments than in the other Intermountain reservoirs studied by Messer and Ihnat (1983b) causes P to be released less readily from the Fe-P pool.

The potential in situ impact of the release rates measured here depends on the timing and spatial relationships surrounding the releases, as well as on the hydrodynamics of the reservoir (e.g. Stauffer 1981), as will be discussed below. However, it would first be useful to relate these results to those obtained in similar studies. For example, Holdren and Armstrong (1980) observed release rates during 2-27 day incubation periods ranging from 0.02 to 83 mg P/m^2-day from some Wisconsin lake sediments, depending on the incubation conditions. Bioturbation by benthic invertebrates was found to greatly increase the rates of P release from these epilimnetic sediments. Redox potential was more important in regulating release from noncalcareous sediments, while temperature was more important in calcareous sediments. Release rates were quite high from cores collected during the summer, when phytoplankton were abundant. Rates were often 5-100 times lower from cores collected from the same lake during the winter. These results suggest that labile organic P pools from senescent phytoplankton or macrophyte detritus may be a significant source of P release from epilimnetic lake sediments. The cores from Scofield Reservoir were collected prior to the late summer phytoplankton bloom, and there was probably little freshly mineralized labile P available to drive P release from the sediments, relative to the situation for many of the other sediment cores studied, most of which were collected during late summer or early winter following the summer/fall bloom.

The results of in situ P release studies by Sonzogni et al. (1977) on the eutrophic, noncalcareous Shagewa Lake, Minnesota, are especially interesting in light of the confirmatory P budget calculations of Larsen et al. (1981. Using benthic release chambers, Sonzogni et al. (1977) determined release reates of P from profundal sediments to range from 6.2 to 8.3 mg P/m2-day. Mass balance calculations led Larsen et al. (1980) to calculate a mean annual release of 10.2 mg P/m^2-day from these sediments. Although not identical, the similarity of these estimates suggests that simulations can be a useful source of information on actual P release rates from lake sediments. Larsen et al. also calculated that the upper 10 cm of profundal sediments in the lake contained 15-25 times the calculated annual internal P loading in the form of NaOH-P. The resulting internal loading has been the cause of the relatively slow response of this lake to restoration by reduction of P inputs (Larsen et al., 1975).

Although not always accompanied by sediment studies, whole-lake P balances frequently reveal quite high internal loadings of P from sediments, especially in response to decreased P loading from surface sources. Allan and Williams (1978) reviewed some of these studies, and cite rates ranging from 7 to 50 mg P/m^2-day, with their Canadian

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prairie lakes falling into the range of 10-12 mg P/m^2-day. The values reported in Table 1 thus are negligible compared to those that have been seen to cause problems in other lakes, especially the culturally eutrophic lakes of Europe (e.g. 20-50 mg/m^2-day) which have received heavy inputs of wastewater P for centuries.

The actual impact of release rates of the magnitude represented in Table H-1 depends on the areal extent ot each sediment type, the length of anoxia, and the effectiveness with which P is transported across the thermocline under stratified conditions. However, in a worst case scenario, if P transport to the euphotic zone were 100% efficient, then the average release rate for the deep water core, 1.0 mg/m^2-day, would only be able to support the production of 20 ug/m3 of chlorophyll a-day (Messer at al. 1983a), over the deepest part of the reservoir (20m). In other words, in the absence of surface P sources, zooplankton grazing, and algal senescence, only 2.2 mg chlorophyll a/m^3 could be produced over a 45 day period of anoxic release, or an amount barely sufficient to be noticed. Because tranport is not very efficient across the thermocline, however, the actual contribution of the sediments is certainly lower. The release rate from aerobic sediments, despite the relatively shallower water depths involved, can be seen to be negligible. Because these sediments were isolated from fresh inputs of algae during the incubations, these results should be thought of as representing potential P loading from past P inputs to the reservoir, rather than recycling of particulate P sedimenting from the water column.

Comparison with other Intermountain reservoirs. Sediment chemical data for several Intermountain reservoirs are compared in Table H-2, including the data for cores SC01-1, SC02-1, and SC04-1 from Scofield Reservoir. Core SC03-1 was excluded, because of the uncharacteristically low release rate. It can be seen that the Scofield sediments have an intermediate level of exchangable (NH_4Cl-extractable) P, relative to the other sediments, and that the available (NaOH-extractable) Fe-P is quite low. The remaining Fe-P is similar to the Deer Creek sediments, and may reflect the higher level of Fe present in the sediments. Scofield Reservoir thus appears to have a relatively high NAI-P concentration, despite its low NaOH-P content. While this factor might be interpreted in the context of Allan and Williams (1978) work to represent an advanced state of eutrophication, it apparently does not result in a high degree of internal P loading, as will be pointed out below.

Apatite P is also relatively high in the Scofield sediments, as is the organic P, which is determined as the difference between total P and the sum of the other fractions. Total P concentrations in the cores thus were the highest of any of the sediments studied thus far. The CDB-extractable Fe is higher in the Scofield sediments than in any of the other reservoirs studied, resulting in a high Fe:NAI-Pratio, as discussed above. The high Fe content would suggest that this reservoir is less susceptable than the others to overloading by antropogenic P sources.

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Phosphorus release rates measured from intact sediment cores in the laboratory are compared in Table H-3. Only sediments that were actually incubated are included, and no values calculated on the basis of the regression equation are included. Scofield Reservoir can be seen to show the lowest rates of both aerobic and anaerobic release among the five reservoirs studied, although individual cores from the upper reaches of Flaming Gorge actually exhibited lower release rates than most of the Scofield cores. Unlike Flaming Gorge, which exhibits a marked upstream-downstream gradient in P chemistry and P release rates, Deer Creek can be seen to exhibit a much smaller standard deviation in anoxic release rates, although there is some station to station difference. Strawberry Reservoir also had very low P release rates, and several of the cores from this reservoir released no P at all under aerobic or anaerobic conditions.

Summary and Conclusions

The results of both the sediment chemistry and the intact core P-release studies indicate that internal P loading from historical P inputs to Scofield Reservoir is probably negligible. Internal loading is affected by anaerobic conditions, but some geochemical mechanism apparently keeps the P concentration from climbing much above 300 ug/l. The high Fe content in the sediment indicates considerable buffering capacity for anthropogenic P loading, and apparently causes the high NaOH-P content in the cores from the Fish Creek arm of the reservoir not to release P to the extent predictead by a model for other Intermountain reservoir sediments. In any case, the reservoir appears to be a relatively good candidate for restoration techniques, based on a low probable rate of internal loading under conditions of reduced surface P inputs.

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Table H-1. Core chemistry and P release data for sediment cores collected from Scofield Reservoir July 1983.

Core Site	CHEMICAL PARAMETER[1] (mg/kg Dry wt)								P RELEASE RATE[2] (mg P/m^2 - Day)		
	NH_4Cl-P	NaOH-P	CDB-P	HCl-P	Total P	CDB-Fe	CDB-Mn	Total S	Aerobic	Anaerobic Measured[2]	Anaerobic Calculated[3]
Middle											
SR01-1	106	165	142	348	998	8,300	230	800	-	-	0.0
SR04-2	96	231	139	367	-	-	-	-	-	1.0	2.5
SC01-3	-	-	-	-	-	-	-	-	0.3	-	-
Scofield Arm											
SR03-1	50	142	142	416	1,158	10,200	110	900	-	-	0.0
SR03-2	-	-	-	-	-	-	-	-	-	0.1	-
SR03-3	-	-	-	-	-	-	-	-	0.0	-	-
Fish Creek Arm											
SR02-1	42	529	152	383	1,243	14,000	190	1,400	0	0	15.9
SR02-2	45	442	155	425	-	-	-	-	0.1	0.3	13.0
SR02-3	-	-	-	-	-	-	-	-	-	-	-
North Arm											
SR05-1	53	225	144	506	1,115	-	-	640	-	-	2.0
SR05-2	-	-	-	-	-	-	-	-	-	0.2	-

1 All P values based on Hieltjes and Lijklema (1980), integrated over top 12 cm.

2 45 day laboratory incubations.

3 Release rate - 16.2 ln (NaOH-P) - 85.7, $r^2 = 0.99$, n = 8.

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Table H-2. Comparison of P fractions and CDB-Fe in some Intermountain reservoir sediments based on the extraction procedure of Hieltjes and Lijklema.

P fraction	Deer Creek	Panguitch	Scofield	Flaming Gorge	Strawberry
Exchangable-P	35	128	63	48	108
Available Fe-P	295	248	177	271	172
E-P	330	376	240	319	280
Unavailable Fe-P	140	76	143	75	74
NAI-P	470	452	383	394	354
Apatite-P	394	146	423	487	267
Organic-P	123	246	284	81	228
Total P	987	864	1,090	962	848
CDB-Fe	8,800	4,800	10,400	5,700	5,200
CDB-Fe:NAI-P[1]	10	6	15	8	8

[1] Mole basis

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Table H-3. Comparison of aerobic and anaerobic P release rates from sediment cores collected from some Intermountain Reservoirs and incubated in the laboratory.

Reservoir	Aerobic (mg P/ m^2 - day ± 1 S.D)	Anaerobic (mg P/ m^2 - day ± 1 S.D)
Flaming Gorge	0.8±0.8 (5)	4.6±4.7 (5)
Deer Creek	0.3±0.3 (7)	3.8±1.8 (11)
Panguitch	0.2 (1)	1.4 (1)
Scofield	0.1±0.1 (3)	0.4±0.4 (4)
Strawberry	0.0 (4)	0.4±0.5 (4)

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APPENDIX I

BIOLOGICAL RESOURCES AND ECOLOGICAL RELATIONSHIPS

Fish Populations

The fish species in Scofield Reservoir have changed over the years and the reservoir has undergone at least two fish eradication programs to get rid of unwanted species, the first in 1958 and the second in 1977. Olsen (1959) studied the fish populations in the reservoir and tributaries, working specifically on the life history of the Utah chub. The data from his gill net collections are given in Table I-1. Because of their small size, perch were not considered game fish.

Utah chubs were found to be present in the lower reaches of all tributaries to the reservoir and in all areas of Fish and Gooseberry Creeks up to Gooseberry Dam. He found various game species in the reservoir including: kokanee salmon, Oncoryhyncus nerka kennerlyi (Suckley); cutthroat trout, Salmo clarki (Girand); rainbow trout, Salmo gairdneri, Gibbons; and brown trout, Salmo trutta Linnaeus. Nongame species included yellow perch, Perca flavescens (Mitchill); redside shiner, Richardsonius balteatus (Richardson); bluehead sucker, Catostomus discobolus; and the Utah chub, Gila atraria (Girard). Olson found that the food habits of the chub and rainbow to be very close indicating that they were competing for the same food. The reservoir and its tributaries were treated with rotenone September 25, 1958.

The reservoir was restocked with trout species after the fish eradication project of 1958. The treatment was either not completely successful in ridding the watershed of the Utah chub or the chub was later reintroduced into the reservoir at a later date. Because of the increase in chub numbers and the chub's competition with the trout for food, another fish eradication project of the lake and watershed was performed in 1977. Rainbow trout and cutthroat trout were restocked and are the only two dominant fish species in the reservoir at this time. Occasional rough fish that have reoccurred in 1982 gill netting are the carp and redside shiner. The present fish composition of the Scofield watershed is listed in Table I-5.

The stocking data that is available for the past three years are presented in Table I-2 and I-3, and the gill netting percentages are given in Table I-1. Opening day creel census data for the past three years are given in Table I-4.

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Table I-1. Number of fish taken by gill netting in Scofield Reservoir, 1957 and 1958.

	Fish Caught	Number	Percent of Total
Non-game fish			
	perch	9,808	61.11
	chub	5,944	37.00
	misc. species	104	0.65
	TOTAL	15,856	98.76
Game fish			
	rainbow trout	96	0.60
	cutthroat trout	60	0.37
	brown trout	4	0.02
	kokanee salmon	40	0.25
	TOTAL	200	1.24

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Table I-2. Fish stocked in Scofield Reservoir, 1980-82.

Year	Fish	Size	Number	Percent
1980	cutthroat	fry	200,326	26
	rainbow	fingerling	394,910	51
	rainbow	adv. fingerling	172,922	23
		TOTAL	768,158	
1981	cutthroat	fingerling	105,000	16
	rainbow	fingerling	535,832	81
	rainbow	adv. fingerling	20,020	3
		TOTAL	660,852	
1982	cutthroat	fry	334,890	28
	rainbow	fingerling	802,569	68
	rainbow	adv. fingerling	51,750	4
		TOTAL	1,189,219	

Table I-3. Percentages of rainbow and cutthroat trout caught in gillnets, spring of the year.

Year	Fish	Percent
1980	rainbow	97
	cutthroat	3
1981	rainbow	54
	cutthroat	46
1982	rainbow	42
	cutthroat	58

Data compiled by Utah Department of Wildlife Resources

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Table I-4. Opening weekend creel census data Scofield Reservoir, 1980, 1981, 1982.*

Year	Anglers	Angler hours	Fish/hour	Total Fish Caught
1980	12,897	50,618	1.0	50,618
1981	14,482	50,333	.73	36,951
1982	21,777	60,908	.45	27,492

* Two-day weekend
Data compiled by the Southeastern Region, Utah Department of Wildlife Resources.
Walt Donaldson, Regional Fisheries Manager.

Table I-5. Fishes in Scofield Reservoir or the above drainage.

Family Salmonidae

Cutthroat Trout (Salmo clarki)
Rainbow Trout (Salmo gairdneri)
Brown Trout (Salmo trutta)

Family Cyprinidae

Carp (Cyprinus carpio)
Utah Chub (Gila atraria)
Longnose Dace (Rhinichthys cataractae)
Speckled Dace (Rhinichthys osculus)
Redside Shiner (Richardsonius balteatus)

Family Catostomidae

Bluehead Sucker (Catostomus discobolus)

Family Cottidae

Mottled Sculpin (Cottus bairdi)

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Two interesting trends in the present fisheries data supplied by the Utah Division of Wildlife Resources are: (1) The decreasing of the opening day catch during 1980-1982, and (2) the increase in percentage of cutthroat trout caught in the gill nets in the spring of 1980-1982. There will be an intensive creel census program during the 1983 fishing season (Walt Donaldson, personal communication) to more completely assess the populations of the two trout species in Scofield Reservoir. Mr. Donaldson indicated that one possible reason for the relative increase of cutthrout trout is the successful spawning of the species in the tributaries to the reservoir and the subsequent recruitment of their offspring into the cutthroat population of the reservoir. Fishing pressure was reduced by about 60% in 1983 due to the closure of US-50 & 6 in Spanish Fork Canyon. The 1983 creel census will reflect this event in a significant reduction in total numbers caught.

Waterfowl Populations

Scofield Reservoir and the streams and ponds in the area serve as important habitat use areas during migration periods in the fall and spring. They also are important nesting and brooding areas between March 15 and July 15 each year and as high-priority use areas for brooding of young waterfowl and the moulting process in adult birds between July 16 and August 15 each year (Collins 1980).

Dalton et al. (1978) list two hundred forty-two species of birds that are known to inhabit the Wasatch Plateau biogeographic area that includes the Scofield Reservoir watershed. Of these, forty-three species are classed as waterfowl and close to one hundred other species are associated with aquatic habitats.

Other Wildlife

Dalton (1978) lists 6 amphibian species, 18 reptile species, and 84 mammal species that inhabit the Wasatch Plateau biogeographical province, most of which could be found on the Scofield Reservoir watershed. Deer, elk, moose, cougar, and bear are principle big-game animals found on the watershed. Seven furbearers are on the watershed including beavers which are sometimes seen swimming on the reservoir. Ten upland game birds are found on the watershed and four small-game mammals.

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APPENDIX J

November 10, 1982

UTAH STATE DEPARTMENT OF HEALTH
DIVISION OF ENVIRONMENTAL HEALTH
PROPOSED
SCOFIELD LAKESHORE MANAGEMENT PLAN

I. OBJECTIVES:

a. Propose sanitary wastewater treatment systems for all developments around the reservoir to protect public health, meet state standards and reduce eutrophication potential.

b. Propose an approved water supply for all developments.

c. Require the establishment of a body politic to manage wastewater treatment systems with an on-site wastewater management district to assume responsibilities for maintenance work on the systems.

d. Close all R.V. parks lacking adequate water and wastewater facilities.

e. Prohibit the installation of additional holding tanks around the lakeshore.

II. PROPOSED GUIDELINES:

a. Forrester Subdivision:

Allow only the development of lots with approved spetic tanks, drainfields and water supply facilities.

b. Singleton Boat Camp:

If Singleton Boat Camp is to remain open as a R.V. Camp the following requirements must be met:

An approved culinary water system must be developed and included as an intergal part of the upgrading of the wastewater treatment facilities.

Wastewater must be treated using an approved central septic tank and the effluent to be pumped to an approved drainfield located southeast of the camp. A single pump station will pump the effluent to the drainfield.

A body politic, required by state regulations, need not be created for this camp if it is to continue, since there is a single owner.

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If the above requirements cannot be met the camp should be closed.

If self contained trailers are allowed access to this camp a dump station must be built. If camping spaces are provided for dependent campers a service building must be built as required by regulations.

c. Bolotas Subdivision:

The five private wells serving some of the homes are not approved, nor can they be approved since they are classified as shallow wells too close to sanitary drainfields. Consideration should be given to the feasability of developing a single acceptable supply and storage facilities.

Holding tanks may be approved for wastewater for those homes directly on the lake shore. All other existing homes must be on an approved septic tank and drainfield to meet requirements of Part IV. A central drainfield may be located east of the road on leased property or south on Bureau of Reclamation land. One pump would be required to pump effluent from a common septic tank, to the drainfield. Existing homes with approved septic systems should not be forced to join a central system.

Inspections of the holding tanks should be done by the local health department or a representative of wastewater management district.

d. Scofield Campsite:

The wells in this campsite may well be shallow and unapproved due to the sewage disposal systems in use. An approved water system must be built to provide an adequate water supply.

A central septic tank, pumping station and common drainfield should resolve the wastewater treatment problem for this campsite.

e. Scofield West:

If Scofield West is to continue as a R.V. Camp the following requirements must be met;

A well to provide an adequate water supply must be approved for development.

A common septic tank and drainfield will resolve the wastewater treatment problems for this development.

If the above requirements cannot be met the camp should be closed.

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III. COMMENTS:

a. A common drainfield for all the developments on the east side of the reservoir with pressure lines to the drainfield should be considered.

b. A sanitary dump station should be built close to these campsites for disposal of sewage from holding tanks and recreational vehicles.

c. Adequate water systems for all the developments must be designed and approved before construction. A strong position must be taken to restrict any expansion if both the wastewater and water supply facilities are not acceptable.

d. Differences in construction and maintenance costs of a common disposal system based on use is not a real concern. All "hook on" fees and monthly costs for municipal sewage systems are the same regardless of the number of individuals in the homes or the amount of water used.

e. There should be consideration of a single wastewater and water supply management district for all developments around Scofield Reservoir.

f. "The Scofield Lakeshore Plan," October 1982 prepared by Carbon County did not discuss the seven or eight homes south of Singleton or the Carbon County Park.

g. An engineering firm should be retained to estimate cost of the necessary water and wastewater treatment facilities.

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APPENDIX K

OTHER RESTORATION ALTERNATIVES

Enforce State Health Department Standards for new sewage systems. New construction should conform to State Health Department Standards for septic systems. The Southeast Utah Health Department should ensure enforcement of existing regulations in the Scofield Reservoir vicinity.

Costs: Moderate. Participation as budgets and programs allow. The Southeast Utah Health Department requires approved septic system on all new construction. Correlation with the Carbon County Building Inspection program is essential. No building permit should be issued until health requirements are met.

Benefits: Good. Improve integrity of the area; insure public health and eliminate potential of phosphorus entering watershed streams and the lake.

Public Acceptance: Good.

Feasibility: Feasible. Public acceptance good.

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Encourage upgrade of nonconforming sewage facilities to meet Department of Health Standards. A friendly visit by a representative of the Southeastern District Health Department or the Carbon County Building Inspector to owners of nonconforming sewer systems should be made. The visits would outline the problem and urge those whose systems may be a present or future problem to make improvements to conform to State standards.

Costs: Participation as budgets and programs allow. Work in the area will proceed in an orderly fashion with common sense prevailing. Owners will be given sufficient and reasonable time to upgrade nonconforming systems. Problem areas will be investigated and corrected as they are identified.

Benefits: Improve integrity of the area; insure public health and eliminate potential of phosphorus entering watershed streams and the reservoir.

Feasibility: Very good. Public acceptance good.

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Removal of Fish prior and following chemical rough fish treatment by Utah Division of Wildlife Resources. Documented sediment core samples at Panguitch Lake indicate the probability of large amounts of phosphorus being released to the ecosystem following treatment to control rough fish populations. Some of the nutrients undoubtedly re-enter the food chain and is consummed by replanted fish the next year. However, since phosphorus is in excess in the system prior to the decay of fish tissue following treatment, it is logical to assume that removing as many fish during treatment would have a net beneficial effect on the nutrient budget. To remove the maximum amount of fish prior to and during treatment, suggested practices may include open seasons, liberal or no creel limits, commercial fishing and a general fish clean-up during or following treatment by the public. Each of these measures would need to be closely correlated with Wildlife Resources to insure efficiency, safety and minimizing conflicts during treatment. Limited budgets and personnel by Wildlife Resources would necessitate a voluntary approach by concerned individuals and groups on the clean-up project.

Costs: Voluntary effort by local concerns .

Benefits: Excellent. Elimination of excess phosphorus spikes periodically injected into the reservoir. Reduce nutrient budgets to maintain the status of the reservoir.

Public Acceptance: Good.

Feasibility: Feasible.

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Adopt fish cleaning policies that require cleaning in approved areas only. Disposal of fish entrails into Scofield Reservoir should be prohibited. The Utah State Park has a fish cleaning facility. Additional fish cleaning facilities should also be constructed for disposal of fish entrails outside the lake. Additionally, as trash fish are caught they should be kept and discarded in a manner similar to game fish entrails.

Costs: $1,000.00 - $20,000.00 depends on system (septic tank and drain field for liquids only vs. septic tank, drain field, and grinder for liquids and solids).

Benefits: Good. The total absorbtion of fish cleaning in the lake or tributary could be significant. An estimation of phosphorus returned to the system can be explained by the following scenario. In 1980, 81, 82 respectively, the Division of Wildlife Resources planted 768,000 - 160,000 - 1,189,000 fish in Scofield Reservoir. For this exercise, 250,000 fish are harvested. The actual number is larger. The following is assumed: 50% were cleaned in the lake or streams, fish averaged 1 pound, ofal = 20% body weight, and phosphorus in organic fish tissue is about 2%.

205,000	fish taken
X 50%	
102,500	fish cleaned in Scofield Reservoir or streams
X 1	pound/fish
102,500	pounds of fish
X 20%	ofal
20,500	pounds of ofel returned
X 2%	phosphorus *
410	pounds of phosphorus returned to lake

Comparison: Sewage effluent from a wastewater treatment plant for 410 people discharges about 410 pounds of phosphorus/year. The proceding scenario of fish cleaned in the lake or stream is similar to a small town of 410 people discharging treated effluent into the lake.*

Public Acceptance: Good.

Feasibility: Feasible.

* Merritt 1976

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Eliminate disposal of human waste from boats. Recreational sports fishermen and other boaters using Scofield Reservoir should be encouraged to use shore-based sanitation facilities or temporary containers in boats for disposal of waste later at shore facilities. The island should not be used as an outhouse. The public education campaign should highlight this problem.

Costs: Good. Additional restroom facilities may need to be constructed. A self contained vault system costs about $2,000 per unit.*

* Utah Division of Parks and Recreation Estimates.

Benefits: Good. Probably minimal in terms of reducing organic loadings. The significance is the total of minor sources of nutrients becomes important when considered as a whole.

Public Acceptance: Good.

Feasibility: Feasible.

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Chemical Treatment

The bottom sediments in Scofield Reservoir have trapped large amounts of phosphorus over the years. As mentioned in the aeration section, phosphorus is released during anoxic conditions. A coating of the bottom sediments by a chemical such as Fly Ash would prevent phosphorus from being released during periods when the hypolimnion is anoxic. Phosphorus would bond with chemicals in the ash.

The lake could be treated with alum at critical periods such as a spring turnover when maximum amounts of phosphorus are in suspension. The alum would precipate the phosphorus to the bottom of the lake. Fly ash would be applied to tie-up the phosphorus preventing it from being available for algae stimulation.

Costs of alum treatment range from $200 - $500/acre. A limitation is the need for retreatment from 3 - 7 years.

Cost: Treatment costs with fly ash would be high. Estimates range from $200 - $1,000/acre depending on availability and transportation costs.

Benefits: Good. Available phosphorus would be greatly reduced, thus decreasing plankton and macraphyte growth. Costs would be prohibitive.

Public Acceptance: Good.

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Aerators and Circulators

Aerators or circulators may be effective tools in adding oxygen to Scofield Reservoir. They would break up stratification and prevent anoxic conditions in the hypoliminion. Phosphorus released during anoxic water periods stimulate algal growth. The extensive algae growth (blooms) deplete oxygen required for fish and wildlife. Substancial fish kills were recorded in 1981 as a result of this scenario.

Costs: Option 1 - Compressed air, initial costs are high, using donated labor, about $5,000.00/unit. Yearly electrical costs could run as high as $2,000/yr./unit. Five units would probably be required for a reservoir the size of Scofield.

Option 2 - Motor driven water recirculators. A unit designed at Iowa State University estimates initial costs to be moderate, about $3,000/unit. A 30 hp motor is required at current electrical costs of 7.17¢/kw hr, 3 months electrical costs/ unit would be:

746 w/hp
X 30 hp
- 1,000 w/kn
X 7.17¢/kw
X 24 hr/day
X 90 days = $2,948.00

Yearly maintenance costs would be minimal. Each unit would circulate water in maximum area of 300 acres. Two to four units would probably be required.

Severe winter conditions may be a limiting factor in installing aerators or circulators. Extended periods of ice cover and cold weather may be detrimental. The units would most effective in breaking down summer stratification and reducing anoxic conditions.

Benefits: Either option would be very beneficial to the lake. They would reduce or eliminate the oxygen devoid hypolimnion thus reducing phosphorus from being released from the sediments during anoxic periods.

Public Acceptance: Moderate.

Feasibility: Option 1 and Option 2 - Installation and power cost are high and both options would not be feasible at this time. Accelerated eutrophication may require a revaluation of the feasibility of there systems.

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Dredging

The reservoir could be hydraulically dredged to remove sediments containing high phosphorus levels. A removal of these sediments would have a beneficial effect by reducing stored phosphorus which are released during anoxic conditions.

Costs: Estimated costs are as high as $2,500/acre.

Benefits: Good. Dredging would be helpful in controlling phosphorus. If inflow loadings were not reduced, periodic dredging would lower the lake trophic state. Dredging would be considered a stop gap measure and is not addressing the major problem - high nutrients loadings entering in the tributaries.

Public Acceptance: Good.

Feasibility: Not feasible due to cost.

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Hypolimnetic Discharge

This option extends a discharge pipe about a 1/2 mile into the reservoir to draw water at 30-40 foot depth.

Review of the water quality and sediment samples data indicate hypolimnetic water is extremely high in phosphorus if the lake becomes anoxic (devoid of oxygen due to organic decomposition). It is during these anoxic periods that large amounts of phosphorus is released into the surface waters. During the study period, short periods during the summer and a extended period in winter exhibited this characteristics. Early through late summer oxygen readings indicated little or no oxygen below about 30 feet. Winter readings showed a oxygen deficient below about 20 feet. If a discharge pipe was extended from the dam outlet into the deep area of the lake (about a 1/2 mile and at least 50 feet in depth) the anoxic water could be drawn off and thus prevent phosphorus from being released from the sediments. Water discharge into Price River would immediately become oxygenated to downstream fisheries.

Design: The following alternative is a rough preliminary design. Staff engineers at the State and at the Cival Engineering Department, BYU, both agree the concept would function. Extended engineering would be necessary to design and construct such an outflow.

Costs: An estimated cost for heavy 24 inch corregated culvert pipe is included. Consturction costs, (equipment, labor, design, etc.) would be additional.

Estimated 2,646 feet of 24 inch corregated culvert at $16.30/foot
2,646 feet X $16.30/foot = $43,129.80

Benefits: Excellent.

Public Acceptance: Good. Approval of Price River water users and the State Engineers would be required. Water users would demand financial costs not be their responsibility. Construction costs should be born by the total population utilizing the lake (recreation, fishery, tourist, county etc.).

Feasibility: Many problems and obstacles to overcome. Not feasible due to costs at this time.

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APPENDIX L

STATE OF UTAH
DEPARTMENT OF SOCIAL SERVICES
DIVISION OF HEALTH

WASTEWATER DISPOSAL REGULATIONS

PART II
STANDARDS OF QUALITY FOR WATERS OF THE STATE

Adopted By
Utah Water Pollution Control Board May 18, 1965
Utah State Board of Health May 19, 1965

Revised by Action of the Boards June 2, 1967 and June 21, 1967

Further Revised by Action of the Utah Water Pollution Committee November 18, 1968 and September 13, 1978, and by Action of the Utah State Board of Health November 20, 1968 and October 23, 1978

Under Authority of
26-15-4 & 5 and 73-14-1 through 13
Utah Code Annotated 1953, as Amended

Certified Official Copy
Utah State Division of Health

By Lyman J. Olsen
Lyman J. Olsen, M.D., M.P.H.
Director of Health

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INTRODUCTION

This is Part II of five parts comprising "Wastewater Disposal Regulation" of the Utah State Division of Health.

The entire set consists of the following:

PART I - DEFINITIONS AND GENERAL REQUIREMENTS

PART II - STANDARDS OF QUALITY FOR WATERS OF THE STATE

PART III - SEWERS AND WASTEWATER TREATMENT WORKS

PART IV - INDIVIDUAL WASTEWATER DISPOSAL SYSTEMS

PART V - SMALL UNDERGROUND WASTEWATER DISPOSAL SYSTEMS

All have been adopted by both the Utah Water Pollution Committee and the Utah State Board of Health with the purpose of coordinating and consolidating the authority and action of the Committee and Board in areas relating to control of water pollution and maintenance of a healthful environment.

The definitions appearing in PART I apply throughout and are not repeated.

The initial document covering the subject of standards of water quality for classification of state waters was adopted by the Utah Water Pollution Control Board (later renamed "Water Pollution Committee") in 1955 under the title "The Standards of Quality and the Regulations for Water Classifications"

It was revised in 1960, 1965, 1967 and 1968. Some requirements of the Federal Water Pollution Control Act were incorporated in 1967.

The current revision (1978) was made to accomplish Utah program needs and to meet requirements of the present Federal Act.

Throughout this document the term "shall" means a mandatory requirement. The terms "should", "recommend" and "preferred" mean a desirable standard.

Issuance of construction permits based on plans reviewed by the Division will not relieve any person of responsibility to meet all requirements of these regulations.

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2.0 PUBLIC POLICY

Whereas the pollution of the waters of this state constitute a menace to public health and welfare, creates public nuisances, is harmful to wildlife, fish and aquatic life, and impairs domestic, agricultural, industrial, recreational and other legitimate beneficial uses of water, and whereas such pollution is contrary to the best interests of the state and its policy for the conservation of the water resources of the state, it is hereby declared to be the public policy of this state to conserve the waters of the state and to protect, maintain and improve the quality thereof for public water supplies, for the propagation of wildlife, fish and aquatic life, and for domestic, agricultural, industrial, recreational and other legitimate beneficial uses; to provide that no waste be discharged into any waters of the state without first being given the degree of treatment necessary to protect the legitimate beneficial uses of such waters; to provide for the prevention, abatement and control of new or existing water pollution; to place first in priority those control measures directed toward elimination of pollution which creates hazards to the public health; to insure due consideration of financial problems imposed on water polluters through pursuit of these objectives; and to cooperate with other agencies of the state, agencies of other states and the federal government in carrying out these objectives. (Section 73-14-1, Utah Code Annotated 1953, as amended).

2.1 AUTHORITY

These standards are promulgated pursuant to Sections 73-14-1 through 73-14-13 and Sections 26-15-4 and 26-15-5, Utah Code Annotated 1953, as amended.

2.2 SCOPE

These standards shall apply to all waters of the state and shall be assigned to specific waters through the classification procedures prescribed by Section 73-14-6, Utah Code Annotated 1953, as amended. (See also Section 2.6 of these regulations).

2.3 ANTI-DEGRADATION POLICY

2.3.1 Maintenance of Water Quality

Waters whose existing quality is better than the established standards for the designated uses will be maintained at high quality unless it is determined by the Committee that a change is justifiable as a result

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of necessary economic or social development. However, existing instream water uses shall be maintained and protected. No water quality degradation is allowable which would interfere with or become injurious to existing instream water uses.

2.3.2 Anti-degradation Segments

Waters of high quality which serve, or which may be reasonably expected to serve, as raw water sources for drinking water supplies or which have been determined by the Committee to be a State or National resource requiring protection shall be maintained at existing high quality through designation, by the Committee after public hearing, as anti-degradation segments. New point source discharges of wastewater, treated or otherwise, are prohibited in such segments after the effective date of designation. Protection of such segments from pathogens in diffuse, underground sources is covered in PARTS IV and V of these regulations. Other diffuse sources (non-point sources) of wastes shall be controlled to the extent feasible through implementation of best management practices or regulatory programs.

Projects such as, but not limited to, construction of dams or roads will be considered in anti-degradation segments on a case-by-case basis where pollution will result only during the actual construction activity, and where best management practices will be employed to minimize pollution effects.

Waters of the state designated as anti-degradation segments are listed in Appendix C.

2.4 COLORADO RIVER SALINITY STANDARDS

In addition to quality protection afforded by these regulations to waters of the Colorado River and its tributaries, such waters shall be protected also by requirements of "Proposed Water Quality Standards for Salinity Including Numeric Criteria and Plan of Implementation for Salinity Control, Colorado River System, June 1975" and a supplement dated August 26, 1975, entitled "Supplement, Including Modifications to Proposed Water Quality Standards for Salinity Including Numeric Criteria and Plan of Implementation for Salinity Control, Colorado River System, June 1975", as approved by the seven Colorado River Basin States and the U.S. Environmental Protection Agency.

2.5 MIXING ZONES

A mixing zone is a limited portion of a body of water, contiguous to a discharge, where dilution is in progress but has not yet resulted in concentrations which will meet standards for all pollutants. Mixing zones may be delineated for the purpose of

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guiding sample collection procedures. The zone shall be small in extent and must not form a barrier to migrating aquatic life. Domestic wastewater effluents discharged to mixing zones shall meet effluent requirements specified in Section 1.3 of these regulations.

2.6 USE DESIGNATIONS

The Committee and Board, as required by 73-14-6 and 63-46-1 through 13, Utah Code Annotated 1953, as amended, shall group the waters of the state into classes so as to protect against controllable pollution the beneficial uses designated within each class as set forth below. Waters of the state are hereby classified as shown in Appendix B.

2.6.1 Class 1 -- protected for use as a raw water source for domestic water systems.

a. Class 1A -- protected for domestic purposes without treatment.

b. Class 1B -- protected for domestic purposes with prior disinfection.

c. Class 1C -- protected for domestic purposes with prior treatment by standard complete treatment processes as required by the Utah State Division of Health.

2.6.2 Class 2 -- protected for in-stream recreational use and aesthetics.

a. Class 2A -- protected for recreational bathing (swimming).

b. Class 2B -- protected for boating, water skiing, and similar uses, excluding recreational bathing (swimming).

2.6.3 Class 3 -- protected for in-stream use by beneficial aquatic wildlife.

a. Class 3A -- protected for cold water species of game fish and other cold water aquatic life, including the necessary aquatic organisms in their food chain.

b. Class 3B -- protected for warm water species of game fish and other warm water aquatic life, including the necessary aquatic organisms in their food chain.

c. Class 3C -- protected for non-game fish and other aquatic life, including the necessary aquatic organisms in their food chain. Standards for this class will be determined on a case-by-case basis. (See Appendix D).

d. Class 3D -- protected for waterfowl, shorebirds and other water-oriented wildlife not included in Classes 3A, 3B, or 3C, including the necessary aquatic organisms in their food chain.

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2.6.4 Class 4 -- protected for agricultural uses including irrigation of crops and stockwatering.

2.6.5 Class 5 -- protected for industrial uses including cooling, boiler make-up, and others with potential for human contact or exposure. Standards for this class will be determined on a case-by-case basis.

2.6.6 Class 6 -- protected for uses of waters not generally suitable for the uses identified in Sections 2.6.1 through 2.6.5, above. Standards for this class will be determined on a case-by-case basis.

2.7 WATER QUALITY STANDARDS

2.7.1 Application of Standards

The standards listed in Appendix A shall apply to each of the classes assigned to waters of the State as specified in Section 2.6 of these regulations. It shall be unlawful and a violation of these regulations for any person to discharge or place any wastes or other substances in such manner as may interfere with designated uses protected by assigned classes or to cause any of the applicable standards to be violated, except as provided in Section 1.3.1.

2.7.2 Narrative Standards

It shall be unlawful, and a violation of these regulations, for any person to discharge or place any waste or other substance in such a way as will be or may become offensive such as unnatural deposits, floating debris, oil, scum or other nuisances such as color, odor or taste; or conditions which produce undesirable aquatic life or which produce objectionable tastes in edible aquatic organisms; or concentrations or combinations of substances which produce undesirable physiological responses in desirable resident fish, or other desirable aquatic life, as determined by bio-assay or other tests performed in accordance with standard procedures determined by the Committee.

2.8 PROTECTION OF DOWNSTREAM USES

All actions to control waste discharges under these regulations shall be modified as necessary to protect downstream designated uses.

2.9 INTERMITTENT WATERS

Failure of a stream to meet water quality standards when stream flow is either unusually high or less than the 7-day, 10-year

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minimum flow shall not be cause for action against persons discharging wastes which meet both the requirements of PART I of these regulations and the requirements of applicable permits.

2.10 LABORATORY AND FIELD ANALYSES

2.10.1 Laboratory Analyses

All laboratory examinations of samples collected to determine compliance with these regulations shall be performed in accordance with standard procedures by the Utah Division of Health Laboratories or by a laboratory certified by the Utah Division of Health.

2.10.2 Field Analyses

All field analyses to determine compliance with these regulations shall be conducted in accordance with standard procedures specified by the Utah Division of Health.

2.11 PUBLIC PARTICIPATION

Public hearings will be held to review all proposed revisions of water quality standards, designations and classifications, and public meetings will be held for case-by-case consideration of discharge requirements set to protect water uses under assigned classifications. All meetings shall comply with the provisions of Section 63-46-1 through 13, Utah Code Annotated 1953, as amended.

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APPENDIX A

NUMERICAL STANDARDS FOR PROTECTION OF BENEFICIAL USES OF WATER

Constituent	CLASSES										
	Domestic Source			Recreation & Aesthetics		Aquatic Wildlife				Agri-culture	Indus-try	Special
	1A	1B	1C	2A	2B	3A	3B	3C	3D	4	5	6
Bacteriological (No./100 ml)												
(30-day Geometric Mean) Maximum Total Coliforms	1	50	5,000	1,000	5,000	•	•		•	•		
Maximum Fecal Coliforms	•	•	2,000	200	2,000	•	•		•	•		
Physical												
Total Dissolved Gasses	•	•	•	•	•							
Minimum DO (mg/l) (a)	•	•	5.5	5.5	5.5	(b)	(b)		•	•		
Maximum Temperature	•	•	•	•	•	6.0	5.5		5.5	•		
Maximum Temp. Change	•	•	•	•	•	20°C	27°C		•	•		
pH	6.5-9.0	6.5-9.0	6.5-9.0	6.5-9.0	6.5-9.0	2°C 6.5-9.0	4°C 6.5-9.0		6.5-9.0	6.5-9.0		
Turbidity increase (c)	•	•	•	10 NTU	10 NTU	10 NTU	10 NTU		15 NTU	•		
Chemical (Maximum mg/l)												
Arsenic, dissolved	.05	.05	.05	•	•	•	•		•	.1		
Barium, dissolved	1	1	1	•	•	•	•		•	•		
Cadmium, dissolved	.010	.010	.010	•	•	.0004(d)	.004(d)		•	•		
Chromium, dissolved	.05	.05	.05	•	•	.10	.10		.10	.01		
Copper, dissolved	•	•	•	•	•	.01	.01		•	.10		
Cyanide	•	•	•	•	•	.005	.005		•	.2		
Iron, dissolved	•	•	•	•	•	1.0	1.0		1.0	•		
Lead, dissolved	.05	.05	.05	•	•	.05	.05		•	.1		
Mercury, total	.002	.002	.002	•	•	.00005	.00005		.00005	•		
Phenol	•	•	•	•	•	.01	.01		•	•		
Selenium, dissolved	.01	.01	.01	•	•	.05	.05		•	.05		
Silver, dissolved	.05	.05	.05	•	•	.01	.01		•	•		
Zinc, dissolved	•	•	•	•	•	.05	.05		•	•		
NH_3 as N (un-ionized)	•	•	•	•	•							
Chlorine	•	•	•	•	•	.02	.02		•	•		
Fluoride, dissolved (e)	1.4-2.4	1.4-2.4	1.4-2.4	•	•	.002	.01		•	•		
NO_3 as N	10	10	10			•	•		•	•		
Boron, dissolved	•	•	•	•	•							
H_2S	•	•	•	•	•	•	•		•	•		
TDS (f)	•	•	•	•	•	.002	.002		•	.75		
						•	•		•	1200		
Radiological (Maximum pCi/l)												
Gross Alpha	15	15	15	•	•							
Radium 226, 228 combined	5	5	5	•	•	15(g)	15(g)		15(g)	15(g)		
Strontium 90	8	8	8	•	•	•	•		•	•		
Tritium	20,000	20,000	20,000	•	•	•	•		•	•		
Pesticides (Maximum ug/l)												
Endrin	.2	.2	.2	•	•							
Lindane	4	4	4	•	•	.004	.004		.004	•		
Methoxychlor	100	100	100	•	•	.01	.01		.01	•		
Toxaphene	5	5	5	•	•	.03	.03		.03	•		
2, 4-D	100	100	100	•	•	.005	.005		.005	•		
2, 4, 5-TP	10	10	10	•	•	•	•		•	•		
Pollution Indicators (g)												
Gross Beta (pCi/l)	50	50	50	•	•							
BOD (mg/l)	•	•	5	5	5	50	50		50	50		
NO_3 as N (mg/l)				4	4	5	5		5	5		
PO_4 as P (mg/l)(h)	•	•	•	.05	.05	4 .05	4 .05		•	•		

STANDARDS WILL BE DETERMINED ON A CASE-BY-CASE BASIS (SEE APPENDIX D)

STANDARDS WILL BE DETERMINED ON A CASE-BY-CASE BASIS

STANDARDS WILL BE DETERMINED ON A CASE-BY-CASE BASIS

• Insufficient evidence to warrant the establishment of numerical standard. Limits assigned on case-by-case basis.

(a) These limits are not applicable to lower water levels in deep impoundments.

(b) Not to exceed 110% of saturation.

(c) For Classes 2A, 2B, 3A, and 3B at background levels of 100 NTUs or greater, a 10% increase limit will be used instead of the numeric values listed. For Class 3D at background levels of 150 NTUs or greater, a 15% increase limit will be used instead of the numeric value listed. Short term variances may be considered on a case-by-case basis.

(d) Limit shall be increased threefold if $CaCO_3$ hardness in water exceeds 150 mg/l.

(e) Maximum concentration varies according to the daily maximum mean air temperature.

Temp. °C	mg/l
12.0 and below	2.4
12.1 to 14.6	2.2
14.7 to 17.6	2.0
17.7 to 21.4	1.8
21.5 to 26.2	1.6
26.3 to 32.5	1.4

(f) Total dissolved solids (TDS) limit may be adjusted on a case-by-case basis.

(g) Investigations should be conducted to develop more information where these pollution indicator levels are exceeded.

(h) PO_4 as P(mg/l) limit for lakes and reservoirs shall be .025.

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CLASSIFICATION OF WATERS OF THE STATE	USE CLASSES							
	DOMESTIC SOURCE	RECREATION AND ESTHETICS		AQUATIC WILDLIFE				AGRICULTURE
	1C	2A	2B	3A	3B	3C	3D	4
UPPER COLORADO RIVER BASIN (continued)								
GREEN RIVER DRAINAGE								
Green River and tributaries, from confluence with Colorado River to state line except as listed below:	X		X		X			X
San Rafael River and tributaries, from confluence with Green River to confluence with Ferron Creek						X		X
Ferron Creek and tributaries, from confluence with San Rafael River to Millsite Reservoir						X		X
Ferron Creek and tributaries, from Millsite Reservoir to headwaters	X			X				X
Huntington Creek and tributaries, from confluence with Cottonwood Creek to Highway U-10 crossing						X		X
Huntington Creek and tributaries, from Highway U-10 crossing to headwaters	X			X				X
Cottonwood Creek and tributaries, from confluence with Huntington Creek to Highway U-57 crossing.								X
Cottonwood Creek and tributaries, from Highway U-57 crossing to headwaters	X			X				X
Cottonwood Canal, Emery County	X							X
Price River and tributaries, from confluence with Green River to Castle Gate below Price City Water Treatment Plant intake.						X		X
Price River and tributaries, from Castle Gate below Price City Water Treatment Plant intake to headwaters	X			X				X
Grassy Trail Creek and tributaries, from Grassy Trail Creek Dam to headwaters	X			X				X
Range Creek and tributaries, from confluence with Green River to Range Creek Pumping Station.				X				X
Range Creek and tributaries, from Range Creek Pumping Station to headwaters	X			X				X
Nine Mile Creek and tributaries, from confluence with Green River to headwaters				X				X

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CLASSIFICATION OF WATERS OF THE STATE	USE CLASSES							
	DOMESTIC SOURCE	RECREATION AND ESTHETICS		AQUATIC WILDLIFE				AGRICULTURE
	1C	2A	2B	3A	3B	3C	3D	4
LAKES AND RESERVOIRS (20 Acres or Larger) (continued)								
CACHE COUNTY (continued)								
Pelican Pond			X	X				X
CARBON COUNTY								
Olsen Pond			X		X			X
Scofield Reservoir	X		X	X				X
DAGGETT COUNTY								
Browne Lake			X	X				X
Daggett Lake			X	X				X
Flaming Borge Reservoir (Utah portion)	X	X	X	X				X
Sheep Creek Reservoir			X	X				X
DAVIS COUNTY								
Holmes Creek Reservoir					X			X
DUCHESNE COUNTY								
Atwine Lake			X	X				X
Atwood Lake			X	X				X
Big Sandwash Reservoir			X	X				X

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APPENDIX M

PHASE II MONITORING AND PUBLIC PARTICIPATION

Monitoring is proposed to continue for one year after purchase and construction of the Pleasant Valley Creek wetland. Phase I has shown nutrients to be the pollution problem in the reservoir. Phase II monitoring will emphasis this aspect and deemphasize the other facets of water quality. Nutrients, field measurements, including DO, temperature, pH and specific conductance, chlorophyll a, and plankton will be monitored. The Bureau of Land Management in conjunction with the U.S. Geological Survey is proposing to examine metals and sediments in 1983 - 84. Their chemistry data will be sufficient to track conditions concerning Phase II.

The above mentioned parameters will continue to be monitored at many of the same sites as in Phase I. Frequency of sampling will be somewhat less as reflected in the following schedule. See Table M-1.

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Table M-1. Reservoir monitoring schedule.

STATION	DEPTH	PARAMETERS	FREQUENCY
4	Surface, above thermocline, below thermocline, bottom	Total phosphorus, ortho-phosphate, nitrates, nitrites, total alkalinity, ammonia, TKN, field measurements (pH, temp-erature, dissolved oxygen, conductivity, secchi disk), chlorophyll $\bar{a}$, and phytoplankton	Monthly-April through July Bimonthly-August through September Monthly-October through March
1, 2, 3	Surface, bottom	Total phosphorus, ortho-phosphate, nitrates, nitrites, total alkalinity, ammonia, TKN, field measurements (pH, temp-erature, dissolved oxygen, conductivity, secchi disk), chlorophyll $\bar{a}$, and phytoplankton.	Monthly-April through July Bimonthly-August through September Monthly-October through March

Tributary monitoring schedule.

STATION	PARAMETERS	FREQUENCY
Pleasant Valley Creek 1 & 2, Fish Creek Pondtown Creek Price River	Total phosphorus, ortho-phosphate, nitrates, nitrites, total alkalinity, ammonia, TKN, field measurements (pH, temp-erature, dissolved oxygen, conductivity, secchi disk), and flow.	Monthly-April through July Bimonthly-August through September Monthly-October through March

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Equipment is available from Phase I. The State will provide monitoring personnel and project coordination to be charged to the grant. The State will administer the project, monitor, review the monitoring data, and file progress reports.

Expenses for laboratory analysis will be covered 100% as inkind match from the State Laboratory.

Travel and per diem will be charged 1/2 to the grant and 1/2 to the State Department of Health.

Plankton analysis will be contracted to Ecological Consultants. The cost of $4,200.00 will be charged to the grant. See Tables M-2 and M-3.

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Table M-2. Budget for monitoring and evaluation.

ITEM	EPA	MATCH STATE HEALTH & LABORATORY
Personnel and Fringe Estimate	$16,476.00 Coordination and Monitoring	
Indirect	$ 1,862.00 (@ 11.3%)	
Pre Diem	$ 1,050.00 ($75/trip X 28 trips)	$ 1,050.00
Travel	$ 1,176.00 (300 mi/trip X 28 trips)	$ 1,176.00
Laboratory	(See Schedule)	$22,538.00*
Plankton	$ 4,200.00 28 trips X $150/sample	
TOTAL	$24,764.00	$24,764.00

* $22,538 Need for Match. Actual Monitoring Estimated at $24,360.

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Table M-3. Laboratory budget.

	Type #3 Nutrients** Per Trip	Total Alkalinity Reg. Trip	Chlorophyll A Per Trip
Reservoir * Stations 1, 2, 3, 4	10 samples @ $40.00 = $400.00	10 samples @ $10.00 = $100.00	6 samples @ $20.00 = $120.00
Streams Pleasant Valley, Fish, Pondtown, Price River	5 samples @ $40.00 = $200.00	5 samples @ $10.00 = $50.00	----------
SUBTOTALS	$600.00	$150.00	$120.00

TOTALS

$600.00 + $150.00 + $120.00 = $870.00 X 28 Trips = $24,360.00

* Reservoir Sample Depths

A = Surface
B = Above Thermocline
C = Below Thermocline
D = Bottom

** Type III Nutrients
Ammonia, nitrate, nitrite, TKN, Total Phosphorus or orth-phosphate.

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Public Participation Program

Activities under taken at Scofield Reservoir have been under the close scrutiny of the Pleasant Valley Committee. This committee, as described earlier, has been involved in problem identification and alternative solutions development. The committee consists of representatives from a variety of interests as well as private citizens. The committee will provide input on all activities to be undertaken. Members will be closely involved in all stages of project development, implementation and evaluation. The committee will be the lead agency in the public participation program.

The general public will be informed of activities and have input opportunities at a number of key points. As public meeting will be advertised in the state and local media and held prior to project implementation. This initial meeting will allow public input into the plan before construction commences.

A second public meeting will be held during the implementation phase to inform the public of progress on the project.

A final public meeting will be held at the conclusion of the implementation phase to inform the public of project completion and to receive input on the monitoring and evaluation plan. This will also inform individuals of how they may become involved in other projects in the future.

These three public meetings will be duplicated in Price City and Scofield Town.

Meetings will be held with key individuals not involved in the Pleasant Valley Committee to inform them of developments and to receive input. The contact point for public involvement will be through the Secretary of the Pleasant Valley Committee.

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APPENDIX N

MEDIA COVERAGE

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Scofield needs a plan to solve problems

Editor's note: Responsible persons or groups who wish to express an opinion are invited to submit guest editorials to be published in the Castle Country Observer column. Items for this column will generally be better researched and more thoughtfully presented than the standard letters to the editor.

This week's Observer column, the second of a two-part series on the future of Scofield Reservoir, is written by Lynn Lewis, a consultant for the Southeastern Utah Association of Local Governments.

Mining operations, recreationists, ranchers, farmers and Pleasant Valley residents all have active interests in the health of the Scofield Reservoir. Yet, for the past 50 years each group, in their own unintentional way, have been killing the reservoir.

It is projected that with the recreational and mining interests in the area, Pleasant Valley is due for a rapid population growth in the next decade. If the community grows as projected and nothing is done to stop the pollution, the lake will become unusable for culinary and recreation purposes. The longer it takes to reverse this trend, the more costly the solutions become.

Already severe problems are evident:

• There are concentrations of mercury in the reservoir occurring from natural sources that occasionally exceed Utah State and Environmental Protection Agency minimum standards for fish and wildlife.

• The combined pollution from camper, residents, mines, ranches and farmers is causing increased eutrophication, the process in which the lake is enriched by nutrients such as nitrates and phosphates. The nutrients may originate from point sources as septic tanks, mines and wastewater treatment plants or non-point sources as farming, grazing or forestry. These nutrients enter the reservoir and algae growth is intensified. The more added nutrients, the greater the algae and aquatic weed growth. When the plant material dies from the effects of colder fall weather, a demand for oxygen develops to decay the summer growth. The decaying process utilizes the oxygen in the water which causes an oxygen depletion in the reservoir. Fish kills may also result from the oxygen demand of plants in the nighttime. During the rest of the year, the decaying matter continues to use oxygen and in July and August the bottom 9 to 12 feet of the reservoir may be completely void of oxygen and fish.

• The water in the area is so unsafe to drink that for the past few months the town of Scofield has had notices posted warning residents to boil their water before drinking it.

• The amount and quality of culinary water available to the Scofield town is well below Utah's Health Department minimum requirements.

The longer the pollution continues, the worse the problems become. Yet, with the growth that is projected for Pleasant Valley, what can be done to fight the problem?

Although the issues of growth and pollution are extremely complex, the answer to the problems can be found in one sentence. To solve the problem facing Scofield Reservoir a coordinated plan of action must be instigated and adhered to.

Throughout the United States many communities similar to Scofield have had to deal with these issues of energy and recreation induced growth, while trying to maintain the quality of their environment. The communities that were successful in dealing with these issues all had plans of action.

Each community carefully evaluated their environment, reviewed their projected growth and determined the life styles they wanted to maintain. With firm objectives in mind the communities then designed specified plans that helped them meet their needs. Because each community had different objectives the specifics of the plans were varied.

Yet, all followed the same basic steps to come up with their plans.

1. They anticipated the growth well in advance.

2. The communities had and used motivated leadership.

3. The citizens became heavily involved in the planning and instigation of the plans.

4. In addition, all incoming developments (whether they were energy, recreational or residential) were required to meet the standards set by the communities.

While these steps are rather general, they do work. It is a proven fact that when a community works together with its leadership, problems can be solved.

The solutions will not be easy. Any solution will take a lot of time, effort and often, initial financial investments by all involved. Mining operations, County, State and Federal Officials all need to work together with the support of Carbon County Citizens. If nothing is done about the pollution now the Scofield reservoir will no longer be able to support Carbon County. We have to start working together now...or there may not be a tomorrow.

New study targets Scofield pollution

5/27/76 Sun Advocate

By BRANDON FORD
Staff Writer

Scofield Reservoir is in danger of becoming a dead lake if something is not done to curb the flow of pollutants into the reservoir. This is one of the findings of a study conducted by the Utah Bureau of Water Pollution Control and reported at a meeting in Price Tuesday by the study's project manager, Richard Benton.

The pollutant that is of most concern, in the case of Scofield, is phosphates, according to Benton. Phosphates come from the decomposition of living things and organic waste, like sewage, dead algae or dead fish, and are also found in significant quantities in eastern Utah soils, he said.

A certian amount of phosphates are necessary to provide nutrients for water plants, which in turn provide food for the animals living in the water. But too much phosphate in the water can cause an explosion of plant growth that chokes the lake, robbing it of oxygen and killing fish.

Benton said there are three general classifications of lakes: oligotrophic, lakes with very few nutrients; mesotrophic, lakes with a good balance of nutrients; and eutrophic, lakes where the nutrient levels are so high that the lake is in danger of oxygen deprivation. Scofield Reservoir is classified as a lower eutrophic lake that is in danger of an anoxic condition which could result in fish kills.

The biggest cause of pollution in Scofield is erosion, Benton said. The soils in eastern Utah are loaded with phosphorus and when the soil is eroded into the reservoir the phosphorus leaches out.

"The worst erosion problem in the Scofield watershed is in Pleasant Valley Creek, below Valley Camp," Benton said. Some of the cliffs he has measured in that area have eroded as much as 10 feet a year.

Other sources of phosphates include the manure of the livestock, which use the area for grazing, being washed into the reservoir, the indiscriminate dumping of holding tanks, unapproved septic tanks and the cleaning of fish in the reservoir, he said.

"One pound of fish entrails contains about 10 percent phosphorus," Benton said. "If 100,000 fish (about ⅜ of the annual catch out of Scofield) were cleaned in the reservoir it would be about the same as if we had a community of 400 dumping their raw sewage into the reservoir."

The people who use Scofield Reservoir for fishing or recreation are not the only people affected by pollution of the reservoir. Except for Price City and Helper City, most of Carbon County gets its culinary water directly out of Scofield.

"If it costs Price River Water Improvement District an extra $100,000 for chemicals to make the water fit to drink it will show up in everybody's water bill," Benton said. Cleaning up the pollution in Scofield would

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reduce the amount of water treatment necessary.

Some of the solutions to the problem of phosphates in the reservoir are very costly and involve special apparatus like circulators to keep the bottom water from stagnating.

Another plan would be to run a line from the outlet from the reservoir to the deepest part of the reservoir. A similar plan for use on Panguitch Reservoir will cost $43,000 for the materials alone. The pipe for Scofield would have to be longer and larger than the one at Panguitch.

The reservoir could also be treated with chemicals that would remove the phosphates from the water. This plan would be very expensive, however, because of the large amounts of chemicals needed, Benton said.

Some less expensive plans were also suggested by Benton.

Probably the most important is to make more of an effort to control erosion in the watershed. Use of the area for livestock grazing should be re-evaluated to make sure there are no over-grazed areas that are contributing to the erosion problem. Areas where there is a high potential for erosion should also be re-seeded, Benton said.

Another plan would be to restrict access of livestock into the area immediately around Scofield so that manure would not be washed directly into the reservoir.

Local health officials should also crack down on the unapproved septic systems in the area around the reservoir, Benton said. A greater effort could be made to prevent the indiscriminate dumping of recreational vehicle's holding tanks around the reservoir. There should also be better enforcement of the law prohibiting the dumping of fish entrails back into the lake.

Copies of the Scofield study will be available to read at the Price City Library, the Carbon County Courthouse and the office of the Southeastern Utah Association of Local Governments.

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Pleasant Valley gears for population explosion

Sun Advocate
Aug. 21, 1981

SCOFIELD — Pleasant Valley's future may not be so pleasant.

It is no secret that stepped up mining activity and the popularity of Scofield Reservoir as a vacation area are about to create a population explosion which could be disastrous for the area during the next two decades.

Yet the availability of federal and state funds, once considered the great hope, is in serious question because of a current belt-tightening mentality in Washington and Salt Lake City.

Jim Paraskeva, planner for the Southeastern Utah Association of Local Governments (SEUALG), said growth may have to be curtailed completely with new mine employees finding homes elsewhere in Carbon and Sanpete counties.

If any growth is allowed, certain courses of action regarding water, sewer and solid waste disposal must be followed to protect the watershed and provide a quality environment to current and future residents, he added.

A funding solution is currently being sought in cooperation with federal, state and local agencies and private industry, Paraskeva said.

The most critical concern is pollution of the lake, already a serious problem.

At two public hearings Sept. 4 and 5 the issue will be discussed and public input and support will be solicited.

The Sept. 4 meeting will be at 7 p.m. in Room 7 of the Price Municipal Building. The following day's meeting will be at 1 p.m. in the Scofield Town Hall.

The Water Pollution Control Bureau of the State Health Department is conducting a detailed assessment of the lake's water quality.

Funded by EPA, the study's purpose is to identify pollution sources, problem extent and possible remedies. Unfortunately, the plan will likely never be implemented because of recent budget cutbacks, Paraskevea said.

Problems identified by the study to date include high accumulations of mercury in the water and fish, probably occurring naturally but contributed to by underground water from the mines, he said.

"The lake is also being enriched by nutrients and phosphates which intensify algae growth. This growth and its associated decay deplete oxygen levels and is responsible for fish kills," he added.

Sources of the nutrients and phosphates include septic tanks, mining operations, farming, grazing and forestry.

With pollution continuing at its current rate, the lake will be unusable for culinary and recreation purposes within the next decade, he said.

Other water in the valley is also jeopardized because of the high ground water level, a major concern to all Carbon County residents because the area stores most of the county's agricultural and culinary water supply.

The main factor causing the expected growth is rapidly stepped up mining activity.

Paraskeva said five new coal mines are expected to begin operation within the next two years.

Currently, the only producing coal mine in the area is operated by Valley Camp Coal which had a 1980 production of more than 600,000 tons. Valley Camp intends to increase production levels by more than five times within the next three years.

Joining the Valley Camp operation will be mines opened by Coastal States Energy Co., producing 1 million tons per year (tpy) by 1983; First Western Coal Co. with 225,000 tpy by 1983; Blazon with 200,000 tpy by late 1982; and UCO Inc. with 672,000 tpy by 1983.

In addition to the announced operations, there are federal and private leases in the area with

(Continued on Page 2)

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Pleasant Valley gears for growth

(Continued from Page 1)

considerable potential for development.

Paraskeva said it is anticipated that about 5.1 million tons will be produced in the valley by 1985, compared to about 6 million tons of coal produced in all of Carbon County last year.

He estimated a direct workforce of 1,200 will be needed to account for the coal production. Considering Utah's average family size of 3.59 and a secondary employment factor (indirectly resulting from mining operations) the total population is estimated at 7,750.

Paraskeva said a large portion of the increased population can be expected to live in Helper and Price and in Sanpete County. If even a fraction decide to live in Scofield it would be a considerable burden on the town and its 100 residents.

A Pleasant Valley Growth Management Plan completed last year discounted the no-growth option for Scofield and favored instead a controlled-growth approach.

Paraskeva said, however, that the mine operators are generally realizing the prohibitive cost of meeting the impact in Pleasant Valley and that their employees will have to find homes elsewhere.

"Early evidence of anticipated problems is shown by construction workforces camped in trailers in Pleasant Valley canyons," Paraskeva said.

The population will attempt to live near their employment even if it is inconvenient and counties and communities will be pressured to enforce rules governing the public health, safety and welfare while providing satisfactory living alternatives, he added.

Aggravating growth impacts related to mining is the popularity of the area for fishing and hunting through Scofield and concludes at Clear Creek.

Paraskeva said there are sharp and blind curves and maintenance is minimal.

In the summer, recreational vehicles parked along the shoulder conflict with coal trucks. Traffic through Scofield endangers small children because there are no sidewalks.

Paraskeva said Scofield is not only unprepared for growth but the residents oppose it. It is estimated that $1.5 million will be required to bring community services up to par for current residents and the town operates on an annual budget of only $5,000. It does not have the bonding capacity to provide necessary law enforcement and fire protection. Solid waste disposal occurs in an open pit east of town and there are no schools, recreation facilities, or medical services.

Assuming less than 10 percent of the incoming population decides to live in Scofield, more than $4 million would be required to prepare for them.

A funding alternative that is being considered is a special service district drawing on coal mines and recreation areas as tax bases. Whether such a proposal would be received favorably is unclear.

"The ideal solutions to this maze of concerns cost a great deal of money," Paraskeva said.

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Board looks ahead at water cleanup

Southeastern Utah has made progress but has some work to do in safeguarding its water, the manager of the district's 208 Water Quality Program said Thursday.

Jim Paraskeva, who manages the program, made the comments at the regular meeting of the Southeastern Utah Association of Local Governments Executive Board.

Paraskeva, who is an association staff member, said the program was set up by the U.S. Environmental Protection Agency to identify pollution problems and set priorities on cleanup. According to EPA mandate, the program must be administered either by the state or by a regional planning agency, such as the association.

Paraskeva said the Scofield area has the highest priority in the four-county district because it is Carbon County's watershed and pollution problems there are solvable.

He said planners are starting to see success in cleaning up the Scofield Reservoir. The success is because of a media campaign urging recreationists to keep the lake clean, the formation of a Pleasant Valley Committee to identify pollution sources and solutions, and sportsmen who were "better behaved" on the opening day of fishing season.

Another effort undertaken through the program is an intensive agricultural survey and assessment in the Montezuma Creek drainage of San Juan County.

The study will determine the impact of agricultural users on the creek, Paraskeva said.

Under the auspices of the program, a salinity project has been undertaken in the Price and San Rafael rivers of Carbon and Emery counties by the federal Bureau of Reclamation and other agencies, he said.

The study will determine the inflow of salt from canal runoff and other sources.

Paraskeva identified a district-wide problem of water being contaminated by septic tanks in the Spanish Valley, Scofield and Miller Creek areas. He said one solution is to certify people to take percolation tests to see if septic tanks meet acceptable standards before building permits can be issued.

Meeting set on lakes study

Sun Advocate 5/20/83

Results of the Clean Lakes Study carried out by the Utah Bureau of Water Pollution Control will be presented at a public meeting Tuesday night.

The meeting will focus on the study's findings for Scofield Reservoir and will discuss alternatives for reducing polution at the reservoir. Richard Benton from the Bureau of Water Pollution Control will present the findings of the study.

The meeting will be in Room 246 of the Social Services Building, 90 N. 100 East, Price, Tuesday at 7 p.m. All interested people are invited to attend.

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County ordinance puts tight grip on Scofield growth

From now on, no development may occur in the vicinity of Scofield Reservoir if it threatens the quality of water there.

That is the intent of an ordinance passed Thursday by the Carbon County Commission.

The ordinance establishes two new zones to be known as the Scofield Lakeshore Zone, applying to the immediate shoreline, and the Scofield Pleasant Valley Zone, relating to development elsewhere in Pleasant Valley.

In summarizing the ordinance, consulting engineer Rodney Despain told the commission the lakeshore zone provides for housing on relatively small lots, provided some form of central sewage facility is available. The sewage facility may be in the form of individual holding tanks which do not allow drainage into the lake.

He said the zone allows construction only in those areas of the shoreline where some development has already occurred.

Despain said the Pleasant Valley zone allows for one dwelling every 10 acres.

A major focus in the development of the new zones was the preservation of the quality of both surface and underground waters in the reservoir area, Despain noted.

He said the ordinance also provides for mountain recreational developments, such as recreational vehicle parks, with limited commercial activities.

The new ordinance was immediately put into practice with the commission's final approval of a planned recreational vehicle park, cafe and lounge to be built on property owned by Ruby Forrester.

The property is located on the east side of U-96 just over the Carbon County line. Plans call for 30-40 parking stalls.

In other business, the commission drew names of the six previously appointed district board members from a hat, thereby designating the length of their terms.

Named as two-year board members were Monty Unsworth, Kathy Iriart and Frank Feichko. Four-year members are Jack Cotner (who serves as chairman), Terry Hopper and Henry Mills Jr.

The board members alternately serve two-year terms and then four-year terms.

The new district has already secured $1,121,696 from federal and state funding agencies for construction of the water system.

The Utah Board of Water Resources approved a loan with interest of $175,000 and an interest-free loan of $324,000.

The state Community Impact Board approved a $154,000 grant for the project and a loan of $200,000.

The federal Farmers Home Administration granted the district $235,000.

The residents of the district put in $33,696 toward the cost of the project.

Cotner said it will cost each water connection holder $27 a month for 5,000 gallons of water. The cost includes paying off the loans.

He said bids would be let on the project after a waiting period of 22.

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Tom Wharton

Pollution Problems Threaten Scofield Fishing Experience

When the general fishing season opens nine days from now, Scofield Reservoir will draw one of the largest crowds in the state. Its few public camping facilities will become completely overtaxed. Crowds will trespass on private land and traffic jams will form. Shoreline fishing space will be difficult to find.

The big draw, of course, is the fishing. Since it was treated for the removal of trash fish several years ago, Scofield has been one of Utah's finest trout producers.

That fact, unfortunately, could change.

Some strange things are happening at Scofield. Normally, fisheries biologists see a 75 to 80 percent survival rate on fingerlings planted at the reservoir. This year, the rate was 25 percent, a 50 percent decrease that could hurt the opening day fishing at Scofield.

Last summer, biologists noticed sustained fish kills at the reservoir. There was nothing major, but the kills persisted over a period of time. Lack of oxygen was the problem.

What is causing this lack of oxygen?

According to Jim Paraskeva, a water quality planner for the Southeastern Utah Association of Local Governments in Price, the nutrient level at Scofield is on the increase. This is causing a process known as eutrofication to occur.

This happens when too much nitrogen, phosphorous and other nutrients pour into a reservoir. Blue algae which are toxic to both fish and wildlife begin to grow. This algae not only makes the water people drink taste a bit strange (and Scofield is a culinary source of water for much of Carbon County), but clogs up agricultural pumps and causes trout to die for a lack of oxygen.

Nutrients in the form of human waste and animal waste are flowing into Scofield at a rapidly alarming rate. This is causing great concern among local officials.

The situation is similar to one that occurred at Strawberry Reservoir a few years ago and had state health department officials threatening to close the area to fishing. The Strawberry situation will be all but solved when the water rises to make the lake deeper and bigger and the U.S. Forest Service takes over management of the recreation facilities from the Strawberry Water Users Association, which hasn't had the money to install proper sewage facilities around the reservoir.

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State must help clean up Scofield

Besides containing the water supply for the entire Price River Valley, Scofield Reservoir is the second most fished body of water in the state, outranked only by Strawberry Reservoir.

Those facts alone are graphic enough to illustrate why local residents should insist that an adequate supply of state funds are made available for maintenance and improvements at the state park.

Recent studies have indicated critical nutrient loads in the lake, leading to overabundant algae growth. Severe fish kills have become common place. The lake is growing old before its time.

Certainly, pollution of Scofield can not be blamed entirely on recreational use. Livestock grazing and use of septic tanks in Pleasant Valley, a region with a high water table, contribute their share.

But 13,000 sportsmen flocked to the lake on opening day of fishing season this year. Last year it was 14,000. It stands to reason that adequate control over the hordes would go a long way toward rehabilitation of the lake.

At Saturday's tour of Pleasant Valley, government and agency officials generally agreed that most people are cooperative and clean so long as adequate facilities exist for waste disposal.

Local Parks and Recreation Division officials are asking the Legislature for funding for such items as an additional campground, expanded areas for day users, additional dumpsters and trailer dump stations.

Politics is one of the variables determining whether or not the funds are forthcoming.

Citizens can help by communicating not only with local legislators but other members of the Legislature and state agency heads.

We all have a stake in the well-being of Scofield.

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Scofield Reservoir may have serious pollution problems

DN 8-12-82

By Joseph Bauman
Deseret News environmental specialist

Scofield Reservoir, in Carbon County, may have serious water pollution problems, according to a Carbon County employee.

Richard Walker testified Wednesday in a hearing of the Utah Water Pollution Committee, held in the Capitol to discuss the state's proposals for federal funds to help water treatment projects.

A priority list of projects the state wants the federal government to fund out of its nearly $12.9 million Utah allocation for the next fiscal year will be sent to the Environmental Protection Agency soon. One state official said he thinks it is likely the top six projects on the list will get federal money.

A new sewage interceptor and treatment plan for the town of Scofield, population 125, is ranked No. 36 on the list.

Walker called for Scofield's ranking to be higher for several reasons: the area is "energy impacted" so that rapid growth might occur, Scofield has inadequate sewage treatment, about 25,000 people downstream use culinary water from the Price River that flows from the reservoir, and the reservoir itself has shown rapid changes in water quality in the last year.

Walker said, "There was a 50 percent fish loss in the reservoir," apparently last year. A study by the State Health Department shows Scofield Reservoir "so far is in a rapidly accelerating putrification condition," he said.

Walker said Scofield's water system has been disapproved by the State Health Department.

He said a study called "Water Quality in Pleasant Valley, Utah" indicates 71 percent of Scofield residents use septic tanks for sewage control. Twelve percent use holding tanks, which he said could be described as a "55-gallon drum in the ground."

"About 14 percent of the people in the town are using pit privies," he added. The water table in Scofield sometimes rises to within four feet of the surface, so most of the sewage facilities are underwater some time of the year.

He said 64 percent of waste material going into the reservoir is from the town of Scofield.

The state has classified the eservoir as a Class 1 fishery. Water from Price River, flowing from the reservoir, is treated to serve about 25,000 people as culinary water, he added.

A letter from Snyderville Basin officials, whose proposed upgrading of the treatment plant is ranked ninth on the priority list, said Snyderville has a problem with disposal of treated sewage sludge.

Because of miscalculations about evaporation rates and other things, the plant's sludge drying beds should be three to 10 times larger, the letter said. Improvements will be needed so that a permanent disposal system can be in place by next year, the letter indicated.

Don Ostler, chief of the grant section for the State Bureau of Water Pollution Control, warned that federal grants are being cut back, and that starting Oct. 1, 1984, grants will be made to fund only 55 percent of eligible costs. Presently, the federal government funds 75 percent.

If appropriations continue at the fully authorized level, Utah will get about the same amount in 1984 and 1985, for a total of around $40 million. But the state's projected needs to serve expected population growth by the year 2000 are for projects costing $595 million.

Ostler said, "Available federal funding will address only a small percentage of Utah's rapidly growing population." He said communities and local sewer districts will have to provide a lot more money.

He called for sewage systems to become "a self-sustaining public utility," and said state officials will work to help find ways to raise money.

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Group has plans to limit pollution at Scofield Lake

SCOFIELD — Activities aimed at minimizing pollution on Scofield Reservoir were outlined Saturday during a special tour for local government officials and media representatives.

The tour was sponsored by the Pleasant Valley Committee, a group formed last year as an umbrella organization involving various interested parties.

James A. Paraskeva, a Southeastern Utah Association of Local Governments official who serves as secretary to the committee, said the lake is suffering from too high a nutrient load.

He said that causes algae to bloom and use up available oxygen needed by fish.

He said the lake has deteriorated to the point where only a small amount of pollution is needed to keep the cycle going.

Sources of pollution in the reservoir, according to Paraskeva include recreational cabins, coal mines, trailers occupied by workers, livestock, Scofield Town and natural erosion.

The state Community Impact Board has recently approved a grant of $25,000 for the town for a landfill to serve the town, campgrounds and mines, he said.

Paraskeva said the committee has recommended the following measures for the reservoir and the Pleasant Valley area:

- The state Department of Natural Resources should make efforts to provide adequate facilities for recreational users.
- A user fee for the Carbon County campground and special use fees for recreational users of $2-$5 per person per season should be established.
- Fire protection, law enforcement and ambulance service should be provided by the county for the town and recreational areas.
- A livestock buffer zone should be established between the lake and grazing areas.
- Future coal leases should be scrutinized very carefully to determine possible impacts and should be denied if they do not meet established standards. (Paraskeva said enforcement by the state and federal government has been very lax.)

Paraskeva said a study of the lake has been under way for about a year and a half to determine pollution levels in the lake at critical times from different sources.

Walter M. Donaldson of the state Division of Wildlife Resources told the group that his agency has manipulated its stocking of the lake so as to ensure the survival of fish.

"We are trying to gear our management to different species so as to preserve the fisheries," he said.

Donaldson said he does not anticipate as large a fish kill as last year, probably due to high precipitation.

Patrick Walsh of the state Division of Parks and Recreation, said that agency expects to enlarge its boat ramp from a width of 12 to 60 feet this fall, helping to mitigate the traffic congestion on the shoreline. He said some people currently must wait up to two hours to launch their boats.

Walsh said the division has established a concept plan involving a new entrance road; future expansion of parking, day use and camp areas; dumpsters and a trailer dump site.

The group toured the portal area of Valley Camp of Utah's Belina No. 2 mine.

Treavor Whiteside, in charge of public relations, said water from the disturbed areas of the mines drains to settling ponds where it is filtered through coke and gravel.

Sun Advocate
Sept. 15/82

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Scofield report is released

SCOFIELD — Water quality in the Pleasant Valley area is threatened by a projected population increase of 200-500 families during the next two decades, according to a report released Tuesday.

The Pleasant Valley Growth Management Plan culminates 10 months of study by Carbon County, Scofield Town and the Southeastern Utah Association of Local Governments. Land Design of Logan participated as primary consultant.

"Because most of Carbon County's water sources are found in this valley, it is critically important that steps are taken to minimize the effects of residential and recreational development," said Richard Walker, SEUALG planner.

It is important that residents know the contents of the study and participate in the process, he added.

Two SEUALG-sponsored public hearings will be held regarding the draft document.

The first is scheduled for Friday, Jan. 30, at 7 p.m. in room 7 of the Price Municipal Building.

The second hearing will be held Saturday, Jan. 31, at 10 a.m. in Scofield Town Hall.

The study indicates that coal mining in the valley will increase and that 20-25 percent of the work force will decide to live there.

"That translates to approximately 200-500 miners and families plus service personnel," Walker said.

Apart from growth in the mining industry, recreational use will continue to increase, the study shows.

"Facilities will need to be drastically increased to serve the need and prevent undue pollution of the lake," he said.

Waste disposal from nearby residences and summer cabins, as well as mining and natural sources, contribute to the pollution, he added.

Specific courses of action are recommended for Scofield Town, Carbon County, Utah County, Sanpete County, mine operators, water users, SEUALG, U.S. Forest Service, Utah State Parks and Recreation, private developers, Utah State Health Department and the Utah Department of Transportation.

General actions recommended in the document are formation of an umbrella organization to discuss common issues and obtain funds, and the formation of environmental controls.

Copies of the growth management plan are available for inspection at the SEUALG office in the Carbon County Industrial Center south of Price.

Copies are also available in Scofield. Interested persons should contact Mayor Paul Helsten, phone 448-9446.

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APPENDIX O

ENVIRONMENTAL EVALUATION CHECKLIST FOR
SOUTH SHORE WETLANDS PROJECT*

1. No people will be displaced.

2. No residencial areas are in the project.

3. No. The project will remove land from commercial use.

4. Yes. Land will be removed from livestock production. However, the land involved is not of prime agriculture value. Livestock removed will be mitigated by development of upstream areas in conjunction with the Soil Conservation Service.

5. No. In fact, it will become public property which will allow public access.

6. No.

7. No.

8. No.

9. No.

10. Yes. The project lies adjacent to Pleasant Valley Creek and along the high water line of Scofield Reservoir. Pleasant Valley Creek is presently eroding the stream bank due to lack of riparian vegetation. Instream improvement structures and developed riparian vegetation will stabilize the stream which will improve water quality by halting erosion.

11. No. Modifications of the lakeshore will occur. Canals, ditches and diversion structures on the stream will be constructed to control and apply water in the project. One adverse effect is being addressed. Minimum stream flows will be maintained to ensure preservation of fishery habitat and spawning channels.

12. No. As stated in #11, minimum stream flows will be maintained. The project will enhance the wetland by insuring regular and constant flows to the area.

13. No endangered species are in the watershed.

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14. A. Environmental Impacts

The local Water Conservancy District owns forty of the sixty acres in the project. The additional twenty acres will be purchased with the grant. No adverse environmental impacts will be observed. In fact, just the opposite will be experienced. The project, although minimal in its direct impact on water quality, will have a significant visual and psychological impact on the management of Scofield Reservoir. Removing livestock which are in direct contact with the reservoir shoreline and receeding lake bed will eliminate some nutrients from the annual loadings. The livestock management has long been a complaint in solving Scofields pollution problem. When pressing lakeshore development cabin owners or recreation users to improve usage practices such as improving sewage facilities, littering, or garbage collection, the rebuttal is always made, "What about the pollution from livestock?" We feel the visual and first step approach of this project will initiate future restoration and better management practices in the watershed. This action will show all concerned that state and local agencies are interested and concerned with solving pollution problems, maintaining water quality and preserving Scofield Reservoir as a vital multiple resource in Southeastern Utah.

B. Resource Commitment

Monitoring and inkind services will be provided by the State Department of Health, Carbon County, the Price River Water Improvement District, Pleasant Valley Committee, Division of Wildlife Resources and Soil Conservation Service. The mining interests may also participate.

C. Public Interest

Public meetings held in the Price area have shown a strong local support and concern for Scofield Reservoir. Elected officials and local agencies have all shown strong support. The Water Conservancy District, Carbon County Commission and Price City have all expressed concern for Scofield Reservoir.

D. Cost

The Soil Conservation District is involved with the design of the project and will give a realistic estimate of cost.

15. No.

* See Clean Lakes Guidance Manual Section 8.6.10, Page 59.

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