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REDLINE AND STRIKEOUT FORMAT

(These pages are for review only)

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Mining Methods. As noted in Section 5.2.3, both room-and-pillar and longwall mining methods are used in the SUFCO Mine. The size, sequence, and timing for the development of the underground workings are shown on Plates 5-7 and 5-8.

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Subsidence Control Measures. Most of the land within the permit area will eventually be affected by subsidence. Anticipated areas of subsidence and those areas planned for protection from subsidence are shown on Plate 5-10. The primary areas where subsidence is not anticipated are the areas overlying the pre-1977 workings in Lease SL-062583 shown on Plate 5-1 (referred to herein as the "Old Mine") and ~~the~~certain lease areas underlying Quitchupah Canyon, Box Canyon, and Muddy Creek ~~(the only locations of perennial streams within the permit area)~~.

The "Old Mine" area was mined in such a manner that coal pillars were left for support throughout the entire workings. Since these pillars are large enough to support the overburden and further mining is not anticipated in these workings, the surface area above the workings should not experience any subsidence.

~~The~~Where perennial streams are not undermined they will be protected from subsidence by establishing stream buffer corridors within the mine from which only limited coal recovery will occur. Support pillars will be left in these locations to preclude subsidence. Underground stream buffers will only be crossed to the extent necessary to allow access to reserves. This access will consist of entries and cross cuts with support pillars. Entries that cross through the underground stream buffer corridors with less than ~~600~~300 feet of cover will be sealed and/or backfilled upon abandonment using the best available technology to prevent disturbance of the overlying streams.

Protected cultural resource sites ~~and perennial stream protection corridors~~ will be designed to include a buffer zone to protect the area from the effects of subsidence caused by underground full extraction mining. The width of the corridor will be calculated as follows: the depth of overburden to the coal seam will first be established. This depth will be multiplied by tan 15° to obtain the distance underground mining needs to be away from the area to not cause subsidence effects. An additional 25 foot buffer will be added to this calculated distance to account for minor irregularities in the course of the stream or cultural resource site.

Surface structures overlying the area to be subsided consist of trails, unimproved dirt roads, fences, ~~and~~ runoff catchment ponds, and streams. The applicant will repair any subsidence caused damage to these or other structures to the extent economically and technically feasible, and will comply with R645-301-525.160 and R645-301-525.230. Additional mediation and remedial measures are described in Section 5.2.5.2 Subsidence Control.

Monitoring within the permit area has shown that subsidence rarely exceeds 50 percent of the mining height where the overburden thickness is greater than 800 feet. This overburden thickness is generally achieved above the rim of the Castlegate Sandstone (see Plate 5-10).

Topography above the Castlegate Sandstone is gently sloping while that within and below the sandstone outcrop contains cliffs and steep slopes. With the exception of the experimental mining practice described below, future subsidence is typically planned only for those areas above the rim of the Castlegate Sandstone where the overburden thickness exceeds 800 feet.

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Previous surveys have indicated that no substantial damage has occurred to vegetation as a result of subsidence within the permit area. The only effects observed have been exposed plant roots where tension cracks have formed.

It is anticipated that subsiding under portions of East Fork Box Canyon will result in a slight flattening of the stream gradient, which will increase pooling of the stream through a stretch of several hundred feet of the stream. Cracks will also likely develop across the East Fork Box Canyon Creek directly above the longwall panels and along the gate roads. These crack zones will form shortly after undermining of the stream bed. They are anticipated to be 1 to 2 inches or less in width with these cracks healing to some degree following formation. Details of the expected location of the cracks are given in Appendix 7-19. If cracks do develop in the channel floor and appear to be taking surface water from the creek, sealing of these cracks will be done with bentonite grout.

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Adopted Control Measures. As indicated above, SUFCO Mine has adopted subsidence-control measures in areas where surface resources are to remain protected. These controls consist primarily of leaving support pillars in place in those areas designated on Plate 5-10 as not planned for subsidence. Based on experience and data collected from the permit area, the design of support pillars for those areas where subsidence is not planned has been based on the following equations:

$$SF = SD/OS \qquad (5\text{-}1)$$

where SF = safety factor against pillar failure (fraction)

SD = support strength density (psi)
= $(Y_c)(1\text{-}ER)$

Y_c = average compressive yield strength of the coal (psi)
= 3090 psi for the Upper Hiawatha seam

ER = extraction ratio (fraction)
= $1\text{-}(A_p/A_t)$

A_p = pillar area (ft^2)

LIST OF APPENDICES

(Appendices appear in Volumes 9 and 10)

Appendix

from the pad area when compared to the contribution of the in-place soils and shale bedrock will be insignificant.

Flooding or Streamflow Alteration. Runoff from all disturbed areas is treated through sedimentation ponds or other sediment-control devices prior to discharge to adjacent undisturbed drainages. Three factors indicate that these sediment-control devices minimize or preclude flooding impacts to downstream areas as a result of mining operations:

1. The sediment-control facilities have been designed and constructed to be geotechnically stable. Thus the potential is minimized for breaches of the sediment-control devices to occur that could cause downstream flooding.

2. The flow routing that occurs through these sediment-control devices reduces peak flows from the disturbed areas. This precludes flooding impacts to downstream areas.

3. By retaining sediment on site in the sediment-control devices, the bottom elevations of stream channels downstream from the disturbed areas are not artificially raised. Thus, the hydraulic capacity of the streams channels is not altered.

Following reclamation, stream channels will be returned to a stable state (see Section 5.4.2.2). The reclamation channels have been designed to safely pass the peak flow resulting from the 100-year, 24-hour storm. Thus, flooding in the reclaimed areas will be precluded. Interim sediment-control measures and maintenance of the reclaimed areas during the post-mining period will preclude deposition of significant amounts of sediment in downstream channels following reclamation, thus maintaining the hydraulic capacity of the channels and precluding adverse flooding impacts.

The mine has been designed to ~~preclude~~minimize subsidence ~~in areas occupied by~~impacts to perennial streams (see Section 5.2.5.1). ~~Thus, no~~Any material damage to the stream channel ~~is anticipated~~will be mitigated. Streamflow volume in the North Fork of Quitchupah Creek will, however, increase due to mine water discharge.

Mine water discharge to the North Fork of Quitchupah Creek has increased streamflow by over 1000 gpm (2.25 cfs). Waters encountered in the Pines Tract will be pumped to the Quitchupah discharge point. The worst case flow increase is estimated to be approximately 3.75 cfs. Once mining has ceased, the mine will be sealed and no discharges will occur. The streamflow volume will return to pre-mining discharge levels. Increased flow to the North Fork of Quitchupah during seasonal flow conditions are addressed by Mayo in Appendix 7-17.

Subsidence tension cracks that propagate to the surface, will increase the secondary porosity of the formations overlying the SUFCO mine. Thiros and Cordy (1991) state that bentonitic shale and plastic flow in mudstone within the perching layers could possibly slow or stop the downward movement of groundwater. If these cracks do not become blocked with bentonite, recharge to aquifers that feed spring flow may increase. Thus, subsidence may contribute to increases in streamflow.

Subsidence may decrease spring flow if the perched aquifer which supplies the spring is intersected by tension cracks, allowing groundwater to drain to underlying strata (Thiros and Cordy, 1991). Subsidence has occurred beneath East Spring (monitoring station 001), but no major changes in flow rate or water quality have been detected from 1985 to 1986 (Thiros and Cordy, 1991). Groundwater monitoring data (Appendices 7-4 and 7-17) indicate that flow rates of this spring have declined from 1987 to 1995. This decline in flow, however, is likely due to the drought conditions of the last several years (Appendix 7-5). Flow rates from other springs currently monitored by SUFCO, but located in unsubsided areas (057A and FS-109), have also declined during the last several years (Appendices 7-4 and 7-17).

Subsidence will occur in areas occupied by ephemeral and perennial stream channels. According to Thiros and Cordy (1991), surface water flow to natural drainages has the potential of being intercepted by subsidence fractures that extend to the land surface. In addition, the broad depressions created by subsidence may locally retain runoff that would normally discharge from an area. Although surface cracks that result from subsidence in the permit area tend to heal with time (see Appendix 5-4), ~~ephemeral~~ stream flows may be partially intercepted prior to completion of the healing process. However, the following factors indicate that the impact of subsidence on ~~ephemeral~~ streamflow will be minimal:

1. Bentonitic shale and plastic flow in mudstone within perching layers could possibly slow or stop the downward movement of previously perched groundwater (Thiros and Cordy, 1991).

2. Field observations indicate that there are no sustained above normal inflows in the mine. Thus, flow along fractures is either from a relatively small source, or the conduits become sealed quickly.

3. Ephemeral streamflow in the area is sporadic, allowing significant periods of time which may allow for surface cracks to heal between flow events.

4. Ephemeral streamflow typically carries a high sediment load. During precipitation runoff events, perennial streams will also carry a high sediment load. This sediment will fill remaining cracks. As the cracks heal, the potential for interception of streamflow is minimized.

5. The depressions created by subsidence are sufficiently broad that changes in slope are not typically of an ample magnitude to cause ponding in anything other than local areas. If ponding does occur, the shallow depressions will fill with sediment quickly due to the periodic high sediment load of ~~ephemeral~~ streams and the drainage will return to the previous pattern.

Groundwater and Surface Water Availability. The potential impacts of mining on reductions in surface-water availability are discussed above. As indicated, these impacts are not considered to be significant.

As noted in Section 7.2.4.2, groundwater is encountered in the SUFCO mine and pumped to the surface, generally into the North Fork of Quitchupah Creek at UPDES station 003.

According to Mayo (Appendix 7-17), the rate of discharge from the mine has increased since 1987 from approximately 1.0 cfs (450 gpm) to about 3.56 cfs (1,600 gpm).

The increase in flow into and out of the mine is considered to be the result of increased coal production. The primary method of mining converted from room-and-pillar to longwall in October 1985. As a result of this change, production in the mine increased (see Figure 7-6). With the increase in production, new areas were mined at an increasingly higher rate. According to Mayo (Appendix 7-17), the mine discharge hydrograph shows that the rate of mine water discharge does not increase as the total area of the mine increases, but rather, the rate of discharge is related to the amount of recently mined areas.

7.30 Operation Plan

7.3.1 General Requirements

This permit application includes an operation plan which addresses the following:

- Groundwater and Surface Water Protection and Monitoring Plan;
- Sediment Pond Sludge Sampling and De-watering Plan;
- Design Criteria and Plans;
- Performance Standards; and
- Reclamation Plan.

7.3.1.1 Hydrologic-Balance Protection

Groundwater Protection. To protect the hydrologic balance, coal mining and reclamation operations will be conducted to handle earth materials and runoff in a manner that minimizes acidic, toxic, or other harmful infiltration to the groundwater system. Additionally, SUFCO will manage excavations and disturbances to prevent or control discharges of pollutants to the groundwater. SUFCO commits to replace loss of any surface water identified for protection in this M&RP that are impacted by mining at the SUFCO mine.

Surface Water Protection. To protect the hydrologic balance, coal mining and reclamation operations will be conducted to handle earth materials and runoff in a manner that minimizes acidic or toxic drainage, prevents, to the extent possible, additional contributions of suspended solids to streamflow outside the permit area, and otherwise prevents water pollution. Additionally, SUFCO will maintain adequate runoff- and sediment-control facilities to protect local surface waters. SUFCO commits to ~~protecting all~~mitigating any material damage resulting from subsiding perennial streams in the permit area ~~from subsidence~~ as indicated in Chapter 5 of this M&RP. The plan for protection of the perennial streams meets the BLM requirements for protection of their water rights (BLM, 1992).

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APPENDIX 1-2

Lease Documents

United States Department of the Interior

BUREAU OF LAND MANAGEMENT
Utah State Office
P.O. Box 45155
Salt Lake City, UT 84145-0155
www.ut.blm.gov

IN REPLY PLEASE REFER TO:
3482
UTU-76195
(UT-070)

JUL 3 1 2003

Certified Mail--Return Receipt Requested
Certificate No.

Ken May
General Manager
Canyon Fuel Company, LLC
SUFCO Mine
397 South 800 West
Salina, Utah 84654

Re: Approval of Mining Underneath Box Canyon in the 3rd and 4th Left Panels, Minor Modification to the Resource Recovery and Protection Plan (R2P2), Federal Coal Lease UTU-76195

Dear Mr. May:

On February 20, 2003, the Bureau of Land Management (BLM) received a written request from Canyon Fuel Company (CFC) to modify the approved R2P2 for the SUFCO Mine. The modification requested approval to shorten the Left Pines East longwall panels due to encountering a sandstone channel and mine the complete shortened panels including subsiding the stream channel in the East Fork of Box Canyon. The affected reserves are located in the Upper Hiawatha seam in Federal coal lease UTU-76195. The minor modification request lies within the lease boundary (UTU-76195) and inside the currently approved permit area.

<u>Background:</u>

SUFCO discovered a major sand channel in the 3LPE located at cross cut 92 in entry 1. Based on longhole drilling, the sand channel severely scoured zone is approximately 320 feet in width. The channel extents were verified by BLM inspector George Tetrault on April 14, 2003 as follows:

Headgate Entries

- in entry 1 of the head gate, full face of rock,
- in entry 2, between cross cut 93 and 94 there was 1 foot of coal and the remaining (7+ feet) was rock, and
- in entry 3 there were 7.7 feet of coal and the remainder was rock at outby cross cut 94.

Tailgate Entries

- in entry 1 there was full face of rock, and
- in entry 2 and 3 there was about 4 feet for rock.

BLM requested that the company submit economic data for mining though the rock and recovering the block of coal north of (or inby) the sand channel. The information submitted by the company (see attached map and summary financial table) indicates that the coal cannot be economically recovered as part of 3LPE or 4LPE as the channel clearly crosses into that longwall panel as well. BLM considered whether a royalty rate reduction could make the block of coal economic to recover. However, there is insufficient information to enable consideration of the risk factors including the unknown width and location of the sand channel(s) and whether this block of coal could be accessed from another location such as 5LPE.

Based on the information submitted by the company and the confirmed geologic conditions, we conclude that the coal north of (or inby) the sand channel is uneconomic from 3LPE panel or 4LPE (due in large part to timing requirements for 4LPE). Approval of the proposed R2P2 modification for 5LPE is withheld pending further exploration and mine planning for the coal north of or inby the sand channel.

It could be economically possible to recover the coal inby the sand channel either with longwall mining or continuous miners. This is yet to be determined.

Approval:

As provided in 43 CFR 3482.2(c)(2), BLM approves the requested R2P2 modification dated February 20, 2003, with respect to the 3LPE and 4LPE panels. BLM approves the shortening of the 3LPE panel with a setup room outby the sand channel, setup rooms at cross-cuts 89-91 of 3LPE (approved verbally on April 14, 2003) and full extraction mining under the East Fork of Box Canyon. Before approval can be given for the proposed 5LPE panel and future longwall panels, your R2P2 submittal must be expanded to address potential recovery of the coal north or inby of the sand channel. This approval is in accordance with Stipulation 9 of coal lease UTU-76195 that allows for approval of mining under perennial streams. No changes in the length of the 5LPE, 6LPE, and 7LPE longwall panels are authorized until further justification is provided that the coal inby the panels is not recoverable. The environmental effects of the modification were analyzed in a Determination of NEPA Adequacy (DNA) document dated July 31, 2003.

Reserves:

There is a change in reserves of approximately 180,600 tons due to geologic factors off-set by mining underneath the East Fork of Box Canyon for this modification:

R2P2 effect on coal reserves with changes to 3LPE and 4LPE panels

	3 LPE	South Block	3 LPE Stream Block	4 LPE	4 LPE Stream Block	Muddy Creek Break out	Total
Original Plan	8,629,800	0	-876,400	6,163,000	0	70,400	13,986,800
New Plan	5,960,900	665,399	939,900	6,163,000	438,000	0	14,167,199
Difference							180,600

Conditions of Approval:

1. Full extraction under the perennial stream in the East Fork of Box Canyon is not authorized until a permit revision is approved by the Utah Division of Oil, Gas, and Mining as provided in 30 CFR 944.3 Article VI D. In order to be consistent with the terms and conditions of federal coal lease UTU-76195, this approval must incorporate appropriate monitoring requirements and implementation of a mitigation plan to minimize impacts to the perennial stream in the East Fork of Box Canyon in accordance with the provisions of SMCRA.

2. Before initiating longwall mining under the perennial stream in the East Fork of Box Canyon, the company must submit to BLM and receive approval for a plan outlining the steps to be taken and timing to ensure that the longwall mines the area under the stream with minimal interruptions in longwall face advance.

3. Following completion of mining under the East Fork of Box Canyon, the company must provide BLM copies of monitoring and mitigation reports required under the provisions of SMCRA.

4. Within 90 days after approval of the modification, the company must submit a modification request to address mining the block(s) of coal north of or inby the sand channel or provide justification why it cannot be economically mined.

MER and Mineral Lease Act Analysis:

Based on our analysis of the North (or inby) Block being uneconomic to mine from 3LPE or 4LPE longwall panels, and with the conditions of approval as stated, we determine that this modification achieves Maximum Economic Recovery and meets the regulations at 43 CFR 3480 and the Mineral Leasing Act of 1920 as amended, and is consistent with the terms of federal coal lease UTU-76195.

For further information, please contact George Tetrault (435) 636-3604 or Stan Perkes at (801) 539-4036.

Sincerely,

James F. Kohler
Chief, Solids Minerals Branch

Enclosures
1-Map 1 (1pg)

bcc: UT-070,
Gtetreault:sa: 05/13/03
SUFCO/Pinestract\LinkCanyon

United States Department of Agriculture | Forest Service | Intermountain Region | 324 25th Street Ogden, UT 84401 801-625-5605

File Code: 2820-4
Date:

Ms. Sally Wisely
State Director
Bureau of Land Management
324 South State Street
P.O. Box 45155
Salt Lake City, UT 84145

Dear Ms. Wisely,

In a telephone call on July 21, we discussed the unresolved issues associated with the pending application before the Bureau of Land Management (BLM) regarding the Resource Recovery and Protection Plan (R2P2) modification proposed by the SUFCO mine on a federal coal lease within the Manti-La Sal National Forest. We believe that the Forest Service (FS) and BLM are in agreement on the following points:

1. The BLM is responsible for enforcing the terms and conditions of a federal coal lease and is the primary point of contact with the lessee.

2. The FS continues to have responsibilities for the management of surface resources on a federal coal lease on National Forest System lands.

3. The FS must consent to the issuance of a federal coal lease and identify conditions or stipulations that are deemed necessary to minimize impacts to surface resources and uses. Subsequent to the leasing decision, the FS must also consent to a federal coal mine plan that is approved by the Interior Assistant Secretary for Lands and Minerals as part of the Federal Mine Plan approval process through the Office of Surface Mining (OSM.)

4. The FS Record of Decision (ROD) that documents our conditional consent to lease issuance contains language that was not specifically incorporated into the lease stipulations. Forest Service special stipulation 9 addresses mining under perennial streams and provides for approval of an R2P2 modification that may affect perennial streams.

As documented in the ROD, it was the intent of the FS that consent to the coal lease was conditioned upon restrictions of mining operations under the drainage in the East Fork of Box Canyon that would cause subsidence. However, based on negotiation between the agencies, those terms were not clearly carried forward in the stipulations attached to the lease that became a contract between the United States and the lessee. We share the concerns of the Manti-La Sal National Forest that subsidence of the area could impact the stream and associated ecosystem. We also recognize that there are differing professional opinions as to the probable duration and significance of these impacts. We recognize that the BLM has the responsibility for administration of federal leases and as such has the authority to approve the proposed R2P2 modification as long as it is consistent with the terms of the lease.

If the BLM approves the proposed R2P2, appropriate monitoring requirements and implementation of mitigation to ensure protection of the perennial stream in the East Fork of Box Canyon and the associated ecosystem should be incorporated into any subsequent modification/revision of the mining and reclamation plan and/or permit. If the State or OSM determines the modification to be significant based on their existing criteria, FS concurrence would be required.

We appreciate your willingness to discuss this situation and share your willingness to continue to work through issues associated with coal resources underlying National Forests. We fully support the ongoing discussions among our agencies and the State of Utah to develop a more definitive process to facilitate cooperation and collaboration in the coal program and to clarify agency roles and responsibilities which will help prevent similar situations in the future.

Sincerely,

for, JACK G. TROYER
Regional Forester

APPENDIX 7 - 19

Probable Hydrologic Consequences of Longwall Mining of the 3 Left Panel Modification Area at the SUFCO Mine

Probable Hydrologic Consequences of Longwall Mining of the 3 Left Panel Modification Area at the SUFCO Mine

10 April 2003

Canyon Fuel Company, LLC
SUFCO Mine
Salina, Utah

PETERSEN HYDROLOGIC
CONSULTANTS IN HYDROGEOLOGY

Probable Hydrologic Consequences of Longwall Mining of the 3 Left Panel Modification Area at the SUFCO Mine

10 April 2003

Canyon Fuel Company, LLC
SUFCO Mine
Salina, Utah

Prepared by:

Erik C. Petersen, P.G.
Senior Hydrogeologist

Kelly L. Payne, P.G.
Senior Hydrogeologist
Norwest Corp

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1.0 INTRODUCTION

The SUFCO Mine, which is located approximately 20 miles east of Salina, Utah, has been in operation since 1977. The mine is owned and operated by Canyon Fuel Company, LLC (Canyon Fuel). In order to access approximately 0.97 million tons of coal that would otherwise be permanently bypassed, Canyon Fuel is seeking approval to undermine the East Fork of Box Canyon Creek (East Fork; Figure 1), which has previously been determined to be a perennial watercourse. The purpose of this report is to evaluate the potential impacts to the hydrologic balance that may occur as a result of longwall mining of the portion of the 3 Left longwall panel that underlies the East Fork (Figure 1).

Canyon Fuel has conducted extensive hydrologic data collection efforts in Box Canyon and its tributaries since 1997. Focused evaluation of the portion of East Fork proposed for undermining is currently underway. Thus, this is an interim report based on previous work, specific data collected for East Fork, and general knowledge of hydrologic impacts related to mine subsidence in the Wasatch Plateau.

The section of East Fork proposed for undermining is located on The Pines Coal Lease Tract administered by the U.S. Bureau of Land Management (BLM). The surface management agency is the Manti-La Sal National Forest.

In 1997-98 the National Forest and BLM jointly prepared an Environmental Impact Statement (EIS) that analyzed impacts of underground mining on the tract (USFS-BLM, 1999). In a separate Record of Decision issued in January 1999, the Forest consented to leasing the tract and imposed Special Stipulations that prohibited subsidence of perennial drainages. The Pines Tract EIS also considered a separate but closely related request by Canyon Fuel to allow subsidence of a portion of the main fork of Box Canyon Creek, which is located on the adjacent, previously-leased Quitchupah Tract.

It is standard Manti-La Sal National Forest policy to protect perennial streams and the ecosystems they support by categorically prohibiting the subsidence of perennial drainages. The Forest Service does consider proposals to undermine drainages where such proposals are supported by convincing scientific analysis indicating that the risk of significant disruption to the hydrologic balance is small. The Forest has previously allowed undermining of the perennial Burnout Canyon drainage at the Skyline Mine. Several rigorous scientific investigations have been performed to determine whether longwall mining has had any quantifiable impact on the surface-water drainage. No significant impacts to the hydrologic balance have been identified in Burnout Canyon despite several years of multiple-seam longwall mining beneath the creek.

Based on the scientific information collected from the Box Canyon area to date, it is considered that the risk of significant disruption to the hydrologic balance resulting from longwall mining of the 3 Left panel modification area is small.

2.0 METHODS OF STUDY

Previous Work

There has been extensive collection and analysis of baseline hydrologic and hydrogeologic data for the Box Canyon Creek drainage, as well as analysis of probable hydrologic impacts. This work includes:

- A rock mechanics evaluation and prediction of the potential surface subsidence impacts from longwall mining under the Box Canyon drainage (Goodrich and Agapito, 1997).
- An analysis of the probable impacts to the hydrologic balance of Box Canyon Creek resulting from longwall coal mining (Mayo and Associates, 1997b).
- The technical reports and draft and final EIS for the Pines Tract Coal Lease, which included extensive descriptions of the baseline conditions and probable hydrologic impacts of mining in the tract (USFS-BLM, 1999).
- A determination of the probable hydrologic consequences of mining in the Pines Tract, as required as part of a mining permit application to the Utah Division of Oil, Gas and Mining (UDOGM; Mayo and Associates, 1999).

More recently an in-depth study of the fluid flow characteristics of the Castlegate Sandstone has been completed for the SUFCO Mine area as part of a Master's degree thesis at Brigham Young University (Black, 2000).

Field Investigations

Ongoing field investigations are being conducted to gather geologic and hydrologic data for the section of East Fork proposed for undermining. As of the present time, the following field investigations have been performed:

- Canyon Fuel personnel have surveyed the longitudinal profile of the East Fork.
- A geologist from Ark Land Company (an affiliate of Canyon Fuel) has recently completed field mapping of the contact between the Castlegate Sandstone and the Blackhawk Formation and measured the geologic section from the top of the exposed Castlegate Sandstone to 100 feet below the Castlegate Sandstone-Blackhawk Formation contact. These data have been used to create a geologic cross section.
- The authors have traveled East Fork by foot on numerous occasions as part of spring and seep surveys and in conjunction with quarterly hydrologic monitoring since 1997.
- In early April 2003, the East Fork section was visited specifically to review geology, spring occurrence, and stream bank conditions in the 3 Left panel modification area. At this time, the creek was impenetrably frozen over and gain-loss and spring discharge measurements could not be performed.

Baseline and Operational Hydrologic Monitoring Data

Baseline and operational hydrologic monitoring data have been collected from the Pines area (including the 3 Left panel modification area) since 1997. Discharge and solute compositions of groundwaters and surface-waters in the vicinity of the 3 Left panel modification area are listed in Table 1.

3.0 GEOLOGY

Stratigraphy

Castlegate Sandstone

The Castlegate Sandstone is a cliff-forming unit comprising the rim rock of Box Canyon. The sandstone is also directly exposed or covered by only a thin soil veneer on the plateau along the rim of Box Canyon. The Castlegate Sandstone is discomformably overlain by the Price River Formation, which forms low lying hills on the plateau in the vicinity of Box Canyon.

The Castlegate Sandstone in the Southern Wasatch Plateau is predominately medium-grained but grain size varies from clay-sized particles to pebbles (Black, 2000). Sorting likewise varies from very well to very poorly sorted, while as a whole the sandstone is moderately well sorted.

Monocrystalline quartz is the dominant grain type in the Castlegate Sandstone with silica the predominant cementing agent although calcite cement also commonly occurs (Black, 2000).

The Castlegate Sandstone was deposited primarily by numerous coalescing streams in a braided stream depositional environment (Van de Graaff, 1972). In this type of depositional environment, changes in flow conditions are common and create lenticular sandstone forms that are often separated by mudstone drapes. These mudstone drapes are called "bounding surfaces" and in the Castlegate Sandstone are often associated with a reduction in permeability and porosity (Black, 2000). This depositional history has a profound effect on the bulk water transmitting properties of the Castlegate Sandstone, which is further discussed later.

In the southern Wasatch Plateau, Black (2000) has divided the Castlegate Sandstone into three units. The upper unit (uppermost 45-60 feet) is medium grained sandstone with common pebble conglomerate lenses. Bounding surfaces in the upper unit are comprised of sand or mud and silt. The middle unit (60-120 feet thick) is the coarsest section with predominately sand-dominated bounding surfaces. The lower unit (basal 90 feet) contains medium-grained sandstone that is commonly interbedded with lenses of silty sand, siltstone, and mudstone.

Blackhawk Formation

The Blackhawk Formation in the study area consists of lenticular, discontinuous beds of sandstone, siltstone, mudstone, shale, and coal. In the study area, the upper 500 feet of the formation generally has massive, fine- to medium-grained, cliff-forming sandstone units. These sandstones were deposited in delta and flood plain environments and are isolated from each other both laterally and vertically by mud-rich overbank and low-flow deposits. The number and thicknesses of sandstone units decreases toward the base of the unit. The lower 300 feet of the formation contains thinly-bedded sandstone and shale layers deposited in a marine shoreface and foreshore depositional environment. The interbedded shale and mudstone units isolate permeable sandstone paleochannels and impede groundwater movement. The Blackhawk Formation is known to contain abundant swelling clays (montmorillonite and bentonite).

Structure

Rock units in the study area strike roughly 40° east and dip 1 to 2° to the northwest. Local dips of the coal seam may range up to 10 degrees in areas where underlying paleochannels caused significant differential compaction.

Small displacement faults (apparent vertical displacement of about three feet or less) and some of greater displacement have been encountered in the SUFCO mine. These faults most commonly strike approximately N10° to 15°W and are inclined nearly vertical. Joints are both parallel and normal to the fault trend. Both faults and joints exist in the Pines Tract area. Joints unrelated to faulting are common in the Castlegate Sandstone. The surface traces of these joints are up to a 1,000 feet in length and are spaced 16 to 33 feet apart.

Geology of the 3 Left panel modification area

Stratigraphy and structure of the section of East Fork proposed for undermining are illustrated on a map showing the geologic contact of the Castlegate Sandstone with the Blackhawk Formation (Figure 2), a stratigraphic section derived from field measurements and a nearby drill hole (Figure 3) and a geologic cross section along East Fork (Figure 4).

The stream bed of East Fork above the 3 Left longwall panel is primarily Blackhawk Formation. The uppermost 200 feet of stream (Figure 2) flows across a thin wedge of Castlegate Sandstone that reaches a maximum thickness of 10 feet at the eastern panel margin (Figure 4). The Castlegate Sandstone is largely exposed as steep cliffs on the canyon rims or is covered by colluvial material. In the area of interest, the Castlegate Sandstone is thickly bedded and massive. The sandstone contains approximately 10% mudrocks in the form of sandy siltstones. These siltsones are apparent in the log of borehole 01-11-2 (Figure 3) but were not noted in the measured section likely due to weathering and colluvial cover.

The Blackhawk Formation underlying the stream consists of 60% mudrocks (claystone, shale, and siltstone) and 40% sandstones. The sandstones form ledges on the lower canyon walls and create waterfalls or water slides in the creek bottom. Except for sandstone ledges, the exposure of the Blackhawk Formation on the lower canyon walls are colluvium-covered slopes.

The thickness of the Blackhawk Formation between the Upper Hiawatha Seam and the stream bed ranges from 600 feet on the western edge of the panel to 750 feet on the east edge.

4.0 CLIMATE

Climatic conditions in the mine area have varied substantially since the commencement of hydrologic data collection in the Pines area (1997 – present). This is illustrated in a plot of the Palmer Hydrologic Drought Index (PHDI) for Utah Region 4 (Figure 5). The PHDI is a monthly value generated by the National Climatic Data Center using a variety of hydrologic parameters that indicates wet and dry spells. The PHDI is calculated from several hydrologic parameters including precipitation, temperature, evapotranspiration, soil water recharge, soil water loss, and runoff. Consequently, it is a useful tool for evaluating the relationship between climate and groundwater and surface water discharge data. The PHDI is useful to assist in determine whether temporal variability in spring or stream discharge rates. The PHDI is useful for determining whether variations in spring or stream discharges are the result of climatic variability or whether they are the result of other factors.

It is apparent in Figure 5 that the region experienced a prolonged period of moderate to extreme wetness beginning in 1997 and continuing through 1999. It was during this period that the spring and seep surveys and the first two years of baseline hydrologic data were collected at the Pines area. During 2000 and 2001 climatic conditions in the region were near normal. From late 2001 to the present, the region has experienced a period of moderate to extreme drought.

5.0 GROUNDWATER AND SURFACE WATER SYSTEMS

A previous investigation of groundwater and surface water systems in the Box Canyon area has been performed by Mayo and Associates (1997b). The purpose of the groundwater and surface-water characterization presented below is to expand on the work of Mayo and Associates with an emphasis on groundwater and surface-water systems in the vicinity of the proposed 3 Left panel modification area.

5.1 Description of Groundwater Systems

Three fundamental groundwater regimes operate in the vicinity of the 3 Left panel area. These include bedrock groundwater systems in the Castlegate Sandstone and Blackhawk Formation, and shallow, colluvial/alluvial groundwater systems that occur in the canyon bottoms adjacent to the East Fork of Box Canyon Creek. The conceptual model of groundwater flow in the Box Canyon area is illustrated in Figure 6. The three groundwater systems are described below.

Castlegate Sandstone Groundwater Systems

Six springs have been identified in the region overlying the proposed 3 Left panel modification area. These include Pines 217 and 217A, Pines 216 and 216A, Pines 215, and Pines 214 (Figure 7). Each of these springs discharges from the Castlegate Sandstone. Two other Castlegate Sandstone springs, Pines 105 and Pines 213, are located adjacent to the 3 Left panel modification area. All of the springs in the 3 Left panel modification area discharge from the Castlegate Sandstone.

The operation of groundwater systems in the Castlegate Sandstone is fundamentally related to the geologic makeup of the rock strata in the formation. While the effective porosity of the formation is relatively high, ranging from 9 to 31% (Black, 2000), the ability of the formation to transmit water both laterally and vertically is poor. This is because, rather than being a uniform sand deposit, the formation consists of a series of lenticular braided stream fluvial deposits. Bounding surfaces present between adjacent fluvial deposits are generally much lower in permeability than that of the surrounding sandstone. These bounding surfaces exist at both the micro- and macro-scales. Most importantly, bounding surfaces that represent a change in the depositional fluvial architecture are present throughout the formation (Black, 2000). Mud- or silt-dominated bounding surfaces commonly have permeabilities less than about 3×10^{-7} cm/sec (Black, 2000). Black (2000) found that in the Quitchupah Canyon area, individual macroforms (intervening sandstone units) range from an average of about 20 to 40 feet in length, with an average height of about 3 feet and a cross-sectional area of about 15 to 40 square feet. Thus, relatively small, isolated partitions of permeable sandstone exist that are three-dimensionally encased in lower permeability fine-grained deposits.

The Castlegate Sandstone bounding surfaces, which can be laterally continuous for hundreds to thousands of feet (Black, 2000), effectively partition groundwater systems within the Castlegate Sandstone. In other words, while groundwater flow can potentially occur within an individual partition, the ability for groundwater to flow across bounding surfaces from one partition to another is very limited. Because the bounding surfaces create partitions that are discontinuous and lenticular in shape, the ability for groundwater to migrate substantial distances laterally (beneath the plateau away from the canyon rims) is minimal. This is evidenced by the fact that many monitoring wells completed in the Castlegate Sandstone away from the canyon rims are always dry (Mayo and Associates, 1997b).

The ability of the Castlegate Sandstone to transmit groundwater is locally enhanced by jointing and fracturing. Where joint or fracture systems are interconnected and have measurable apertures, some lateral migration of groundwater can occur. Additionally, field observations indicate that where the sandstone rocks have been decemented along the canyon walls, the ability of the formation to transmit water is locally enhanced.

Field observations indicate that in the East Fork of Box Canyon area, groundwater discharge to springs usually occurs along fracture systems near the contact with the underlying Blackhawk Formation. The base of the Castlegate Sandstone sits atop a sequence of essentially impermeable Blackhawk Formation shale and/or mudstone horizons. These low-permeability horizons effectively prevent the downward migration of groundwater from the Castlegate Sandstone into deeper horizons. Thus, where a water-bearing fracture system intersects the canyon wall overlying the Blackhawk Formation, a spring occurs. Because the regional dip of the strata in the Box Canyon area is to the northwest, the Castlegate Sandstone springs in the 3 Left panel modification area all discharge along the east side of the canyon.

Chemical information indicates that groundwaters in the Castlegate Sandstone in the Box Canyon area have not migrated through the overlying Price River Formation (Mayo and Associates, 1997). Thus, recharge to the Castlegate Sandstone most likely occurs where the Castlegate Sandstone is exposed near the surface. This is consistent with recharge in the plateau regions along the canyon rims where the Castlegate Sandstone is exposed at the surface.

Discharge hydrographs for Castlegate Sandstone springs Pines 105 and Pines 106 (Figure 8) demonstrate that Castlegate Sandstone groundwater systems in the East Fork of Box Canyon area are influenced by seasonal and climatic variability. Groundwater discharge in the headwaters of the East Fork of Box Canyon Creek measured at Pines 106 (Figure 7) also indicates seasonal and climatic variability.

5.2 Alluvial/Colluvial Groundwater Systems

In some locations the thin veneer of colluvial and alluvial sediments along the canyon bottom in the East Fork of Box Canyon Creek are saturated. This condition is particularly apparent on the east side of the canyon along the Castlegate Sandstone – Blackhawk Formation contact. Although no measurable groundwater discharge from these systems is visible, diffuse seepage of groundwater through these sediments supports vegetation locally.

The alluvial/colluvial groundwater systems are likely recharged by three primary mechanisms. These include 1) infiltration of local precipitation or snowmelt waters, 2) infiltration of stream water from the creek into the shallow subsurface, and 3) infiltration of spring discharge waters from Castlegate Sandstone groundwater systems that are in direct physical contact with the colluvial and alluvial sediments. Based on the fact that the alluvial/colluvial groundwater systems are best developed in areas immediately below areas of known Castlegate Sandstone groundwater system discharge, it is apparent that the latter of the above described recharge mechanisms is the most important of the three.

5.3 Blackhawk Formation Groundwater Systems

The nature of groundwater flow in the Blackhawk Formation is a result of the lateral and vertical heterogeneity of rock strata in the Blackhawk Formation. Groundwater systems in the Blackhawk Formation operate independently of groundwater systems in the overlying Castlegate Sandstone. The Blackhawk Formation underlying the stream in the 3 Left panel modification area contains approximately 60% low-permeability fine-grained rocks and approximately 40% sandstone (written communication, Mark Bunnell, 2003). Thus, the ability of the Blackhawk Formation to transmit water vertically through this sequence of low-permeability bedrock is low. That this is the case is demonstrated by the complete lack of Blackhawk Formation springs identified in the East Fork of Box Canyon area.

The lack of vertical groundwater migration through the Blackhawk Formation is also evidenced by the tritium and radiocarbon contents of groundwaters encountered in the SUFCO Mine.

Mining has occurred at the SUFCO mine since 1977. Historically, most mining areas have been relatively dry. Where encountered, groundwater drains from sandstone paleochannels in the immediate mine roof with lesser amounts of water encountered in fault systems. Water also drains from longwall gob areas (areas of collapsed rock created by collapse of the mine roof as the longwall face advances). Water draining from gob areas is also believed to be from saturated strata closely overlying the mined horizon.

SUFCO has commissioned extensive characterizations of the sources of groundwater inflows to the mine as well as the relationship between groundwater inflows and near surface groundwaters and surface waters. These investigations have relied on long-term hydrologic monitoring data from creeks, springs, and monitoring wells as well as on powerful isotope hydrogeochemistry tools, namely tritium and radiocarbon.

Tritium and radiocarbon are unstable isotopes that are commonly used in hydrogeologic investigations. Tritium is a radioactive isotope of hydrogen that is used to determine whether groundwater has a component that recharged in the past approximately 50 years. Tritium is generated through cosmic radiation in the atmosphere and is readily incorporated into precipitation. Naturally occurring tritium concentrations in precipitation commonly range between about 4 and 25 tritium units (TU). Because of the short half-life of tritium (12.32 years), groundwater older than about 50 years will contain essentially no tritium.

Radiocarbon (^{14}C) is an unstable isotope of carbon with a half-life of 5,570 years. Information on radiocarbon content is used together with the carbon-13 composition to calculate the time that has elapsed since a groundwater became isolated from the surface.

Numerous tritium and radiocarbon analyses have been completed on groundwater inflows to the mine (Mayo and Associates, 1997a; Mayo and Associates, 1999). Tritium has not been detected in mine waters and radiocarbon ages are between 7,000 and 20,000 years. These results indicate that groundwaters encountered by the mine are part of inactive groundwater systems that have essentially no communication with the surface or near surface.

It has also been convincingly demonstrated that subsidence and associated fracturing does not induce vertical groundwater migration. In 1996, water samples were collected from a longwall gob area that had been mined in 1989 and from which discharge had steadily decreased since mining was completed. The water from this gob area contained no tritium and had a radiocarbon age of 13,000 years.

In the Box Canyon area, it is confidently anticipated that groundwaters encountered by mining will be derived from storage in inactive groundwater systems. Significant groundwater inflows were encountered while mining the longwall panels adjacent to Box Canyon Creek (immediately south and east). Radiocarbon and tritium data were collected from two locations in one of these panels (14 Left 4 East) in late 2000 (Table 2). Radiocarbon data indicate that groundwater encountered in the SUFCO Mine beneath the Box Canyon area is approximately 4,000 to 6,000 years old. The complete lack of tritium in the mine groundwater demonstrates that it has been isolated from the surface for at least the past 50 years.

5.4 Description of Surface-Water Systems in the 3 Left Panel Modification Area

The headwaters of the East Fork of Box Canyon Creek are located near the stream monitoring station Pines 106 (Figure 7). Field observations indicate that from a point approximately 100 feet above Pines 106, the stream channel is commonly dry. Below Pines 106, although meager, continuous flow can be present to the confluence with the main fork of Box Canyon. During April 2003 it was observed that the East Fork of Box Canyon Creek was completely frozen over below a point about 200 feet below Pines 106.

A plot showing discharge at Pines 106 and Pines 408 (lower East Fork of Box Canyon) is shown on Figure 9. It is apparent that the discharge at Pines 408 is consistently greater than that at Pines 106. This indicates that this is a gaining reach of the creek. During baseflow conditions, the discharge at 408 is commonly on the order of 10 to 20 gpm greater than that at Pines 106. Field observations suggest that the stream flow gains in this reach originate mostly between Pines 106 and Pines 214 (Figure 7). Diffuse seepage of groundwater from the streambank or from the channel substrate below Pines 214 has not been observed. This suggests that the increases in flow in the East Fork of Box Canyon Creek are likely attributable to discharge from Castlegate Sandstone groundwater systems in this reach of the creek.

6.0 PROBABLE IMPACTS TO THE HYDROLOGIC BALANCE

Longwall mining under East Fork in the 3 Left panel would result in surface subsidence of the creek bottom, canyon walls, and upland areas. Coal left in place between longwall panels causes differential subsidence of the land surface with areas along the panel margins subsiding less than areas in the central portion of the panel. The result of this differential subsidence is the creation of "tension zones" along the panel margins that often create tension cracks at the surface. It is these tension cracks that have the greatest potential to alter the hydrologic balance. From our view, potential impacts can be divided into two categories. First, tension cracks can occur in the stream substrate and have the possibility of diverting stream flows into the subsurface. Second, tension cracks on the upland areas can alter groundwater flow paths and affect groundwater discharge characteristics. Because East Fork is largely sustained by groundwater discharge, alteration of groundwater discharge characteristics would have a direct impact on stream flows. Both of these types of potential impacts are discussed below.

Fracturing of the Stream Substrate

Based on empirical observations and rock mechanic analysis (Goodrich and Agapito, 1997), it is confidently anticipated that fractures that form in the stream substrate would have small apertures (usually less than ½ inch) because of lateral confining pressure present in the interior of the canyon (i.e. although the rock fractures, there is little space created).

Observations from other subsided areas above the SUFCO mine (Mayo and Associates 1997a, 1997b) suggest that the small-aperture cracks that do form in the channel substrate will be "dead-end" fractures that will likely fill in with sediment rapidly (within a few weeks). Observations also suggest that these tension cracks do no extend below the surface more than a few tens of feet. Field observations in East Fork indicate that the stream in the 3 Left panel modification area visibly transports sandy and silty sediment that would readily fill any tension cracks that would form. Additionally, the presence of swelling clays in the Blackhawk Formation would readily seal tension fractures to heal to prevent water transmittal from the surface to deeper horizons.

It is important to note that in all but the upper 200 feet of the stream channel in the 3 Left panel modification area, the channel substrate is developed on the Blackhawk Formation. In the upper 200 feet of the drainage where there is a 10-foot-thick (or less) layer of Castlegate Sandstone between the stream channel and the Blackhawk Formation, we anticipate that the stream will respond to subsidence fractures in a manner that is not substantively different from that where the Blackhawk Formation is directly exposed in the channel substrate. As demonstrated in previous sections, the ability of the Castlegate Sandstone to convey groundwater laterally beneath the plateau is minimal. Therefore, the potential for surface waters to be diverted in any perceptible or quantifiable way from the drainage via tension fractures in the Castlegate Sandstone is considered negligible.

Thus, we strongly expect that tension fractures that form in the creek bottom will not significantly alter the hydrologic balance of East Fork by diverting surface waters into the subsurface. There may be some short-term diminution in flow as fractures fill with water.

sediment, and clays; however, this is not expected to be a major impact because of the localized areas where tension fractures may occur.

Fracturing of Upland Areas

Tension fractures that may potentially form along the canyon rims will likely have larger apertures than fractures in the canyon bottom due to the lack of confining pressures. Where tension cracks at the surface do form, they can temporarily divert shallow, active-zone groundwaters and cause minor changes to groundwater discharge locations. Spring discharge locations could be moved a short distance down gradient as a result of groundwater flow path alterations. However, these potential effects would be relatively short-lived. It has been the experience in Burnout Canyon that tension cracks that form at the surface are rapidly filled with sediment over time. Thus, the cumulative impacts to groundwater systems resulting from tension cracking at the surface is considered minimal.

As discussed in previous sections, the Castlegate Sandstone is not capable of transmitting appreciable quantities of groundwater laterally. Based on field inspection of existing tension fractures in the SUFCO Mine area, it is apparent that these fractures are of limited extent and are generally confined to the region immediately adjacent to the margins of longwall panels. Thus, the potential for groundwater to be conveyed significant distances, either through the rocks of the Castlegate Sandstone or through tension fractures is limited (i.e., the tension fractures will be dead-end openings). It should be noted that whether the 3 Left panel modification area is mined or not, tension fractures in the vicinity of the 3 Left panel will likely form. As currently permitted, the longwall panel will terminate adjacent to the East Fork Creek, which will create a permanent tension zone. Open fractures will likely form at that location as well as at the location where mining of the panel is later resumed on the other side of the creek. If a continuous progression of the 3 Left panel occurs, subsidence effects are more uniform and many of the anticipated open tension cracks in the vicinity of the 3 Left panel modification area will likely not form.

Kadnuck (1994) observed that shallow groundwater regimes may be temporarily altered as the stress field associated with longwall mining passes through a region. It is apparent that a similar condition may have been created in the main fork of Box Canyon associated with nearby longwall mining activities. Two springs currently monitored by Canyon Fuel (Pines 212 and Pines 209; Figure 8) have shown a gradual increase in discharge as longwall mining in the area has proceeded. Similarly, the discharge in the main fork of Box Canyon Creek as monitored at site Pines 407 has shown an increase as longwall mining has progressed in the vicinity (Figure 8). This condition may be related to a "squeezing" of the rock strata as the stress regime is locally altered.

A similar situation could develop in the vicinity of the East Fork as longwall mining proceeds there. This condition could potentially develop whether the 3 Left panel modification area is undermined or not (the main fork of Box Canyon Creek was not directly undermined, nor were the spring discharge locations for Pines 212 and Pines 209 undermined). If discharge from Castlegate Sandstone groundwater systems increases as longwall mining progresses in the vicinity, the potential for diminution of stream flows or spring discharges associated with the temporary diversion of groundwater into newly formed tension fractures will be mitigated. After any tension fractures (which would be dead-end openings) have initially filled with water the hydrologic conditions at the site would likely return to pre-mining conditions.

Where differential subsidence of the land surface occurs in stream drainages, there is the potential for the temporary increase of sediment yield in these drainages. This potential impact is primarily the result of subsidence induced gradient changes along areas of differential subsidence. However, this effect is generally expected to be short lived. This is because the channel substrate in areas of increased stream gradients is down-cut while sediment is being deposited in areas of decreased stream gradients and the stream gradually returns to equilibrium with its channel substrate.

7.0 CONCLUSIONS

- Three different groundwater systems exist in the vicinity of the 3 Left panel modification area. These include bedrock groundwater systems in the Castlegate Sandstone and Blackhawk Formation, and shallow, colluvial/alluvial groundwater systems in the thin, unconsolidated sediments adjacent to the East Fork of Box Canyon Creek.

- Unfractured Castlegate Sandstone is unable to transmit groundwater significant distances vertically or laterally because of the heterogeneity of the sandstone rocks of the formation. Specifically, bounding surfaces associated with the fluvial depositional environment of the Castlegate Sandstone partitions groundwater systems creating isolated groundwater compartments that are not in good hydraulic communication with adjacent compartments.

- Shallow Blackhawk Formation groundwater systems do not visibly discharge measurable quantities of groundwater in the 3 Left panel modification area. This is because the low-permeability bedrock present at the top of the formation effectively prohibits vertical groundwater flow through the formation. Consequently, local recharge to the Blackhawk Formation does not occur.

- Groundwater systems in the Castlegate Sandstone and the Blackhawk Formation are not in hydraulic communication. This is the result of the low-permeability strata present at the top of the Blackhawk Formation.

- The thin alluvial/colluvial groundwater systems in the 3 Left panel modification area are recharged by 1) infiltration of precipitation and snowmelt waters, 2) seepage from the East Fork Creek into the alluvial/colluvial sediments, and 3) the infiltration of groundwater discharge from Castlegate Sandstone groundwater systems that are in physical contact with the alluvial/colluvial sediments. The latter of the above described recharge mechanisms is believed to be most important in the 3 Left panel modification area.

- Historically, the groundwater encountered in the SUFCO Mine has been from about 7,000 to 20,000 years old and has been taken from storage. Groundwater sampled from the 14 Left area beneath Box Canyon in 2000 ranged from about 4,000 to 6,000 years in age and contained no tritium. The interception and diversion of shallow groundwaters or surface waters into the mine has not occurred anywhere in the mine. Tritium concentrations of in-mine groundwaters indicate that the water encountered in the SUFCO has been isolated from the surface for at least the past 50 years.

- We strongly believe that groundwater potentially encountered while undermining the 3 Left panel modification area will occur under similar conditions as that elsewhere in the SUFCO Mine.

- Long-term impacts to the hydrologic balance resulting from the longwall undermining of the 3 Left panel modification area are not anticipated.

- Short-term decreases in spring and/or stream discharge rates could occur as newly formed tension cracks are initially filled with water and sediment. The tension fractures would likely be dead-end openings, which, after being filled initially, would not accommodate significant additional quantities of water over time.

- As a result of longwall mining adjacent to the main fork of Box Canyon, some spring and stream discharges have increased. This phenomenon is likely related to a change in the local stress regime associated with the progression of longwall mining. Such an increase in discharge from springs and the creek in the 3 Left panel modification area, were it to occur, would help to mitigate the potential short-term impacts related to diversion of surface water and/or groundwater to initially fill potential newly formed tension fractures.

8.0 REFERENCES CITED

Goodrich, R.R., and Agapito, J.F.T., 1997, Evaluation and prediction of potential surface subsidence impacts from longwall mining under the Box Canyon Area: unpublished consulting report, Agapito Associates, Inc., Grand Junction, Colorado.

Black, B.J., 2000, Fluid flow characterization of the Castlegate Sandstone, southern Wasatch Plateau, Utah: interpretation of reservoir partitioning through permeability and porosity analysis, Brigham Young University, Department of Geology, Master's Theses, 145 p.

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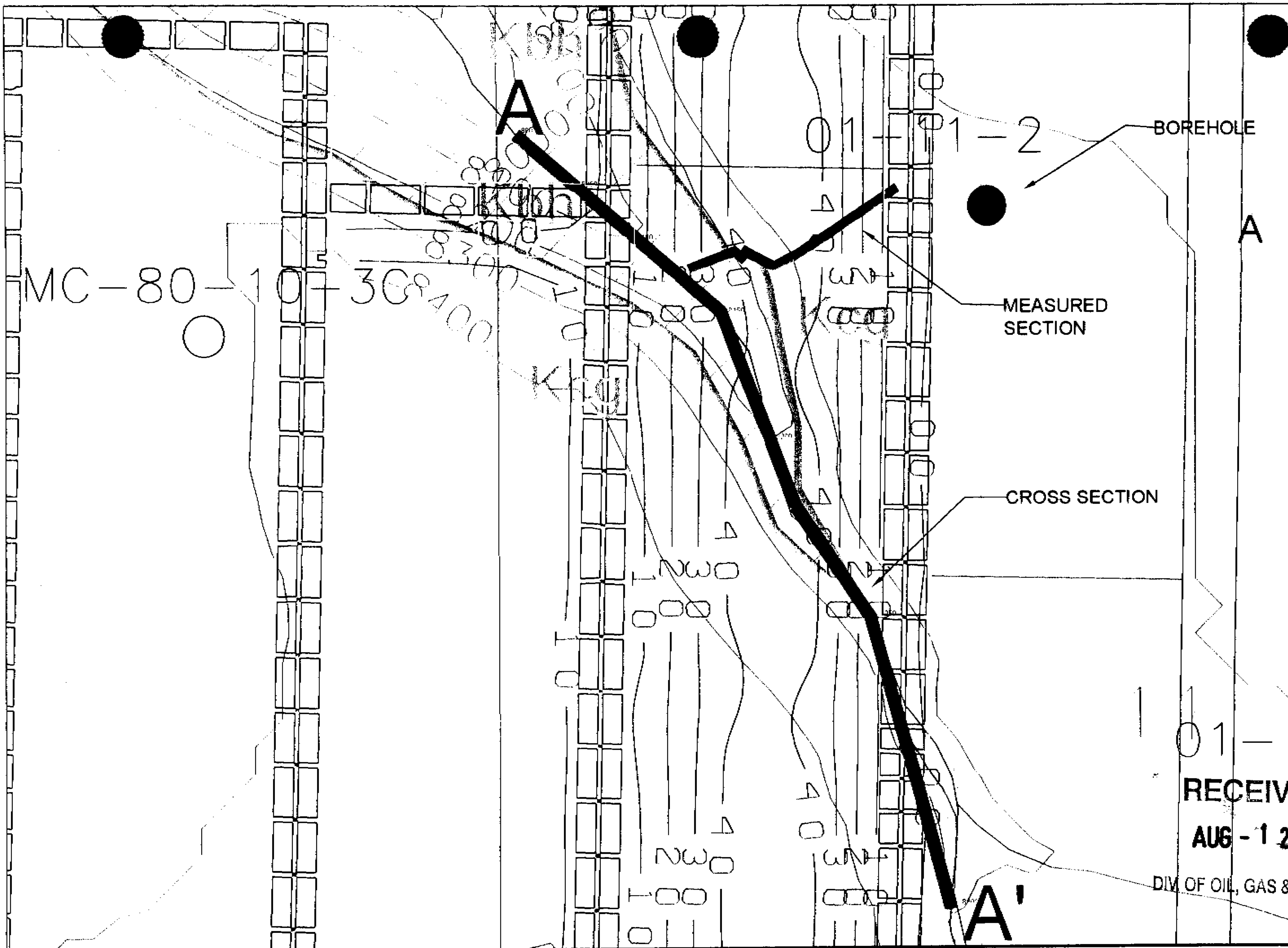
Mayo and Associates, 1999, Investigation of groundwater and surface-water systems in the Pines Tract: Probable hydrologic consequences of coal mining in the Pines Tract. Unpublished consulting report prepared for Canyon Fuel Company, LLC.

Mayo, A.L., and Morris, T.H., 2000, Conceptual model of groundwater flow in stratified mountainous terrain, Utah, USA in Groundwater: Past achievements and future Challenges, Sililo et al. ed: Proceeding XXX IAH Congress on Groundwater, Capetown South Africa, 26 November – 1 December, 2000, p. 225-229.

Map(s) is kept with this application located in the Public Information Center of our Salt Lake City office.

FIGURE 1, SUFCO MINE MAP



Castlegate Sandstone

Blackhawk Formation

—1.0— Projected Subsidence Contour (-ft.)
(projections based on CISPM empirical modeling software)

N

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FIGURE 2
SURFACE GEOLOGY
EAST FORK BOX CANYON
3 LEFT PANEL AREA
SUFCO MINE

1"=500'

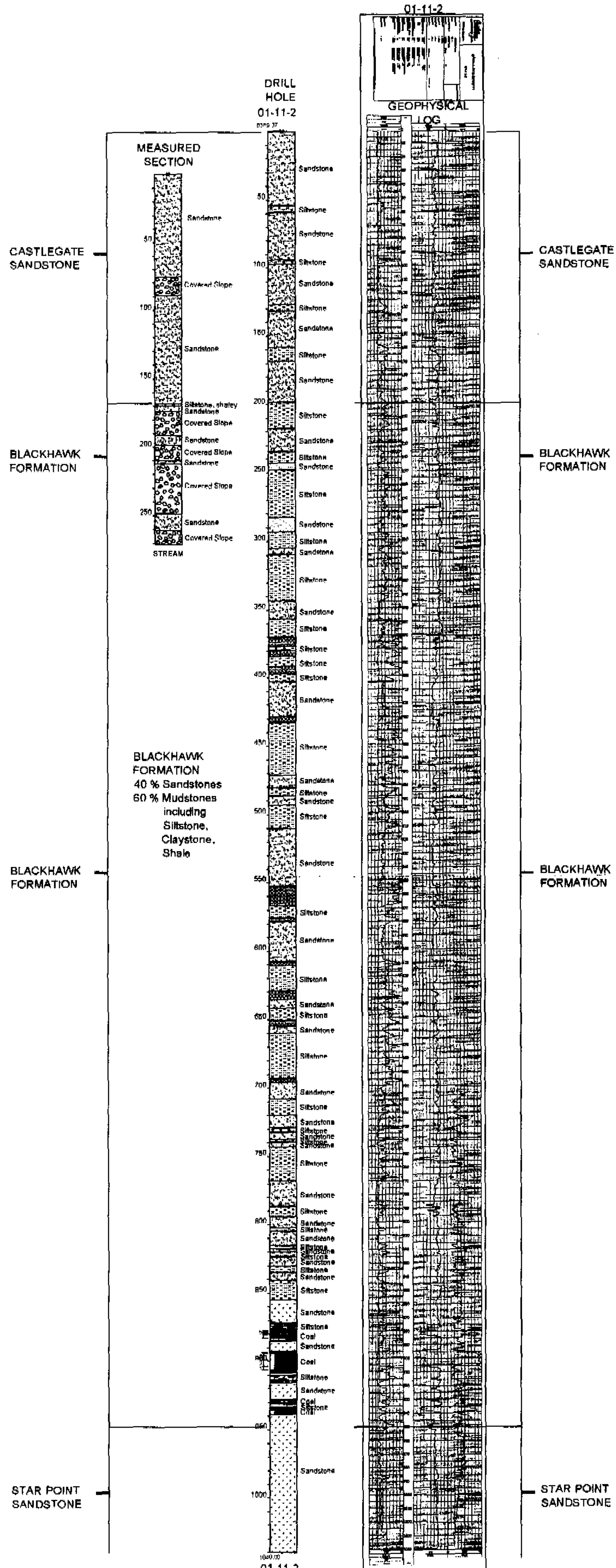

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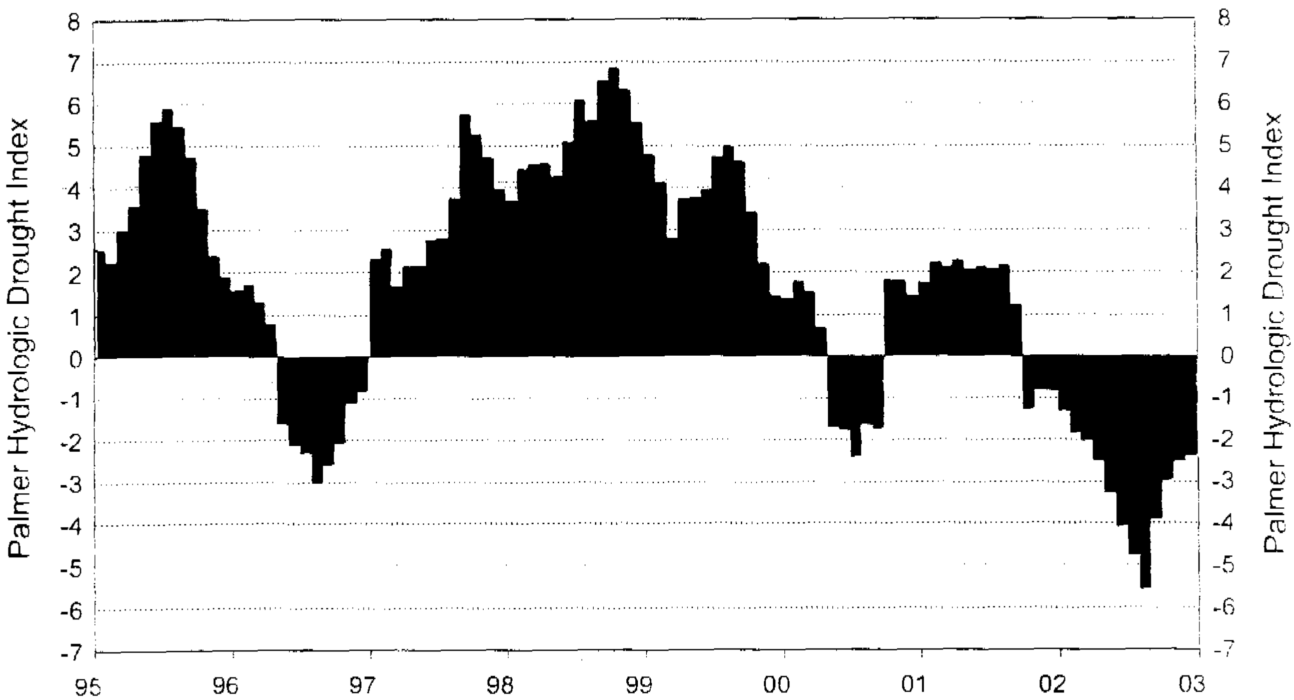
FIGURE 3
BOREHOLE 01-11-2
W/ MEASURED SECTION
EAST FORK
BOX CANYON

1"=60'

Map(s) is kept with this application located in the Public Information Center of our Salt Lake City office.

FIGURE 4, CROSS SECTION EAST FORK BOX CANYON



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

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

Figure 5 Palmer Hydrologic Drought Index, Utah Region 4.

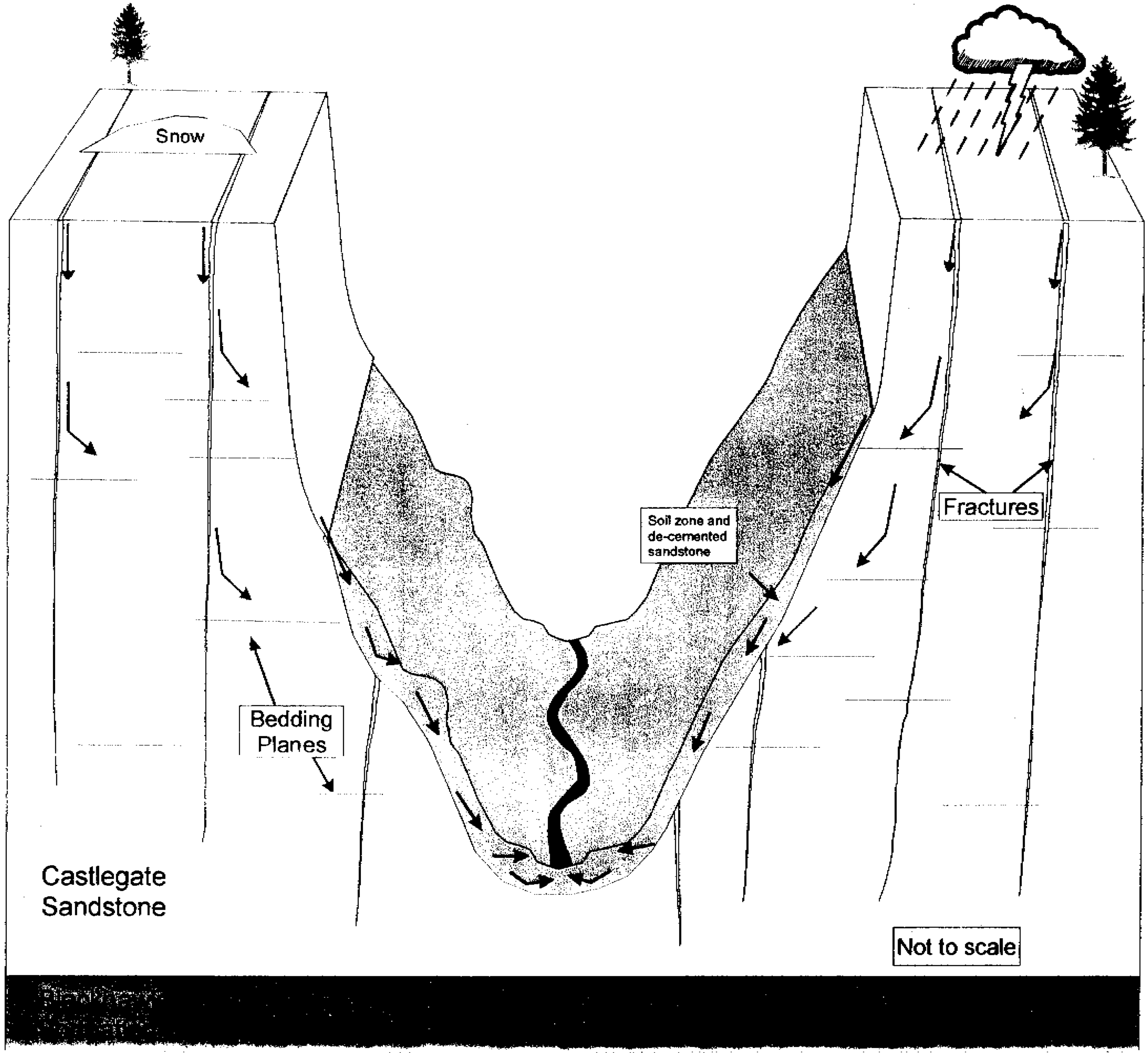


Figure 6 Conceptual model of groundwater flow in the Box Canyon area (from Mayo and Associates, 1997b).

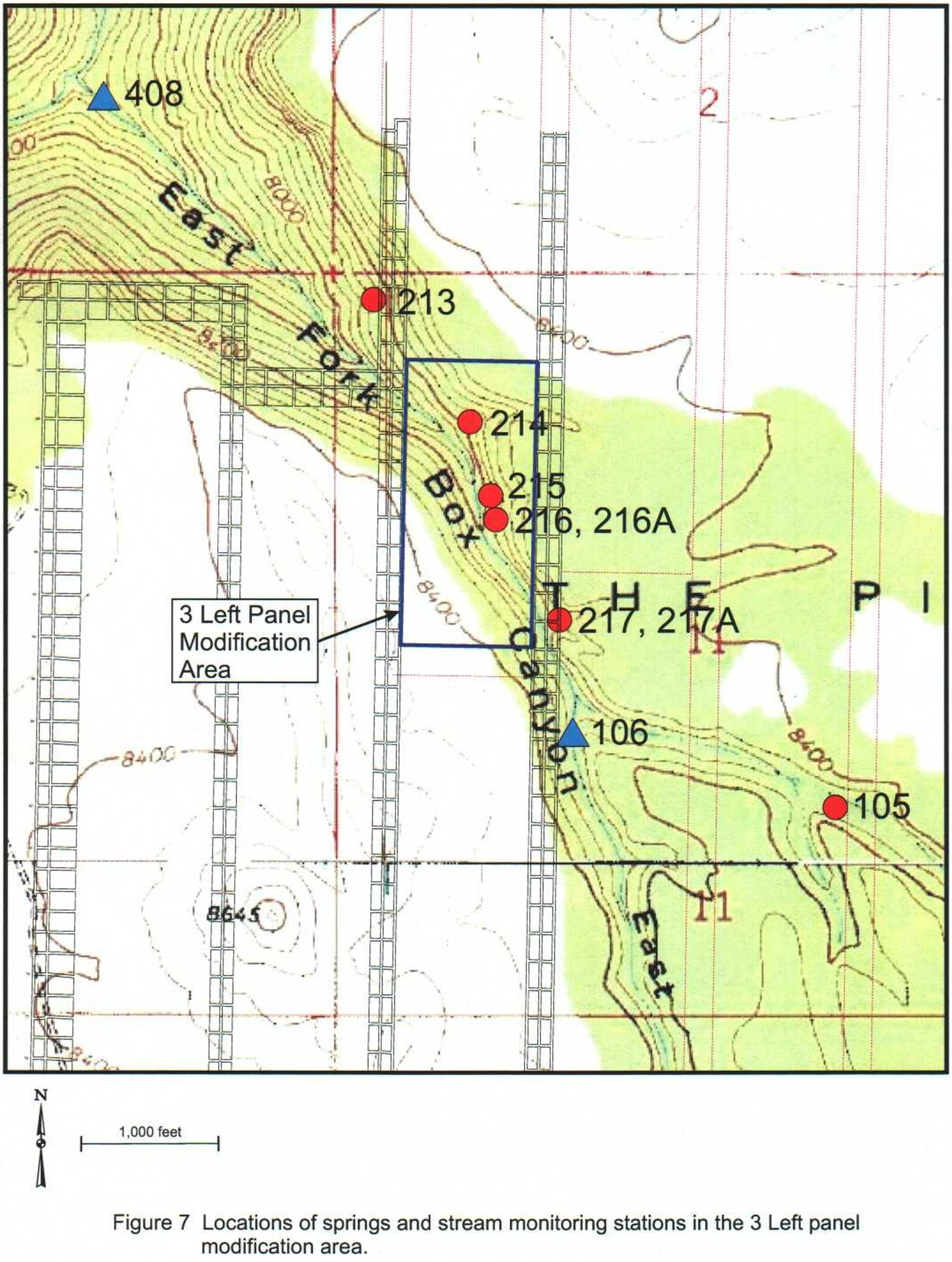


Figure 7 Locations of springs and stream monitoring stations in the 3 Left panel modification area.

Spring Pines 105

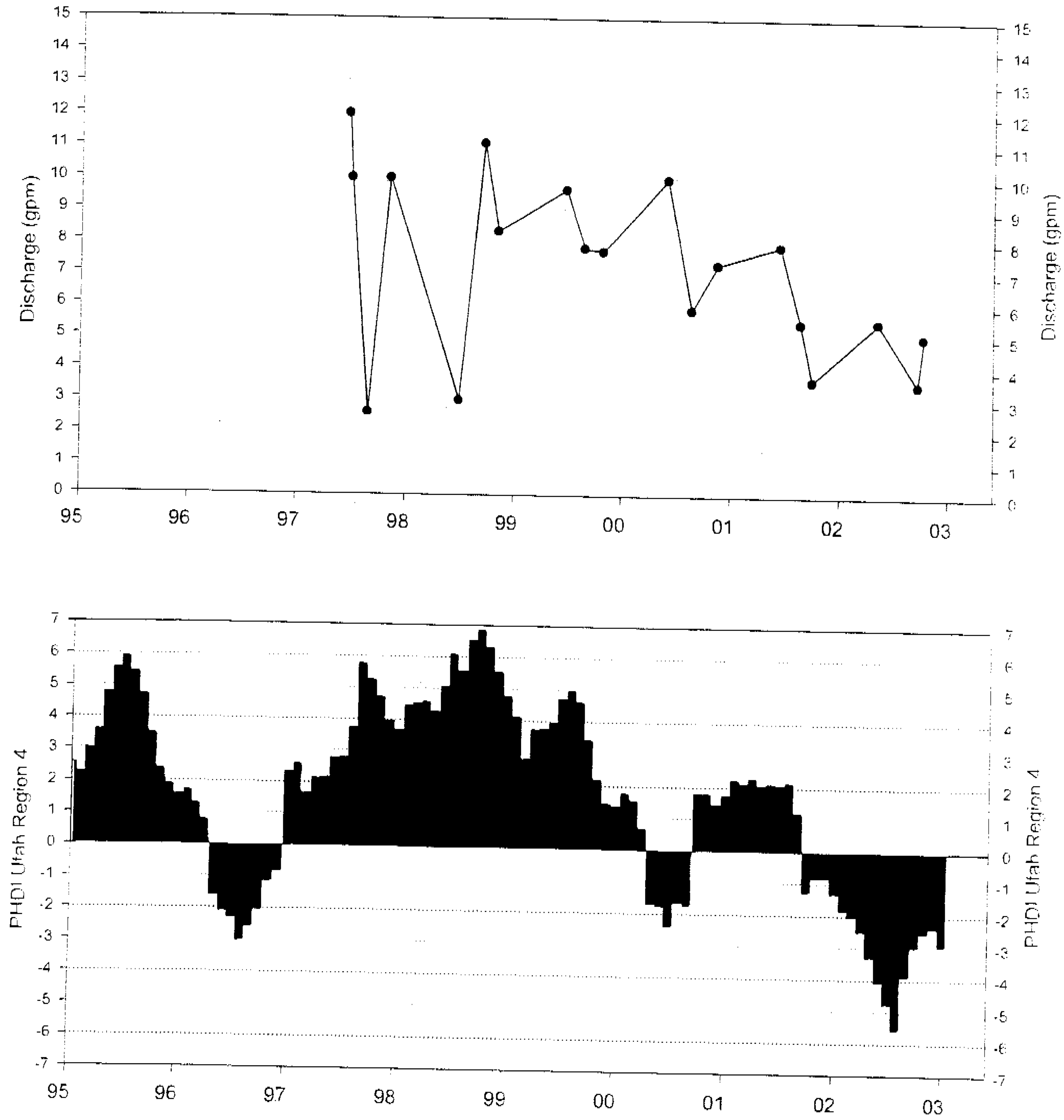


Figure 8a Discharge hydrograph for spring Pines 105 and plot of PHDI for Utah Region 4.

Creek Pines 106

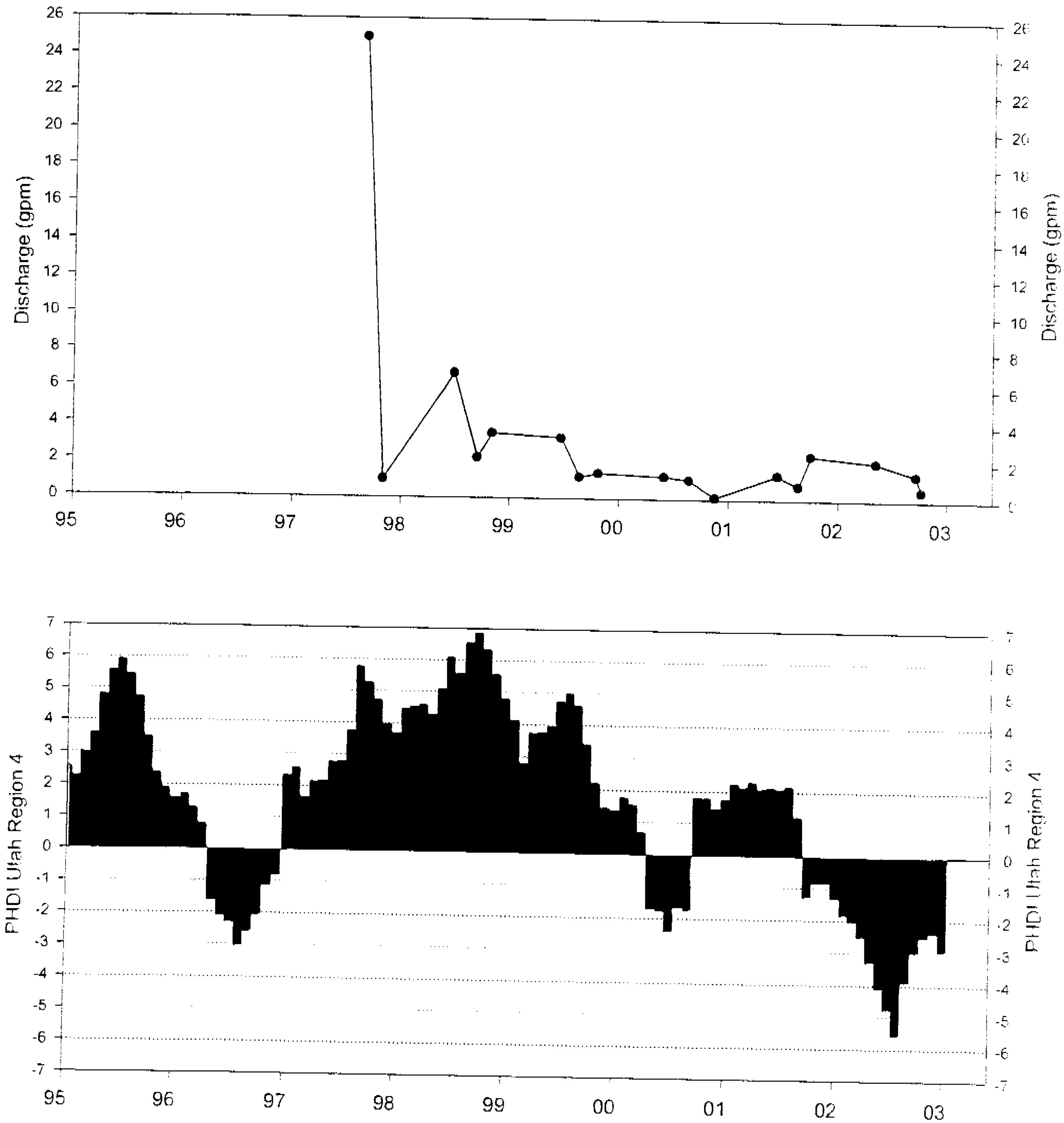
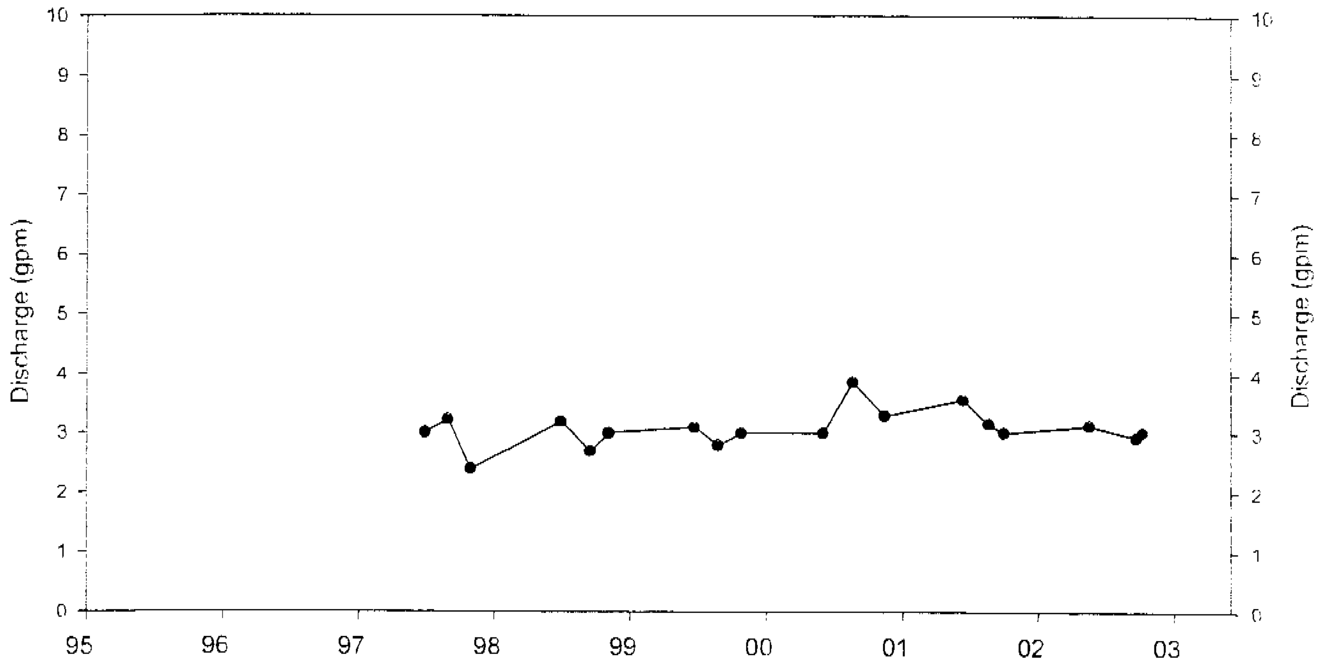


Figure 8b Discharge hydrograph for creek Pines 106 and plot of PHDI for Utah Region 4.

Spring Pines 206



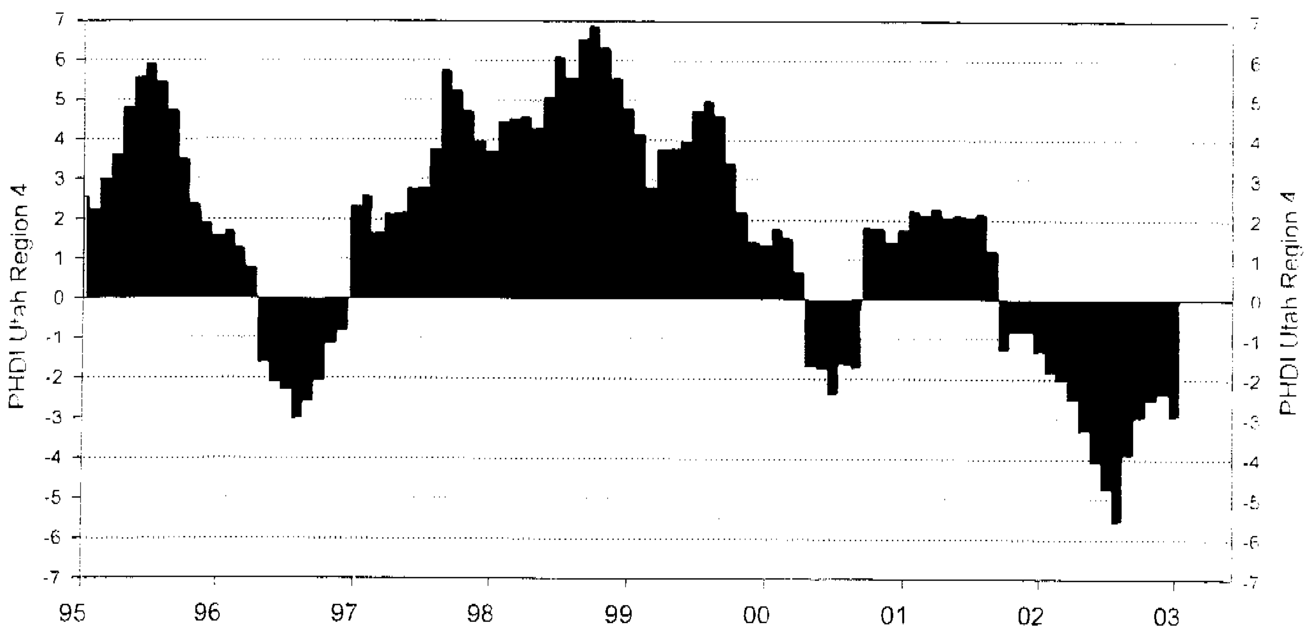
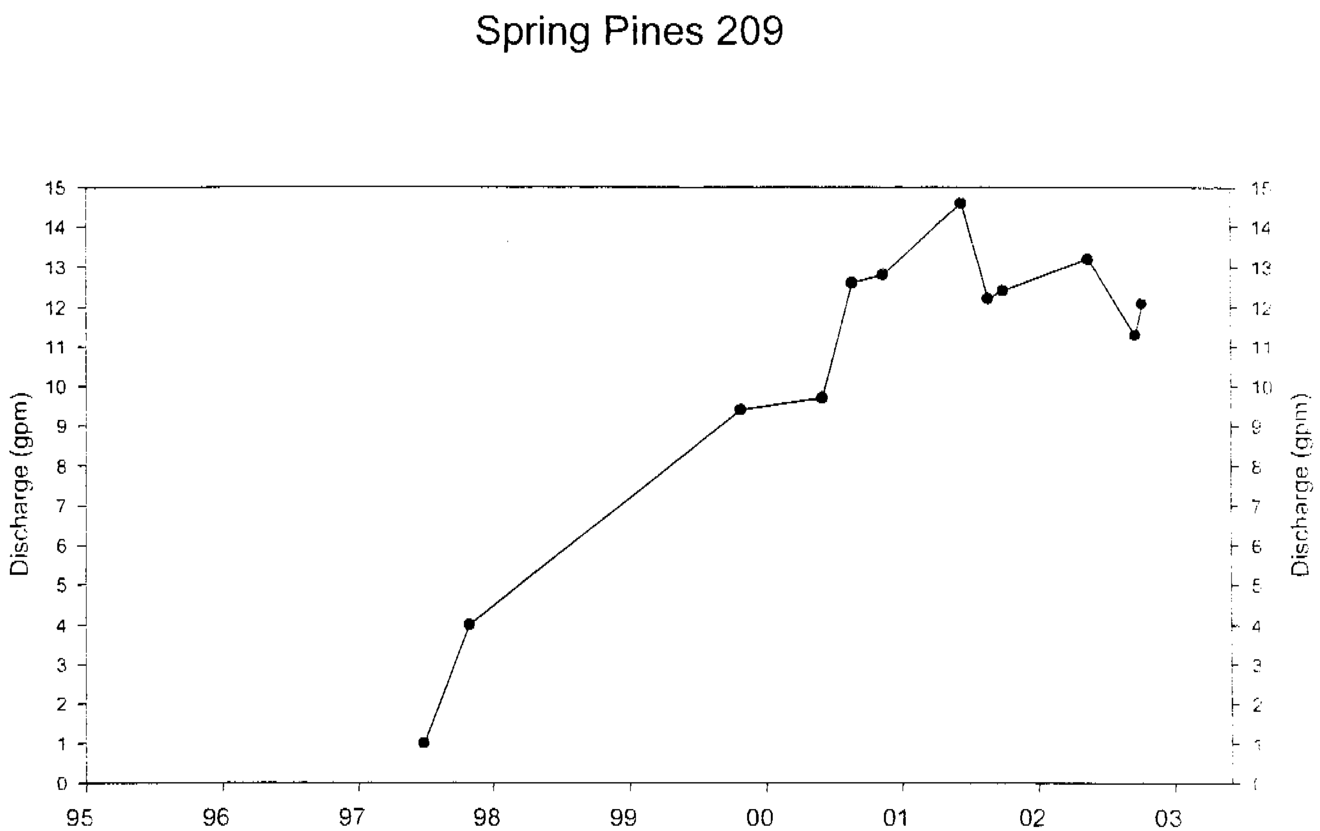


Figure 8c Discharge hydrograph for spring Pines 206 and plot of PHDI for Utah Region 4.



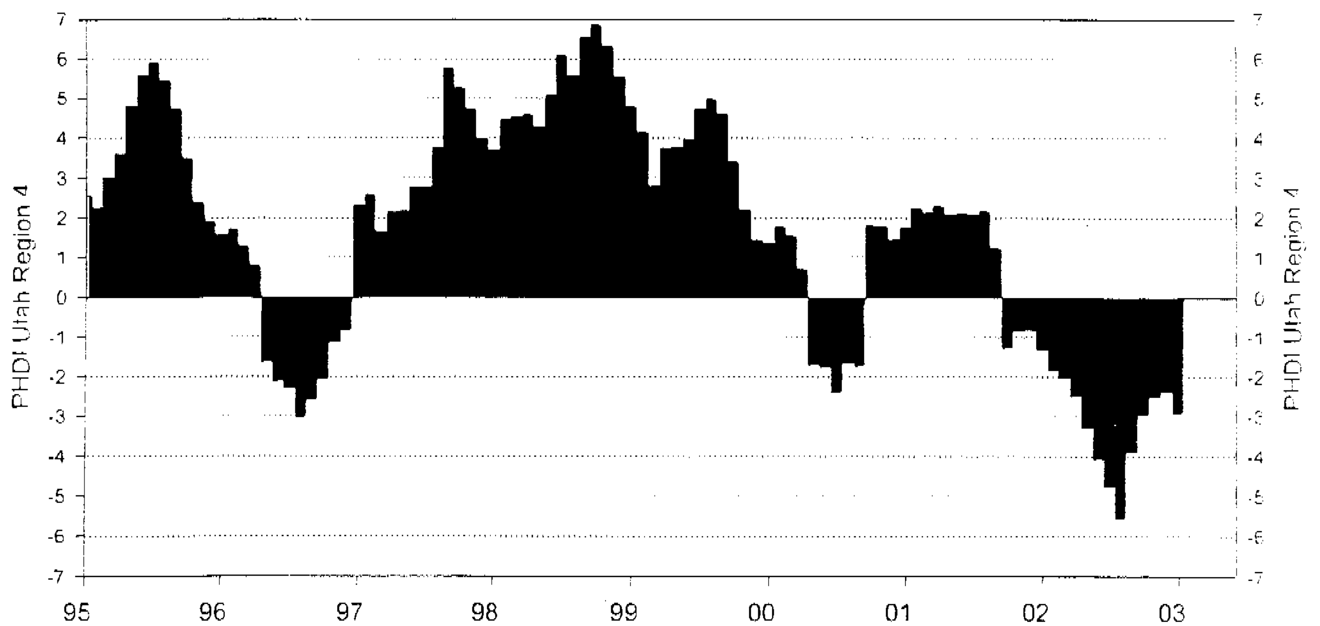


Figure 8d Discharge hydrograph for spring Pines 209 and plot of PHDI for Utah Region 4

Spring Pines 214

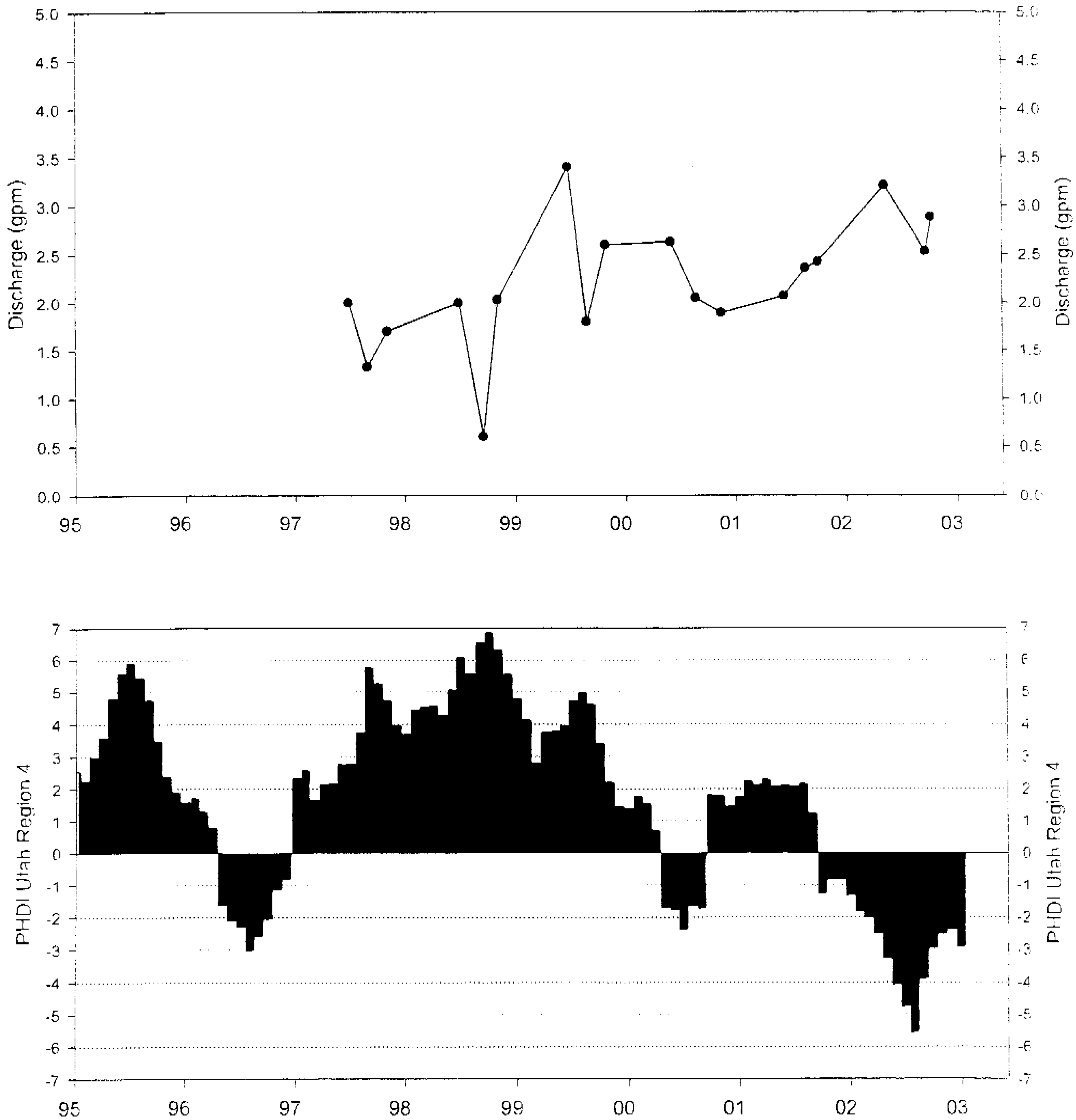


Figure 8e Discharge hydrograph for spring Pines 214 and plot of PHDI for Utah Region 4.

Spring Pines 212

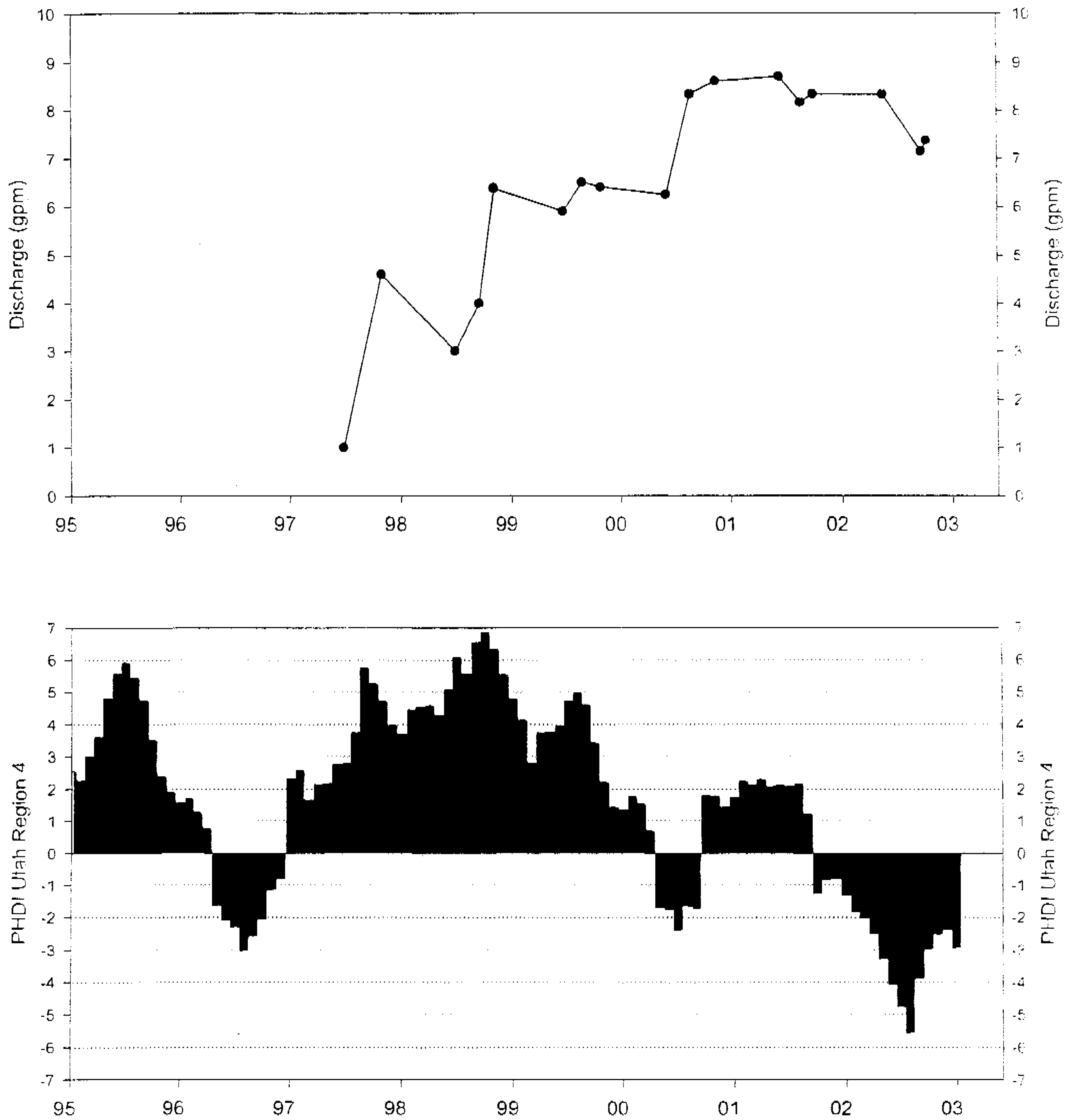
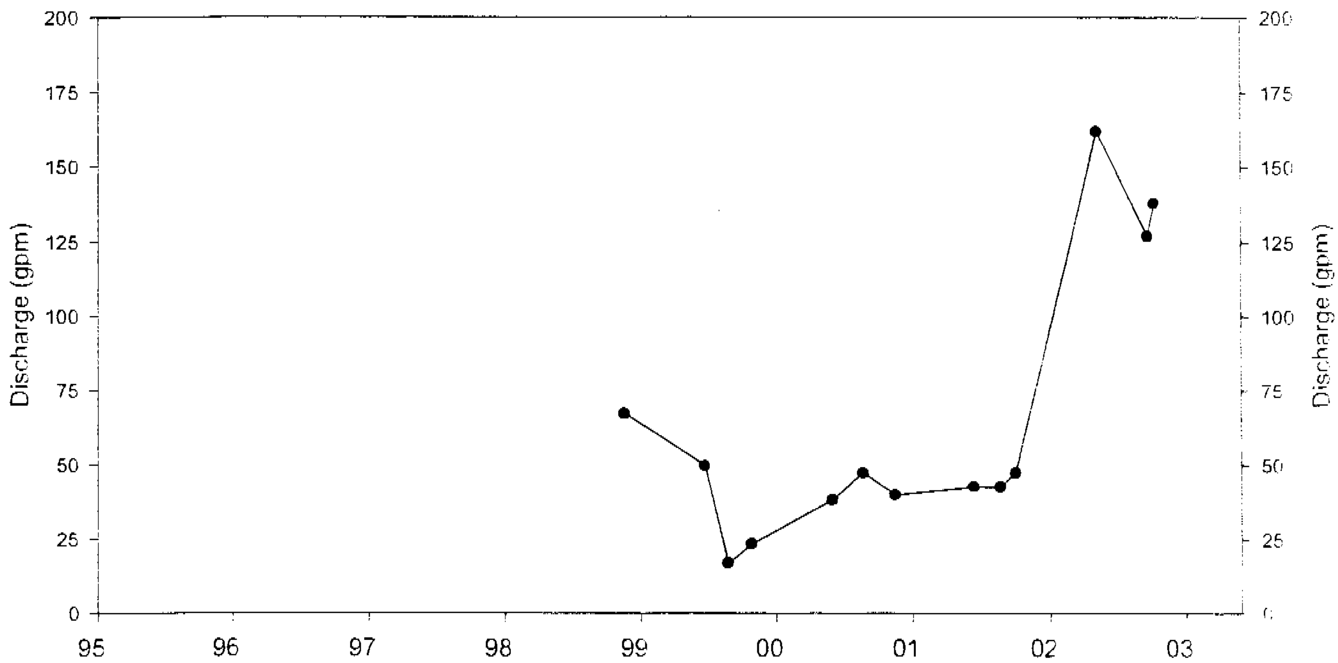


Figure 8f Discharge hydrograph for spring Pines 212 and plot of PHDI for Utah Region 4.

Creek Pines 407



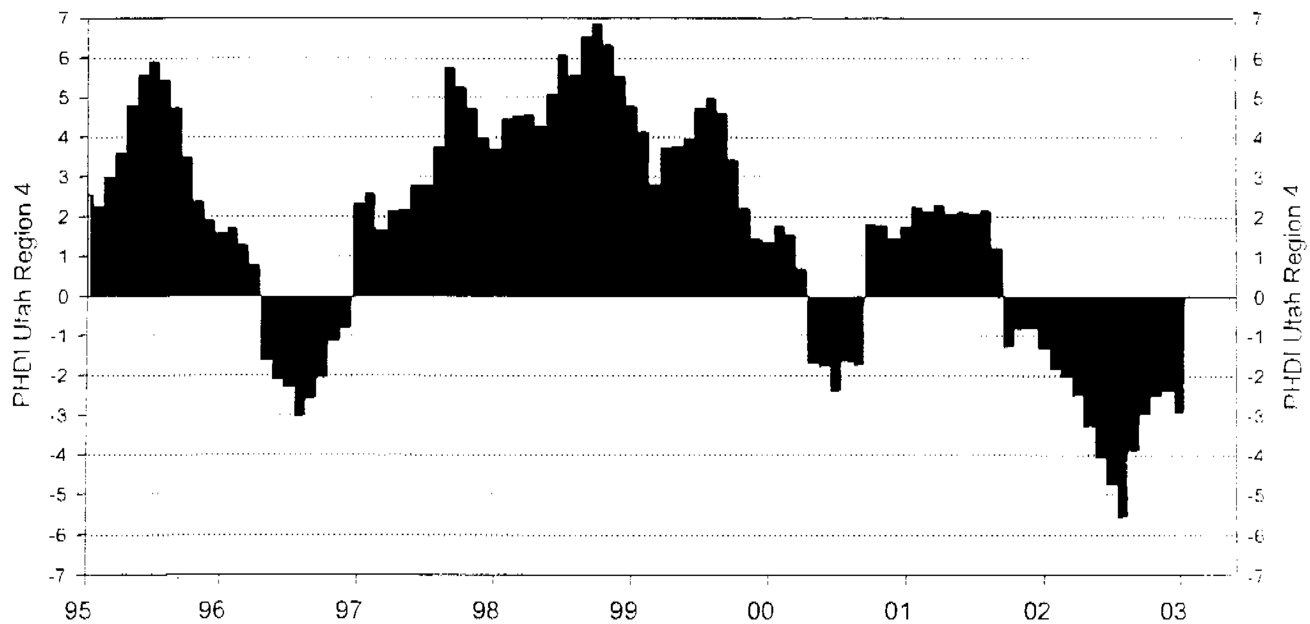
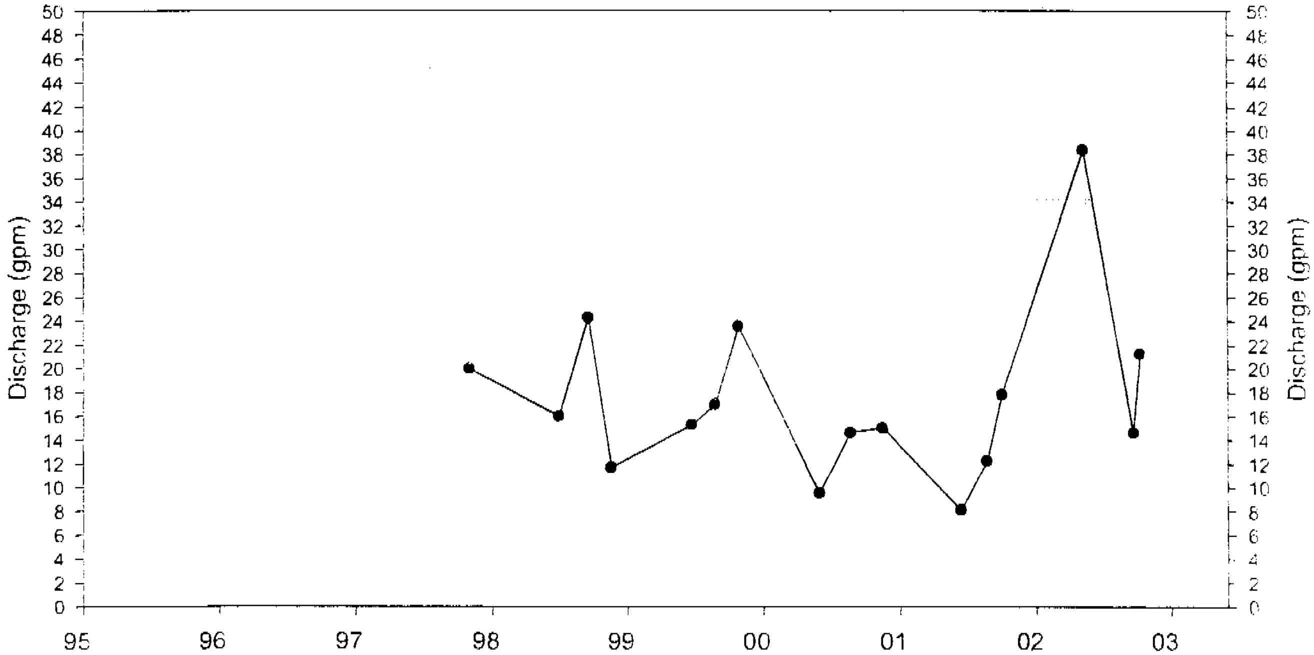


Figure 8g Discharge hydrograph for creek Pines 407 and plot of PHDI for Utah Region 4

Creek Pines 408



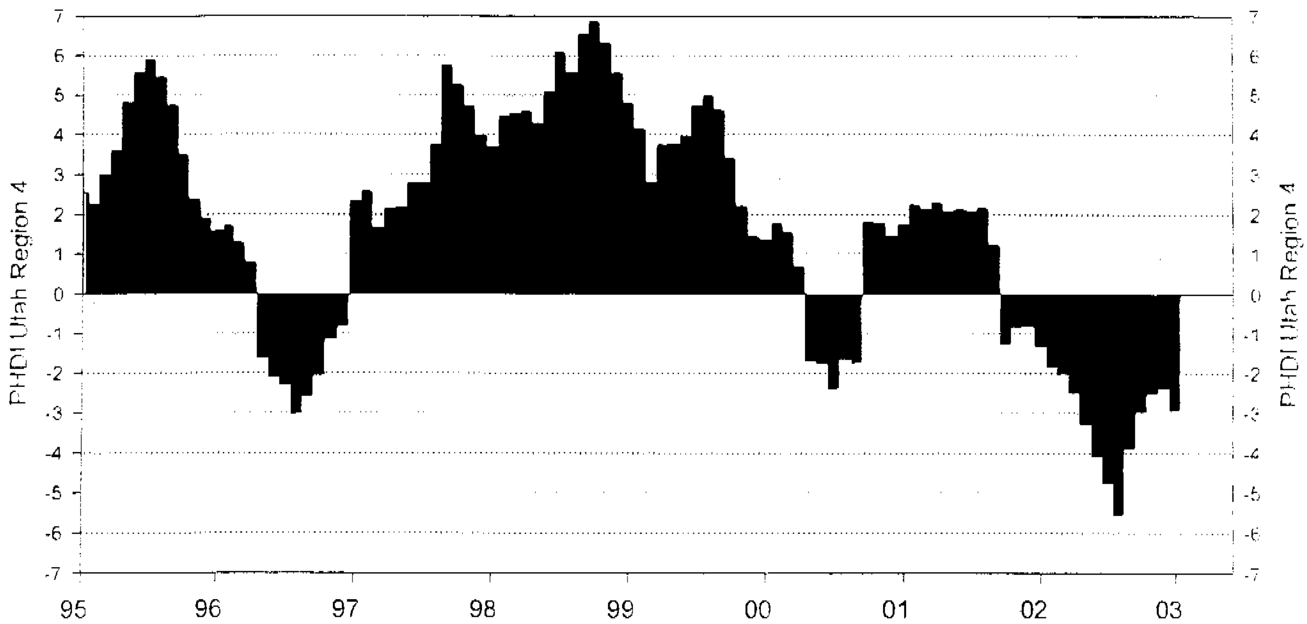


Figure 8h Discharge hydrograph for spring Pines 408 and plot of PHDI for Utah Region 4.

East Fork Box Canyon Creek

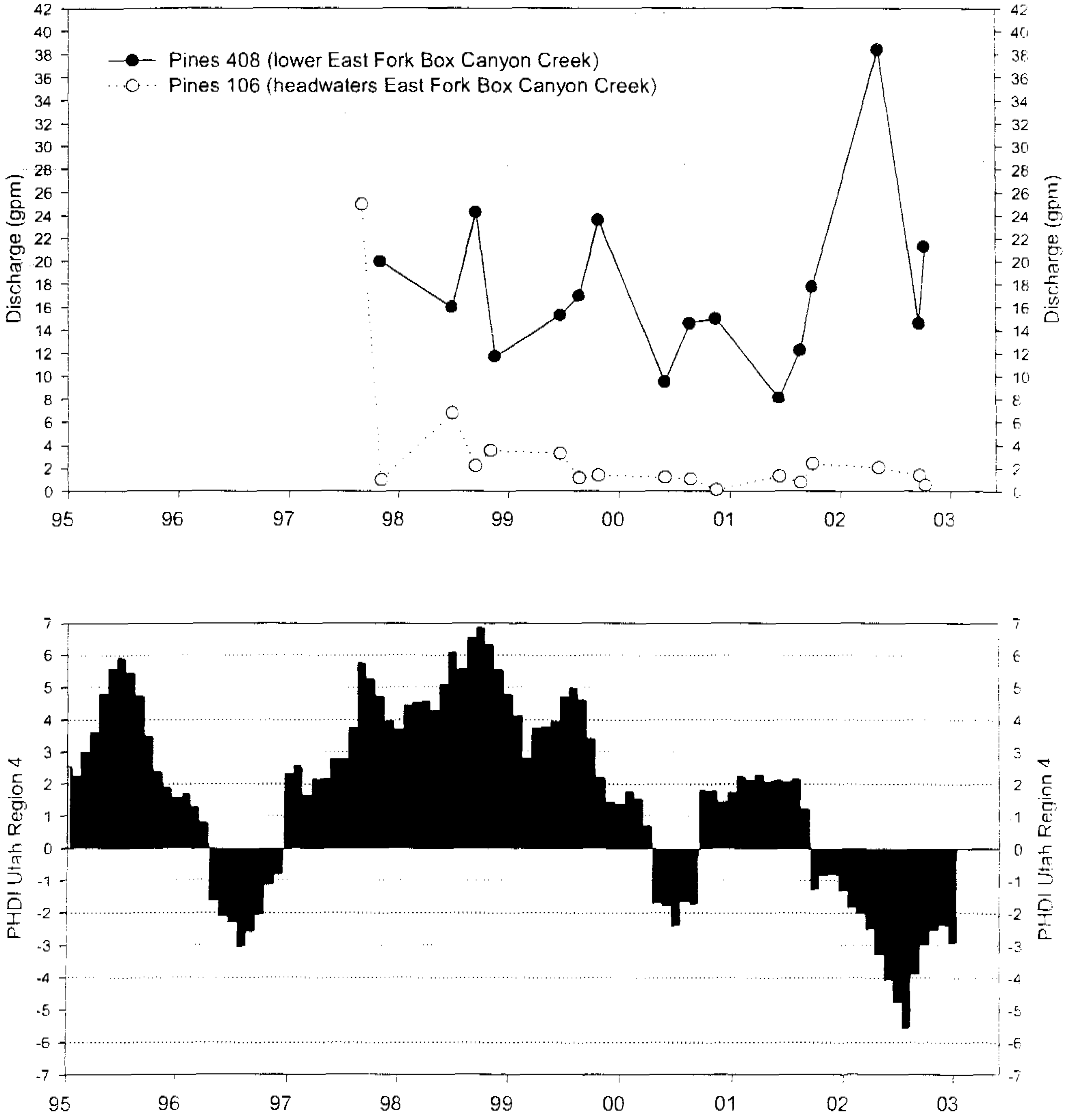


Figure 9 Discharge hydrograph for creeks Pines 106 and Pines 408 and plot of PHDI for Utah Region 4.

Table 1 Discharge and water quality of springs and streams in the East Fork of Box Canyon

Site	Date	Flow gpm	T °C	pH	Cond µS/cm	TDS mg/l	TSS mg/l	Turb NTU	DO mg/l	O&G mg/l	Ca mg/l	Mg mg/l	Na mg/l	K mg/l	HCO_3 mg/l	CO_3 mg/l	SO_4 mg/l	Cl mg/l
SPRINGS																		
Pines 105	6/17/1997	12	7	6.31	252	130					24	5	8	1	94	<5	5	9
Pines 105	6/28/1997	10	5.2	7.1	202	140					25	5	8	1	87	<5	13	8
Pines 105	8/28/1997	2.61	5.5	7.5	306	120		3			23	5	8		92	<5	10	9
Pines 105	11/3/1997	10	5.3	7.5	193	120	28	4.5			22	5	7	<1	88	<5	9	9
Pines 105	6/29/1998	3	6.9	8.35	260	135		62.5			23	5	8	4	100	<5	11	11
Pines 105	9/16/1998	11.1	5.5	7.7	190	157		0.2			23	5	8	<1	98	<5	13	11
Pines 105	11/4/1998	8.33	5	6.7	170													
Pines 105	6/22/1999	9.65	4.4	7.2	193													
Pines 105	8/25/1999	7.8	4.9	6.5	195													
Pines 105	10/27/1999	7.7	3.7	6.75	188													
Pines 105	6/1/2000	10.0	4.4	7.86	148													
Pines 105	8/23/2000	5.88	4.7	7.34	189	117					22	6	9	<1	88	<5.	8	5
Pines 105	11/16/2000	7.3	4.4	7.39	118	137					21	5	7	<1	86	<5.	11	8
Pines 105	6/13/2001	7.89	5.3	6.93	158													
Pines 105	8/22/2001	5.4754	5.4	7.15	180													
Pines 105	10/1/2001	3.66	5.2	6.64	265													
Pines 105	5/9/2002	5.52	4.7	6.77	189													
Pines 105	9/21/2002	3.56	5.5	8.27	197													
Pines 105	10/9/2002	5.06	5.8	7.45	147													
Pines 214	6/27/1997	2	7.4	8.8	350	230					40	13	7	1	188	<5	22	6
Pines 214	8/28/1997	1.33	10	8.2	364	230		2.1			47	16	8		227	<5	14	3
Pines 214	11/3/1997	1.7	0.5	8.1	206	210	13	1			44	15	7	<1	218	<5	17	8
Pines 214	6/29/1998	2	11.1	8.26	290	193		0.8			42	14	8	1	207	<5	17	10
Pines 214	9/16/1998	0.61	12.2	7.8	340	248		2.6			46	15	8	<1	215	<5	19	9
Pines 214	11/4/1998	2.03	-0.1	8.25	280													
Pines 214	6/23/1999	3.4	8	8.4	365													
Pines 214	8/25/1999	1.8	10.5	8.4	385													
Pines 214	10/27/1999	2.6	1.8	8.5	340													
Pines 214	6/1/2000	2.63	11.4	8.3	364													
Pines 214	8/23/2000	2.05	9.6	8.29	372	223	<5		7.8	<2.	45	16	8	<1	216	<5	16	7
Pines 214	11/16/2000	1.89	-0.4	7.82	108	235					47	16	8	<1	216	<5	18	8
Pines 214	6/12/2001	2.07	[illegible]	8.33	351													
Pines 214	8/21/2001	2.3532	11.6	8.57	334													

Flow	T			Cond	TDS	TSS	Turb	DO	O&G	Ca	Mg	Na	K	HCO_3	CO_3	SO_4	Cl	
Site	Date	gpm	°C	pH	µS/cm	mg/l	mg/l	NTU	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
Pines 216A	11/3/1997	1	5.3	8.3	163	170	137	18			30	10	7	<1	141	<5	13	9
Pines 217	6/27/1997	<1	12.4	7.8	334													
Pines 217	11/3/1997	<0.5	1.5	8	150													
Pines 217A	11/3/1997	<0.1	1.2	7.9	172													
CREEKS																		
Pines 106	6/18/1997		8	7.5	411	200					44	14	9	1	177	<5	30	11
Pines 106	8/28/1997	25	18.5	7.9	381	220		3.4			46	16	9		192	<5	27	11
Pines 106	11/3/1997	1	6.3	7.6	420	260	19	4.5	6.3	<2	43	16	8	1	219	<5	39	11
Pines 106	6/29/1998	6.8	23.4	7.55	340	214	14	18	4.7	<2	40	13	9	4	186	<5	31	13
Pines 106	9/16/1998	2.2	20.3	7.4	380	274	10	3.3	6.1	<2	48	17	9	2	204	<5	40	13
Pines 106	11/4/1998	3.53	4.5	6.6	320													
Pines 106	6/22/1999	3.3	11	7.8	413													
Pines 106	8/25/1999	1.2	15.2	6.7	151													
Pines 106	10/27/1999	1.4	3.9	7.5	295													
Pines 106	6/1/2000	1.25	15.1	8.1	404													
Pines 106	8/23/2000	1.09	13.9	7.16	277	241			8.69	<2.	45	18	10	1	213	<5.	30	10
Pines 106	11/16/2000	0.13	-0.3	7.36	296	256	22		10.7	<2.	45	17	9	<1	201	<5.	34	11
Pines 106	6/13/2001	1.36	11.4	7.29	315	248			7.47	<2.	50	19	10	1	206	<5.	39	11
Pines 106	8/21/2001	0.7809	11.5	7.23	490	279			7.68	<2.	48	19	9	1	214	<5.	33	11
Pines 106	10/1/2001	2.42	14	7.11	476	255			6.23	<2.	49	18	10	1	215	<5.	33	10.8
Pines 106	5/9/2002	2.07	15.4	7.77	409	239			6.54	<2	51	18	10	1	214	<5.	35	11
Pines 106	9/21/2002	1.4	16.5	8.24	402	248			6.65		48	19	11	1	211	<5.	31	10
Pines 106	10/9/2002	0.556	12.7	7.84	404	234			6.18	<2	49	18	11	1	206	<5.	35	12
Pines 408	10/29/1997	20																
Pines 408	6/29/1998	16.0	18.8	8.54	390	250	<5	2.9	5.2	<2	47	16	10	2	221	<5	36	14
Pines 408	9/16/1998	24.3	15	8.3	390	290	59	15.5	5.5	<2	52	17	10	1	236	<5	34	13
Pines 408	11/18/1998	11.7	0.4	7.8	300				10.4									
Pines 408	6/23/1999	15.3	16.2	8.2	434													
Pines 408	8/25/1999	17	11.5	8.5	428													
Pines 408	10/27/1999	23.6	0.7	8.4	400													
Pines 408	6/1/2000	9.53	16.3	8.3	405	266	6		6.8	<2	53	17	9	2	213	<5.	29	9
Pines 408	8/22/2000	14.6	16.6	8.41	372	196	447		7.47	<2	45	15	10	2	226	<5.	19	9
Pines 408	11/16/2000	15	0	7.49	392	262	16		11.5	<2	51	17	10	1	222	<5	34	13
Pines 408	6/12/2001	8.1	15.7	8.66	337				8.96									
Pines 408	8/21/2001	12.252	13.2	8.49	420				7.74									
Pines 408	10/1/2001	17.8	10.9	8.22	404				7.11									

Table 2 Radiocarbon ages and tritium contents of groundwater sampled in the SUFCO Mine beneath the Box Canyon area.

	Date	$\delta^{13}C$ (‰)	^{14}C (pmC)	Tritium (TU)	Radiocarbon age (years)
14 Left Setup Room	9/20/2000	-9.9	31.42	0.07	4,000
14 Left E2 XC101	9/20/2000	-10.2	24.45	0.01	6,000

APPENDIX

Isotopic laboratory
Reporting sheets

GEOCHRON LABORATORIES

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t (617) 876-3691 *f* (617) 661-0148 www.geochronlabs.com

RADIOCARBON AGE DETERMINATION — REPORT OF ANALYTICAL WORK

Our Sample No.	**GX-27349**	Date Received:	10/27/2000
Your Reference:	Skyline & SUFCO Mines	Date Reported:	11/08/2000
Submitted by:	Dr. Alan Mayo Mayo & Associates, Inc. 710 East 100 North Lindon, Utah 84042		

Sample Name: **14L E2 XC 102 (lab 1326)**

AGE = **24.45 ± 1.90 % of the modern (1950) ^{14}C years activity.**

Description: Sample of groundwater precipitate.

Pretreatment: The barium salt precipitate was rapidly vacuum filtered and immediately hydrolyzed, under vacuum, to recover carbon dioxide from the barium carbonates for the analysis. ^{13}C analysis was made from a small portion of the same evolved gas.

Comments:

$\delta^{13}C_{PDB}$ = **-10.2 ‰**

Notes: This date is based upon the Libby half life (5570 years) for ^{14}C. The error is +/- 1 s as judged by the analytical data alone. Our modern standard is 95% of the activity of N.B.S. Oxalic Acid.

The age is referenced to the year A.D. 1950.

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RADIOCARBON AGE DETERMINATION — REPORT OF ANALYTICAL WORK

Our Sample No.	**GX-27348-AMS**	Date Received:	10/27/2000
Your Reference:	Skyline & SUFCO Mines	Date Reported:	11/22/2000

Submitted by: Dr. Alan Mayo
Mayo & Associates, Inc.
710 East 100 North
Lindon, Utah 84042

Sample Name: **14L Setup (lab 1327)**

AGE = **31.42 ± 0.13 % of the modern (1950) ^{14}C years activity.**

Description: Sample of groundwater precipitate.

Pretreatment: The barium salt precipitate was rapidly vacuum filtered and immediately hydrolyzed, under vacuum, to recover carbon dioxide from the barium carbonates for the analysis. ^{13}C analysis was made from a small portion of the same evolved gas.

The sample yielded very little carbon and analysis by accelerator mass spectrometry (AMS) was required.

Comments:

$\delta^{13}C_{PDB}$ = **-9.9 ‰**

Notes: This date is based upon the Libby half life (5570 years) for ^{14}C. The error is +/- 1 s as judged by the analytical data alone. Our modern standard is 95% of the activity of N.B.S. Oxalic Acid.

The age is referenced to the year A.D. 1950.

UNIVERSITY OF
Miami
THE ROSENSTIEL SCHOOL

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TRITIUM LABORATORY

Data Release #00-125
Job # 1398

MAYO & ASSOCIATES
TRITIUM SAMPLES

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GENERAL COMMENTS ON TRITIUM RESULTS

Tritium Scale (New)

Tritium concentrations are expressed in TU, where 1 TU indicates a T/H ratio of 10^{-18}. The values refer to the new tritium scale of U.S. National Institute of Science and Technology (formerly NBS), and based on their tritium water standard #4926 as measured on 1961/09/03 and again 1978/09/03, and age-corrected with the new half-life of 12.43 years, i.e., λ = 5.576% $year^{-1}$. In this scale, 1 TU is 7.088 dpm/kg H_2O, or 3.193 pCi/kg H_2O, or 0.1181 Bq/kg H_2O (Bq = disint/sec). TU values are calculated for date of sample collection, REFDATE in the table, as provided by the submitter. If no such date is available, date of sample arrival at our laboratory is used. The stated errors, eTU, are one standard deviation (1 sigma) including all conceivable contributions. In the table, QUANT is quantity of sample received, and ELYS is the amount of water taken for electrolytic enrichment. DIR means direct run (no enrichment).

Through 31 December 1993, we reported tritium values in the "old" scale using the half-life 12.26 years, i.e., λ = 5.65% $year^{-1}$. In that old scale, 1 TU(old) is 7.186 dpm/kg H_2O, 3.237 pCi/kg H_2O. To convert from the new scale back to the old at any given point in time, multiply the listed TU(new)-values by F, where

$$F = 0.9645 - (\text{year}-1990) \times 0.0008$$

i.e. for 1994 the factor is 0.9613. The formula is correct within 0.02% between 1962 and 1999. To convert data from the old scale to the new, divide by F.

Very low tritium values

In some cases, negative TU values are listed. Such numbers can occur because the net tritium count rate is, in principle the difference between the count rate of the sample and that of a tritium-free sample (background count or blank sample). Given a set of "unknown" samples with no tritium, the distribution of net results should become symmetrical around 0 TU. The negative values are reported as such for the benefit of allowing the user unbiased statistical treatment of sets of the data. For other applications, 0 TU should be used.

Reliability of results

Refer to Services Rendered (Tritium), Section II.8, in the "Tritium Laboratory Price Schedule; Procedures and Standards; Advice on Sampling". Tritium efficiencies and background values are different in the nine counters and values are corrected for cosmic intensity, gas pressure and other parameters. For tritium, the efficiency is typically 1.00 cpm per 100 TU (direct counting). At 50x enrichment, the efficiency is equivalent to 1.00 cpm per 2 TU. The background is about 0.3 cpm, known to about ± 0.02 cpm. Our reported results include not only the Poisson statistics, but also other experimental uncertainties such as enrichment error, etc.

References

Mann, W.B., M.P. Unterweger, and B.M. Coursey, Comments on the NBS tritiated-water standards and their use, *Int. J. Appl. Radiat. Isot.*, 33, 383-386, 1982.

Taylor, C.B., and W. Roether, A uniform scale for reporting low-level tritium measurements in water, *Int. J. Appl. Radiat. Isot.*, *33*, 377-382, 1982.

Client: MAYO and ASSOCIATES - SUFCO
Recvd : 00/10/02
Job# : 1398
Final : 00/11/01

Purchase Order: 2000-
Contact: K. Payne 801/796-0211
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Cust	LABEL INFO	JOB.SX	REFDATE	QUANT	ELYS	TU	eTU
MAYO-	14L SETUP	1398.01	000920	1000	210	0.07	0.10
MAYO-	14L E2 XC101	1398.02	000920	1000	227	0.01	0.09

Map(s) is kept with this application located in the Public Information Center of our Salt Lake City office.

PLATE 5-7, UPPER HIAWATHA MINE PLAN 5 YEAR PROJECTION

PLATE 5-10A, POTENTIAL SUBSIDENCE LIMITS QUITCHUPAH TRACT

PLATE 5-10B, POTENTIAL SUBSIDENCE LIMITS PINES TRACT