Trail mtn Act/015/009

APPENDIX 7-D (9)

EXCHANGE OF WATER RIGHTS

STATE OF UTAH
NATURAL RESOURCES
Water Rights

Norman H. Bangerter, Governor
Dee C. Hansen, Executive Director
Robert L. Morgan, State Engineer

1636 West North Temple • Suite 220 • Salt Lake City, UT 84116-3156 • 801-533-6071

March 7, 1986

Trail Mountain Coal Company
P.O. Box 550
Orangeville, UT 84537

Dear Applicant:

RE: APPROVED EXCHANGE APPLICATION
NUMBER 2402 (93-Area)

Enclosed is a copy of approved Exchange Application No. 2402 and the memorandum decision stating the conditions for approval. This is your authority under Section 73-3-20, Utah Code Annotated, as amended, to proceed with the construction work and use as approved.

This approval is effective only as long as you have a legal interest in the underlying water right used as a basis for the exchange and you are meeting the conditions established in approving the exchange. The Utah State Legislature has provided that the State Engineer may require the owner of record to provide such information as may be required to assure that the exchange is taking place as described. Failure to respond to such a request may result in lapsing of this application. Therefore, it is necessary that the Division of Water Rights be informed of any changes in ownership or address.

Sincerely,

Robert L. Morgan, P.E.
State Engineer

RLM:laz

Encl.: Copy of Approved Application
Memorandum Decision

BEFORE THE STATE ENGINEER OF THE STATE OF UTAH

IN THE MATTER OF EXCHANGE APPLICATION NUMBER E2402 (93-AREA)) MEMORANDUM DECISION

Exchange Application No. E2402 (93-AREA) was filed by Trail Mountain Coal Company of P.O. Box 550, Orangeville, Utah 84537 for the right to exchange 17.6 acre-feet of water represented by Stock Certificate #542 of the Cottonwood Creek Consolidated Irrigation Company, indicating the ownership of said company which has direct flow rights on Cottonwood Creek. Stock certificate #542 has been stamped non-transferable by the Cottonwood Creek Consolidated Irrigation Company. It is proposed that in lieu of diverting 17.6 acre-feet from Cottonwood Creek, that this same quantity of water be diverted from a 12-inch diameter well 300-350 feet deep located at a point North 3350 feet & East 1952 feet from the SW Corner, Section 25, T17S, R6E, SLB&M. The water will be used on an annual basis for the domestic requirements of 80 people, dust suppression and other industrial uses in conjunction with the Trail Mountain Coal Mine located within the E1/2 Section 25, T17S, R6E, SLB&M. If this Exchange Application is approved, it will supersede Exchange Application E2137, approved by the State Engineer on August 26, 1983. The application was advertised in the Emery County Progress from December 18, 1985, through January 1, 1986 and was not protested.

It is the opinion of the State Engineer that this exchange may be made providing the provisions of the Cottonwood Creek Exchange Policy of the Utah State Engineer as outlined herein are adhered to.

It is therefore ordered and Exchange Application E2402 (93-AREA) is hereby APPROVED subject to the following stipulations:

1. No more water may be diverted during the use period than is represented by the stock in the Cottonwood Creek Consolidated Irrigation Company, which is the basis for the exchange.

2. Installation of a totalizing meter at the expense of the applicant will be required before any water is diverted. Water meters shall be available to the Cottonwood Creek River Commissioner for examination at all reasonable times.

3. The water being exchanged shall be regulated by the Cottonwood Creek River Commissioner at the expense of the applicant.

4. Continued ownership of the stock certificate which is the basis for the exchange, shall be required in order to maintain this exchange.

5. No change of point of diversion or place of use of the water covered by this exchange shall be made without first obtaining the approval of the State Engineer.

This decision is subject to the provisions of Section 73-3-14, Utah Code Annotated, 1953, which provides for plenary review by the filing of a civil action in the appropriate district court within sixty days from the date hereof.

Dated this 7th day of March, 1986.

Robert L. Morgan, P.E., State Engineer

RLM:MP:laz

Mailed a copy of the foregoing Memorandum Decision this 7th day of March, 1986 to:

Trail Mountain Coal Company
P.O. Box 550
Orangeville, UT 84537

BY: Laurel A. Zundel, Secretary

STATE ENGINEER'S ENDORSEMENT

EXCHANGE APPLICATION NUMBER: E2402   WATER USER'S CLAIM NUMBER: 93 - AREA

1. October 11, 1985   Exchange Application received by MP.

2. October 11, 1985   Priority of Exchange Application.

3. October 16, 1985   Application reviewed and approved for advertising by MP.
   December 18, 1985   Publication began in Emery County Progress.
   February 5, 1986   Publication completed and verified by DL.

4. January 31, 1986   End of protest period.
   Application protested: NO

5. February 11, 1986   Application designated for APPROVAL by MP and SG.

6. Comments:

Conditions:
This application is hereby APPROVED by Memorandum Decision, dated March 7, 1986, subject to prior rights.

Robert L. Morgan, P.E.
State Engineer

APPLICATION FOR EXCHANGE OF WATER

STATE OF UTAH

Rec. by ________
Fee Paid $________
Receipt # ________
Microfilmed ________
Roll # ________

For the purpose of obtaining permission to make an exchange of water in the State of Utah, application is hereby made to the State Engineer, based upon the following showing of facts, submitted in accordance with the requirements of the Laws of Utah. (Sec. 73-3-20, Utah Code Annotated, 1953)

EXCHANGE: E2402 (93-AREA) Priority Date: 10/11/1985

1. **NAME:** Trail Mountain Coal Company PHONE #: 801-748-2140
   ADDRESS: P.O. Box 550, Orangeville, UT 84537

**************************************C U R R E N T   R I G H T**************************************

2. **RIGHT EVIDENCED BY:** Cottonwood Creek Irrigation Co. Cert. No. 542

3. **FLOW:** 17.6 acre-feet
   SOURCE: Cottonwood Creek TRIBUTARY: San Rafael River
   COUNTY: Emery

5. **NATURE OF USE:** **PERIOD OF USE:**
   'THER: Irrigation purposes on Cottonwood Creek. Jan 1 to Dec 31

********************************P R O P O S E D   E X C H A N G E********************************

6. **FLOW:** 17.6 acre-feet PERIOD OF USE: Jan 1 to Dec 31
   SOURCE: Underground water well
   COUNTY: Emery COMMON DESCRIPTION: 8 mi. NW of Orangeville

7. **POINT OF EXCHANGE -- UNDERGROUND:**
   (1) N 3350 ft. E 1952 ft. from SW corner, Section 25, T 17S, R 6E, SLBM
   Diameter of Well: 12 ins. Depth: 300 to 350 ft.

8. **POINT(S) OF RELEASE:**
   FLOW: 17.6 acre-feet PERIOD OF USE: Mar 1 to Nov 30

9. **NATURE OF USE:** **PERIOD OF USE:**
   DOMESTIC: 80 Persons Jan 1 to Dec 31
   INDUSTRIAL: Minig related, dust suppression Jan 1 to Dec 31

PLACE OF USE:

	NORTH-EAST¼ NE NW SW SE		NORTH-WEST¼ NE NW SW SE		SOUTH-WEST¼ NE NW SW SE		SOUTH-EAST¼ NE NW SW SE
Sec 25 T 17S R 6E SLBM	X: X: X: X		: : :		: : :		X: X: X: X

Continued on Next Page

Exchange

EXPLANATORY

This Exchange Application, if approved will replace Exchange Application No. 2137, approved August 26, 1983.
Water currently diverted at Cottonwood Creek Irrigation Company diversion points. Water used on Cottonwood Creek Irrigation Company lands.

****

If applicant is a corporation or other organization, signature must be the name of such corporation or organization by its proper officer, or in the name of the partnership by one of the partners, and the names of the other partners shall be listed. If there is more than one applicant, a power of attorney, authorizing one to act for all should accompany the application.

****

The undersigned hereby acknowledges that even though he/she may have been assisted in the preparation of the above-numbered application through the courtesy of the employees of the State Engineer's Office, all responsibility for the accuracy of the information contained therein, at the time of filing, rests with the applicant(s).

____
Signature of Applicant

FORM 108

Exchange Application No. 2137

93-Area

APPLICATION FOR THE RIGHT OF EXCHANGE OF WATER STATE OF UTAH

SEP 28 198_

RECEIVED

For the purpose of obtaining permission to make an exchange of water, application is hereby made to State Engineer, based upon the following showing of facts submitted in accordance with the requirements of Sec. 73-3-20, Utah Code Annotated, 1953.

1. The name of the applicant is Natomas Trail Mountain Coal Co.
2. The post office address of the applicant is P.O. Box 551 Orangeville, Utah 84537
3. The right to be exchanged was acquired by Cottonwood Creek Consolidated Irrigation Company Certificate No. 542
   (Give application No., certificate No., Decree, stock purchase, or other identification.)
4. The quantity of water is ______ second-feet, or 17.6 acre-feet.
5. The period of use from March *(Month)* 1 *(Day)* to November *(Month)* 30 *(Day)*, inc.
6. The period of storage from ______ *(Month)* ______ *(Day)* to ______ *(Month)* ______ *(Day)*, inc.
7. The direct source of supply is Cottonwood Creek tributary to ______ in Emery county.
8. The point of diversion is* various point on Cottonwood Creek as established by decrees, WUC, etc.
9. The water is, or was, to be used for the following purposes: irrigation purposes on Cottonwood Creek. (as per mark 10/24/80)
   ______, Total ______ acres.
   (Give place of use by legal subdivision of land)

THE FOLLOWING EXCHANGE IS PROPOSED

10. ______ second-feet or 17.6 acre-feet of water represented by the foregoing right will be delivered from March *(Month)* 1 *(Day)* to November *(Month)* 30 *(Day)* incl. of each year, to satisfy other rights, into ______ at a point* various points of diversion on Cottonwood Creek.
11. In exchange for the water delivered and described in par. 10, there will be ______ second-feet or 17.6 acre-feet diverted from January *(Month)* 1 *(Day)* to December *(Month)* 31 *(Day)* incl. of each year from a well ______ *(diameter and depth)* or stream Cottonwood Creek, at a point* N. 600 ft. & W. 1950 ft. from the E¼ Cor. Sec. 25, T17S, R6E, SLB&M.
    (8 miles NW of Orangeville)
12. The water will be used for Industrial purposes, dust suppression, culinary water for 80 people at the Natomas Trail Mountain Coal Mine. (E½ Sec. 25, T17S, R6E, SLB&M).
    ______, Total ______ acres.

NOTE: *The point of diversion, point of return or point of delivery must be located by course and distance or by rectangular distances with reference to some United States land survey corner.*

EXPLANATORY

The following additional facts are set forth in order to define more clearly the full purpose of the proposed application:

Year Round Use - Industrial Uses at a Coal Mine

Signature of Applicant*

*If applicant is a corporation or other organization, signature must be the name of such corporation or organization by its proper officer, or in the name of the partnership by one of the partners, and the names of the other partners shall be listed. If there is more than one applicant, a power of attorney, authorizing one to act for all should accompany the application.

This section is not to be filled in by applicant

STATE ENGINEER'S ENDORSEMENTS

1. 28 ... Application received by mail / over counter in State Engineer's office by
2. Priority of Application brought down to, on account of
3. Application fee, $ ..., received by ... Rec. No. ...
4. Application microfilmed by ..., indexed by ...
5. Application platted by
6. 12-5-82 Application examined by
7. Application returned ..., or corrected by office
8. Corrected Application resubmitted by mail / over counter to State Engineer's Office.
9. 12-...-82 Application approved for advertisement by
10. DEC ... 82 Notice to water users prepared by WW ...
11. DEC ... 82 Publication began; was completed ...
    Notice published in Emery Co. Progress
12. Proof slips checked by
13. ... /83 Application protested by ...
14. 1/20/83 Publisher paid by M.E.V. No. 631206
15. Hearing held by
16. Field examination by
17. 7/1/83 Application designated for approval SG SMP
18. 8/26/83 Application microfilmed and/or photostated by slm
19. 8/26/83 Application approved

THIS APPLICATION IS APPROVED ON THE FOLLOWING CONDITIONS:

By Memorandum Decision dated August 26, 1983.

Earl M. Staker

FOR Dee C. Hansen, P.E., State Engineer

Exchange Application No. 2132

93-Area

APPENDIX 7-D (10)

WELL APPROVAL

FORM 108

Exchange Application No. 2402

93-Area

APPLICATION FOR THE RIGHT OF EXCHANGE OF WATER

STATE OF UTAH

For the purpose of obtaining permission to make an exchange of water, application is hereby made to State Engineer, based upon the following showing of facts submitted in accordance with the requirements of Sec. 73-3-20, Utah Code Annotated, 1953.

1. The name of the applicant is Trail Mountain Coal Company
2. The post office address of the applicant is P.O. Box 550 Orangeville, Utah 84537
3. The right to be exchanged was acquired by Cottonwood Creek Irr. Co. Certificate No. 542 *(Give application No., certificate No., Decree, stock purchase, or other identification.)*
4. The quantity of water is ______ second-feet, or 17.6 acre-feet.
5. The period of use from March 1 *(Month)* *(Day)* to November 30 *(Month)* *(Day)*, inc.
6. The period of storage from ______ *(Month)* *(Day)* to ______ *(Month)* *(Day)*, inc.
7. The direct source of supply is Cottonwood Creek tributary to ______ in Emery county.
8. The point of diversion is* various points on Cottonwood Creek as established by decrees, WUC, etc.
9. The water is, or was, to be used for the following purposes: Irrigation purposes on Cottonwood Creek. ______, Total ______ acres. *(Give place of use by legal subdivision of land)*

THE FOLLOWING EXCHANGE IS PROPOSED

10. ______ second-feet or 17.6 acre-feet of water represented by the foregoing right will be delivered from March 1 *(Month)* *(Day)* to November 30 *(Month)* *(Day)* incl. of each year, to satisfy other rights, into ______ at a point* various points of diversion on Cottonwood Creek
11. In exchange for the water delivered and described in par. 10, there will be ______ second-feet or 17.6 acre-feet diverted from January 1 *(Month)* *(Day)* to December 31 *(Month)* *(Day)* incl., of each year from a well 12-inch diameter, 300-350 ft. *(diameter and depth)* or stream ______, at a point* N.3350 ft. & E. 1952 ft. from SW Cor. Sec. 25, T17S, R6E, SLB&M. (8 miles NW of Orangeville)
12. The water will be used for Industrial purposes, dust suppression, culinary water for 80 people at the Trail Mountain Coal Mine (E½ Sec. 25, T17S, R6E, SLB&M). This exchange application, if approved will replace Exchange Application No. 2137, approved August 26, 1983. Total ______ acres.

NOTE: *The point of diversion, point of return or point of delivery must be located by course and distance or by rectangular distances with reference to some United States land survey corner.*

Num ______
Appl ______

EXPLANATORY

The following additional facts are set forth in order to define more clearly the full purpose of the proposed application:

Signature of Applicant*

*If applicant is a corporation or other organization, signature must be the name of such corporation or organization by its proper officer, or in the name of the partnership by one of the partners, and the names of the other partners shall be listed. If there is more than one applicant, a power of attorney, authorizing one to act for all should accompany the application.

This section is not to be filled in by applicant

STATE ENGINEER'S ENDORSEMENTS

1. Oct 11, 1985 Application received by mail / over counter in State Engineer's office by
2. Priority of Application brought down to, on account of
3. Application fee, $, received by Rec. No.
4. Application microfilmed by , indexed by
5. Application platted by
6. 12-16-85 Application examined by
7. Application returned , or corrected by office
8. Corrected Application resubmitted by mail / over counter to State Engineer's Office.
9. 12-16-85 Application approved for advertisement by
10. Notice to water users prepared by
11. Dec 17, 1985 Publication began; was completed Dec 25, 1985 ... Jan 1, 1986
    Notice published in Emery County Progress
12. Proof slips checked by
13. Application protested by
14. Publisher paid by M.E.V. No.
15. Hearing held by
16. Field examination by
17. 2-11-86 Application designated for approval / rejection
18. Application microfilmed and/or photostated by
19. 3-7-86 Application approved / ~~rejected~~

WATER RIGHTS DATA BASE
ENTERED - DATE 1/1/... BY ...
VERIFIED - DATE 1/1/... BY ...

THIS APPLICATION IS APPROVED ON THE FOLLOWING CONDITIONS:

State Engineer

Exchange Application No. 2462

43-4...

RECEIVED

MAR 13 1986

WATER RIGHTS
PRICE

BEFORE THE STATE ENGINEER OF THE STATE OF UTAH

IN THE MATTER OF EXCHANGE APPLICATION)
) MEMORANDUM DECISION
NUMBER E2402 (93-AREA))

Exchange Application No. E2402 (93-AREA) was filed by Trail Mountain Coal Company of P.O. Box 550, Orangeville, Utah 84537 for the right to exchange 17.6 acre-feet of water represented by Stock Certificate #542 of the Cottonwood Creek Consolidated Irrigation Company, indicating the ownership of said company which has direct flow rights on Cottonwood Creek. Stock certificate #542 has been stamped non-transferable by the Cottonwood Creek Consolidated Irrigation Company. It is proposed that in lieu of diverting 17.6 acre-feet from Cottonwood Creek, that this same quantity of water be diverted from a 12-inch diameter well 300-350 feet deep located at a point North 3350 feet & East 1952 feet from the SW Corner, Section 25, T17S, R6E, SLB&M. The water will be used on an annual basis for the domestic requirements of 80 people, dust suppression and other industrial uses in conjunction with the Trail Mountain Coal Mine located within the E1/2 Section 25, T17S, R6E, SLB&M. If this Exchange Application is approved, it will supersede Exchange Application E2137, approved by the State Engineer on August 26, 1983. The application was advertised in the Emery County Progress from December 18, 1985, through January 1, 1986 and was not protested.

It is the opinion of the State Engineer that this exchange may be made providing the provisions of the Cottonwood Creek Exchange Policy of the Utah State Engineer as outlined herein are adhered to.

It is therefore ordered and Exchange Application E2402 (93-AREA) is hereby APPROVED subject to the following stipulations:

1. No more water may be diverted during the use period than is represented by the stock in the Cottonwood Creek Consolidated Irrigation Company, which is the basis for the exchange.

2. Installation of a totalizing meter at the expense of the applicant will be required before any water is diverted. Water meters shall be available to the Cottonwood Creek River Commissioner for examination at all reasonable times.

3. The water being exchanged shall be regulated by the Cottonwood Creek River Commissioner at the expense of the applicant.

4. Continued ownership of the stock certificate which is the basis for the exchange, shall be required in order to maintain this exchange.

5. No change of point of diversion or place of use of the water covered by this exchange shall be made without first obtaining the approval of the State Engineer.

This decision is subject to the provisions of Section 73-3-14, Utah Code Annotated, 1953, which provides for plenary review by the filing of a civil action in the appropriate district court within sixty days from the date hereof.

Dated this 7th day of March, 1986.

Robert L. Morgan
Robert L. Morgan, P.E., State Engineer

RLM:MP:laz

Mailed a copy of the foregoing Memorandum Decision this 7th day of March, 1986 to:

Trail Mountain Coal Company
P.O. Box 550
Orangeville, UT 84537

BY: Laurel A. Zundel
Laurel A. Zundel, Secretary

COTTONWOOD CREEK CONSOLIDATED

IRRIGATION COMPANY

Orangeville, Utah 84537

January 8, 1982

Natomas Trail Mountain Coal Co.
Box 551
Orangeville, Utah 84537

Attn: Andrew King

Dear Sir;

The records of the Cottonwood Creek Consolidated Irrigation Company have Trail Mountain Coal Company as owning 20 shares of the primary stock of the Irrigation Company. The yield of this stock on an average year would be .88 of an acre foot of water per share. However, this is an average which was established before the Joe's Valley Dam was built and since that time it is a rare year that the yield is below 1.00 acre foot per share.

Respectfully,

John L. Jorgensen

John L. Jorgensen
Secretary.

1982 JAN
RECEIVED
Natomas Trail
Mountain Coal

Diamond Shamrock
Coal Company

RECEIVED
OCT 24 1985

October 22, 1985

Mark Page
State Engineer
Division of Water Rights
P. O. Box 718
Price, Utah 84501

RE: Drilling of an Observation Well at Trail Mountain Mine Site

Dear Mark;

I am writing at this time, to request of you and the State Engineer, approval to drill an observation well at a location within the following legal description:

> The following described land situated in Emery County, State of Utah; beginning at the southwest corner of the northwest quarter of the southeast quarter of Section 25, Township 17 south, Range 6 east, SLB&M, thence north 160 rods; thence east 44 rods, more or less to the center line of Cottonwood Creek, thence in a southerly direction along the center line of said Cottonwood Creek to a point 76 rods, more or less, east of beginning; thence west 76 rods, more or less, to the point of beginning.

The above legal description is on fee property owned by the Trail Mountain Coal Company. (see enclosure)

The primary objectives of this observation well and others by the United States Geological Survey and the Division of Oil, Gas and Mining are to determine aquifer characteristics, hydraulic connection between aquifers and with streams, recharge and discharge relationships and the effects of underground mining on the ground water system.

The above mentioned well will have a total depth of approximately 300 feet. The top 60 feet will be 9 7/8 inch diameter and will be cased with 8 7/8 inch metal casing and will have a concrete grouted seal. Under the casing will be a 7 7/8 inch diameter hole for a depth of approximately 240 feet.

Trail Mountain Coal Company A Subsidiary of Diamond Shamrock
P.O. Box 370, Orangeville, Utah 84537-0370 Phone: 801 748-2140

This well will be drilled by Mr. Alan Tracy, who is a licenced driller with experience in this area. This well will be drilled pursuant to section 13 of the State of Utah regulations for water well drillers.

Because of weather and budgeting constraints, we would desire to drill this well as soon as possible. Your response and consideration in this matter is greatly appreciated.

Should you need additional information or have further questions, please feel free to contact me at 748-2140.

Sincerely;

TRAIL MOUNTAIN COAL COMPANY

Allen Childs

Allen P. Childs
Engineer

APC/gg

At the request of this office, Allen Childs called on October 30, 1985 with the following information:

The location of the test well is:
N. 3350 ft. & E. 1952 ft. from the SW Cor. Sec. 25, T17S, R6E, SLB&M.

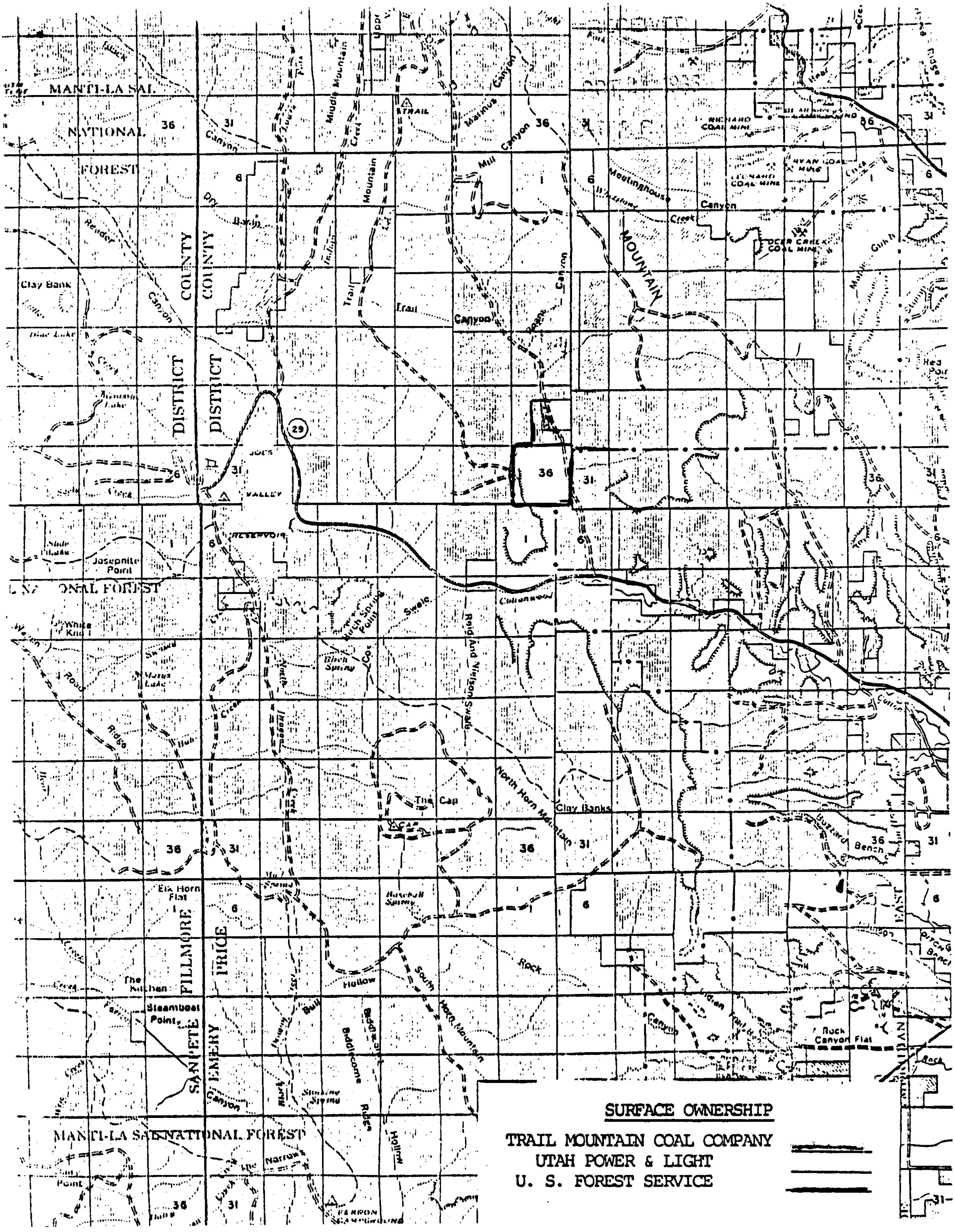
Mark Page

Attn: Kent Jones

The applicant has an exchange application in process to cover this test hole if it is productive. They are using Alan Tracy to drill the well. He is on site doing some core work. I feel like we should approve this request.

If you have any questions give me a call

Thanks Mark


MANTI-LA SAL
NATIONAL
FOREST
COUNTY
COUNTY
DISTRICT
DISTRICT
Clay Bank
Mill Canyon
Trail Canyon
Trail
Middle Mountain
Mountain
Magnus Canyon
Canyon
MOUNTAIN
RICHARD COAL MINE
RYAN COAL MINE
LEONARD COAL MINE
DEER CREEK COAL MINE
Canyon
Creek
Red Point
29
JOES VALLEY
RESERVOIR
Josephite Point
NATIONAL FOREST
Cottonwood
White Knoll
Swale
Reid And Nielson Swale
North Horn Mountain
Clay Banks
The Cap
Buzzard Bench
Elk Horn Flat
FILLMORE
PRICE
The Kitchen
Steamboat Point
SANPETE
EMERY
Rock
Hollow
South Horn Mountain
Canyon
Rock Canyon Flat
EAST
MANTI-LA SAL NATIONAL FOREST
The Narrows
FERRON CAMPGROUND
36
31
6
1
SURFACE OWNERSHIP
TRAIL MOUNTAIN COAL COMPANY
UTAH POWER & LIGHT
U. S. FOREST SERVICE

APPENDIX 7-D (11)

ANALYTICAL COMPARISON OF SPRING TM-23 and UNDERGROUND LOCATION UG-1**

**Ch 7 Rev. 1-11-87

TM23-1 1986 SPRING ANALYSIS

TM23-1 1986	FEB	MARCH	APRIL	MAY	JUNE	MIN	MAX	AVE.
ACIDITY <	1	1	1	1	1	1	1	1
ALKALINITY,TOTAL	297	296	288	286	285	285	297	290.4
ALKALINITY,BICARBONATE	362	361	351	350	348	348	362	354.4
ALKALINITY,CARBONATE <	1	1	1	1	1	1	1	1
CLORIDE	13	13	12	14	12	12	14	12.8
CONDUCTIVITY *	700	790	700	700	700	700	790	718
FLUORIDE	0.18	0.14	0.14	0.12	0.15	0.12	0.18	0.146
NITROGEN,NITRATE	0.2	0.22	0.25	0.25	0.44	0.2	0.44	0.272
OIL & GREASE <	0.5	0.5	0.5	1.2	0.5	0.5	1.2	0.64
PH **	7	7.1	7.15	7.8	7.7	7	7.8	7.35
PHOSPHORUS,ORTHO	0.03	0.06	0.05	0.02	0.07	0.02	0.07	0.046
PHOSPHORUS,TOTAL	0.03	0.06	0.06	0.04	0.08	0.03	0.08	0.054
S,TD	367	365	388	391	359	359	391	374
S,TS	1	0.05	5.5	5	0.5	0.05	5.5	2.41
SULFATE	75	75	80	75	75	75	80	76
TURBIDITY ***	2	0.6	2	2	1.1	0.6	2	1.54
CATION,TOTAL****	7.93	7.89	7.79	7.74	7.56	7.56	7.93	7.782
ANION,TOTAL ****	7.88	7.86	7.77	7.69	7.6	7.6	7.88	7.76
ALUMINUM <	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
ARSENIC <	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
BARUIM <	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
BORON	0.15	0.12	0.13	0.1	0.17	0.1	0.17	0.134
CADMIUM <	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005
CALCIUM	70	72	68	70	68	68	72	69.6
CHROMIUM <	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
COPPER <	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
IRON	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
LEAD <	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
MAGNESIUM	44	43	44	43	42	42	44	43.2
MANGANESE <	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
MERCURY <	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
NICKEL <	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
POTASIUM	2	2	2	2	2	2	2	2
SELENIUM <	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005
SODIUM	18	17	17	16	16	16	18	16.8
VANADIUM <	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
ZINC <	0.005	0.005	0.005	0.005	0.16	0.005	0.16	0.036
* UMHOS/CM								
** UNITS								
*** NTU								
**** MEG/1								
< LESS THAN %								

UG-1 1986 ANALYSIS

TM23-1 1986	JAN	FEB	MARCH	APRIL	MAY	JUNE	MIN	MAX	AVE
ACIDITY <	1	1	1	1	1	1	1	1	1
ALKALINITY,TOTAL	258	250	260	247	242	239	239	260	249.3
ALKALINITY,BICARBONATE	290	305	317	301	295	292	290	317	300
ALKALINITY,CARBONATE <	1	1	1	1	1	1	1	1	1
CLORIDE	3	4	3	3	4	4	3	4	3.5
CONDUCTIVITY *	500	510	480	483	487	455	455	510	485.8
FLUORIDE	0.4	0.49	0.51	0.49	0.51	0.53	0.4	0.53	0.488
NITROGEN,NITRATE	0.2	0.38	0.11	1.9	0.36	1.63	0.11	1.9	0.763
OIL & GREASE <	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
PH **	7.75	7.3	7.8	7.8	7.25	7.95	7.25	7.95	7.642
PHOSPHORUS,ORTHO	0.04	0.03	0.04	0.05	0.08	0.06	0.03	0.08	0.05
PHOSPHORUS,TOTAL	0.04	0.03	0.04	0.06	0.12	0.06	0.03	0.12	0.058
S,TD	241	238	257	279	279	264	238	279	259.7
S,TS	4	7	16	2	2	10	2	16	6.833
SULFATE	3	4	6	7	15	4	3	15	6.5
TURBIDITY ***	30	3	11	1	1	8	1	30	9
CATION,TOTAL****	5.3	5.3	5.43	5.35	5.31	5.39	5.3	5.43	5.347
ANION,TOTAL ****	5.32	5.24	5.42	5.18	5.27	4.98	4.98	5.42	5.235
ALUMINUM <	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
ARSENIC <	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
BARUIM	1.21	0.98	0.96	0.86	1.28	1.5	0.86	1.5	1.132
BORON	0.27	0.06	0.22	0.24	0.28	0.24	0.06	0.28	0.218
CADMIUM <	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005
CALCIUM	30	30	28	28	28	28	28	30	28.67
CHROMIUM <	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
COPPER <	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
IRON	0.13	0.16	0.1	0.12	0.24	0.4	0.1	0.4	0.192
LEAD <	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
MAGNESIUM	13	13	16	16	16	14	13	16	14.67
MANGANESE <	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
MERCURY <	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
NICKEL <	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
POTASIUM	7	7	8	7	7	8	7	8	7.333
SELENIUM <	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005
SODIUM	58	58	58	57	56	60	56	60	57.83
VANADIUM <	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
ZINC <	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005
* UMHOS/CM									
** UNITS									
*** NTU									
**** MEG/1									
< LESS THAN %									

APPENDIX 7-D (12)*

FIELD MEASUREMENTS

*Ch 7 Rev. 1-11-87

SURFACE WATER SW-1

I.D. NO.	DATE	TEMP. (C)	P.H.	COND(UMHOS)	FLOW (CFS)
6561	1/18/85	4º	7.3	370	9.8
6714	3/3/85	4º	7	360	12.8
6762	3/28/85	5º	8	325	9.8
6937	5/1/85	12º	8.2	395	*OVERFLOW
7028	5/30/85	8º	8.1	340	*OVERFLOW
7189	6/26/85	15º	7.2	390	*OVERFLOW
7234	7/10/85	10º	8.3	470	12.8
7414	8/30/85	17º	8.1	410	9.2
7513	9/26/85	6º	8	360	9.8
7633	10/31/85	5º	7.7	390	9.2
7741	12/26/85	-1º	8.1	340	9.2
7801	1/27/86	0º	8.1	370	9
7872	2/28/76	7º	8.2	435	9.8
7912	3/13/86	1.5º	8	420	9.8
7963	4/7/86	7.5º	7.8	450	9
8035	5/5/86	3.0º	7.1	305	12.2
8272	6/30/86	15º	7.8	420	11
8433	7/30/86	14º	7.8	390	8
	8/29/86	15º	7.8	410	12
8572	9/29/86	9.1º	7.9	360	9.8
	10/20/86	6.2º	8.8	301	8
	11/11/86	4.1º	8.1	326	8

* OVERFLOW AT WIER +13 CFS

SURFACE WATER SW-2

I.D. NO.	DATE	TEMP. (C)	P.H.	COND(UMHOS)	FLOW (CFS)
6562	1/18/85	6º	7	360	9.8
6715	3/5/85	4º	7.3	370	12.8
6763	3/28/85	4º	7.6	315	9.8
6938	5/1/85	8º	8.1	405	OVERFLOW
7029	5/30/85	8º	7.8	330	OVERFLOW
7190	6/26/85	13º	7.8	410	OVERLFOW
7235	7/10/85	10º	8.4	470	12.8
7415	8/30/85	17º	7.8	410	9.2
7514	9/26/85	6º	7.9	360	9.8
7634	10/31/85	3º	7.8	370	9.2
7742	12/26/85	0º	7.9	330	9.2
7802	1/27/86	-1º	8	360	9
7873	2/28/86	6.5º	7.7	420	9.8
7913	3/13/86	2º	7.5	410	9.8
7964	4/7/86	5.5º	7.8	420	9
8036	5/5/86	3º	7.2	305	12.2
8273	6/30/86	5º	7.8	380	11
8434	7/30/86	19º	8.8	435	8
	8/29/86	15º	7.8	420	12
	9/29/86	10º	6.5	342	9.8
	10/20/86	5.8º	8.5	379	8
	11/11/86	3.5º	8.2	325	8

SURFACE WATER SW-3

I.D. NO.	DATE	TEMP. (C)	P.H.	COND(UMHOS)	FLOW (CFS)
6563	1/18/85	6º	7	360	9.8
6716	3/5/85	4º	7.1	360	12.8
6764	3/28/85	7º	7.2	325	9.8
6938	5/1/85	10º	8.4	425	OVERFLOW
7030	5/30/85	10º	7.2	345	OVERFLOW
7191	6/26/85	13º	8.1	410	OVERFLOW
7236	7/10/85	10º	8	460	12.8
7416	8/30/85	18º	7.6	420	9.2
7515	9/26/85	8º	7.7	360	9.8
7635	10/31/85	5º	7.9	380	9.2
7743	12/26/85	1º	7.6	330	9.2
7803	1/27/86	2º	7.7	355	9
7874	2/28/86	6.5º	7.1	420	9.8
7914	3/13/86	2º	7	415	9.8
7965	4/7/86	6º	7.7	390	9
8037	5/5/86	2º	7.1	300	12
8274	6/30/86	15º	7.7	420	11
8435	7/30/86	19º	8.8	405	8
	8/29/86	15º	7.6	410	12
8574	9/29/86	10.8º	8.5	354	9.8
	10/20/86	6.7	8.9	358	8
	11/11/86	2.8º	8.2	313	8

WELLS TM-1

I.D. NO.	DATE	TEMP. (C)	P.H.	COND(UMHOS)	FLOW (GPM)	LEVEL (FT)
	07-02-85		8.35	1700	.5*	
7232	07-10-85		8.4	1700	.5*	
7640	10-31-85		8.2	1550	.5*	
	03-13-86		8.4	1470	.5*	
	04-08-86		8.56	1200		25.6
	06-30-86		7.9	1600		21.3
	08-29-86	13	7.8	1352		18.1
	09-29-86	12.8	6.6	1325		16.8
	10-16-86	12	8.87	1295		16.4

* Artesian

WELLS TM-2

I.D. NO.	DATE	TEMP. (C)	P.H.	COND(UMHOS)	FLOW (GPM)	LEVEL(FT)
	10-24-85		7.5	550		16.5
7641	10-31-85		NO FIELD	MEASUREMENTS		
	01-29-86		7.6	600		16.8
	03-28-86		7.15	610		15.5
	08-29-86	12.6	7.6	570		17.2
	09-29-86	12.6	6.8	561		17.1
	10-16-86	9.8	8.26	610		17.1

UNDERGROUND (IN-MINE)

I.D. NO.	DATE	TEMP. (C)	P.H.	COND(UMHOS)	FLOW (GPM)	LEVEL
6560	01-18-85		NO MEASUREMENTS			
	10-23-85		7.8	440	0.08	
	01-29-86		7.75	500		
	04-08-86		7.8	483		
	06-30-86		7.95	455		
	08-29-86	12.8	7.9	475	0.04	
	09-29-86	12.1	5.8	463	0.02	
	10-16-86	9.7	8.05	465	0.01	

SPRINGS TM 23

I.D. NO.	DATE	TEMP. (C)	P.H.	COND(UMHOS)	FLOW (CFS)
7031	05-30-85	10º	7.9	415	(4L/SEC) .14
7192	06-27-85	10º	7.9	440	0.14
7237	07-10-85	9º	8.1	550	0.8
7417	08-30-85	12º	8.1	450	0.3
7516	09-26-85	8º	7.7	435	0.2
7636	10-31-85	7º	7.6	470	0.17
7875	02-28-86	8.5º	8.3	480	
7915	03-13-86	7º	8.2	490	0.26
7966	04-07-86	4.5º	8.3	480	0.31
8038	05-05-86	9º	8.2	430	0.12
8275	06-30-86	9º	8.2	470	0.12
8436	07-30-86	11º	7.6	440	0.25
	09-30-86	7.7º	8.7	555	0.05
	10-20-86	8.2º	7.6	801	0.045
	11-11-86	7º	7.1	359	0.046

SPRINGS TM 22

I.D. NO.	DATE	TEMP. (C)	P.H.	COND(UMHOS)	FLOW (CFS)
7194	06-27-85	8º	8.2	310	0.07
7239	07-10-85	8º	7.9	340	0.07
7419	08-30-85	11º	8.7	330	0.012
7518	09-26-85	8º	8.1	320	0.007
7638	10-31-85	5º	8.6	330	0.007
8438	07-30-86	10º	8.7	330	0.17
	09-30-86	7.7º	8.7	555	0.01
	10-17-86	4.8º	7.7	375	0.002
	11-11-86	2.7º	7.3	359	0.002

SPRINGS TM 21

I.D. NO.	DATE	TEMP. (C)	P.H.	COND(UMHOS)	FLOW (CFS)
7193	06-27-85	8º	8.2	410	0.04
7238	07-10-85	6º	7.8	500	0.03
7418	08-30-85	12º	8	460	0.006
7517	09-26-85	7º	7.8	450	0.005
7637	10-31-85	6º	7.9	500	0.005
8437	07-30-86	9º	7.9	500	0.03
8604	09-30-86	7.3º	8.2	734	0.003
	10-17-86	4.9º	7.9	445	0.001
	11-11-86		FROZEN-NO FLOW		

Appendix 7-E Macroinvertebrate Study (Cottonwood Creek)**

**Ch 7 Rev. 1-11-87

Interim Report

The Benthic Macroinvertebrates of Cottonwood Creek

Prepared for the
Trail Mountain Coal Company

by
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Station Description

The benthic community of Cottonwood Creek was examined at two locations, Surface Water Monitoring Stations SW-1 and SW-2. These stations were sampled on July 31, 1985 and again on October 25, 1985. Station SW-1 is located upstream from the Trail Mountain Coal Company facilities. The riparian vegetation produces a closed canopy over the stream. The stream bed itself is a large rubble substrate with a matrix of sand. Station SW-2 is downstream from the mining facilities and the riparian vegetation is more open resulting in very little shading of the station. The substrate here is a small rubble with a matrix of sand. The matrix and rubble tended to be cemented together by a calcarious marl. The marl was more noticeable on the first sampling date.

Sampling Procedure

Four samples were taken at each station. This number of samples was determined to be adequate for monitoring purposes. Samples were taken with a standard surber sampler with a 351 micron mesh net. Sampler positioning within each sampling station was determined randomly so as to eliminate any potential investigator induced bias. The substrate was removed to a depth of ten centimeters and placed in a plastic container. The contents of the surber sampler was also washed into this container. The sample was preserved with a 10% formalin solution with rose bengal stain added. The samples were washed in the laboratory and organic materials were retained in a 64 micron mesh sieve. The organic residue was washed into a bottle and preserved with the 10 % formalin - rose bengal solution until it could be sorted. The sediments were oven dried and then separated into size fractions with a Tyler sieve shaker set at 20 minutes. The size fractions were weighed to determine proportional weight content.

Sample sorting was done under a dissecting microscope. Organisms were removed and placed into two dram vials and 70% ethyl alcohol was added as a preservative. These samples were later sorted to Order and Family levels and Generic identification was accomplished with the use of several keys for aquatic invertebrates (see bibliography). Identification was made with a dissecting microscope and occasionally with the aid of a compound microscope for those specimens which required dissection and slide mounting.

Preliminary Results

The sediment data are summarized in a table. While this only depicts the average proportional composition for each sampling site and sampling date, it does reveal the gross differences between the sediments of the two stations. SW-1 on both sampling dates had the highest proportion of the substrate particles in the 64mm + category (74% and 64% respectively). While SW-2 samples taken on 10-25-85 did have the dominant substrate as 64mm + (53%), it is also apparent that the smaller rubble sizes are more predominant. For instance the 32-8 mm size range for SW-1 was 11% and 14% for July and October respectively while the same size range for SW-2 was 40% and 25%. This implies that substrate may be important in influencing the structure of the communities at the two respective stations and a certain degree of confounding may occur when attempting to determine any impact form mining activities. An additional confounding factor was alluded to earlier, that is the difference in canopy cover at the two sites. The open canopy of station SW-2 is likely the cause of the calcareous marl on the substrate. The marl is induced by the action of photosynthetic organisms, in this case epilithic algae. This marl will reduce the interstitial spaces available to the benthic fauna and thus will influence the community. The reduced marl on the second sampling date could be from either lower overall photosynthesis on the benthos due to season or it could result from the disturbance induced by the sampling three months earlier in July. Regardless, the samples taken in October are more comparable between stations than are those taken in July. This is easily seen in the densities of the invertebrates. The October samples are more similar between the stations than are the July samples. In July the SW-2 station has about 30% fewer taxa than SW-1, while in October SW-2 has approximately the same number of taxa. From these preliminary results it appears that the mining activities are having little or no impact on the stream communities, although more definitive conclusions must await a final analysis with quantitative methods.

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Substrate Size (%)

Date and Sample	Rubble (mm)			Gravel (mm)			Sand (mm)			
	64+	64-32	32-8	8-4	4-2	2-1	1-.5	.5-.25	.25-.125	.125-.063
7/31/85 SW-1	74.2	9.6	10.7	2.1	1.3	0.6	0.4	0.9	0.2	0.2
7/31/85 SW-2	12.6	26.3	39.8	7.8	4.0	2.5	2.3	4.4	0.5	0.1
10/25/85 SW-1	64.4	13.1	13.9	4.2	1.3	0.7	0.6	1.5	0.5	0.1
10/25/85 SW-2	52.8	14.2	25.0	4.2	1.2	0.6	0.4	1.0	0.5	0.1

Date: 7-31-85
Sample site: SW-1

	Sample Number			
	1	2	3	4
Ephemeroptera				
Baetidae				
Baetis sp.	285	72	147	148
Heptageniidae				
Heptagenia sp.	0	0	0	0
Plecoptera				
Perlodidae				
Cultus sp.	29	19	8	13
Chloroperlidae				
Chloroperla sp.	3	0	0	0
Nemouridae				
Malenka sp.	0	5	3	11
Trichoptera				
Hydropsychidae				
Hydropsyche sp.	11	3	3	5
Brachycentridae				
Brachycentrus sp.	0	0	0	3
Limnephilidae	0	0	0	0
Diptera				
Chironomidae	24	3	21	5
Rhagionidae				
Atherix varigata	0	3	0	0
Simuliidae				
Prosimulium sp.	77	0	19	5
Tipulidae				
Tipula sp.	0	0	0	0
Coleoptera				
Dytiscidae				
nr. *Agabus*	0	0	0	3
Copepoda				
Harpacticoida	0	0	0	0
Oligocheta	19	64	8	11
Nematoda	0	0	0	0

Date: 7-31-85
Sample site: SW-2

	Sample Number 1	2	3	4
Ephemeroptera				
Baetidae				
Baetis sp.	259	149	155	75
Heptageniidae				
Heptagenia sp.	0	0	0	0
Plecoptera				
Perlodidae				
Cultus sp.	0	3	3	11
Chloroperlidae				
Chloroperla sp.	0	0	0	0
Nemouridae				
Malenka sp.	0	3	8	3
Trichoptera				
Hydropsychidae				
Hydropsyche sp.	3	0	0	8
Brachycentridae				
Brachycentrus pp.	0	0	0	0
Limnephilidae	0	0	0	0
Diptera				
Chironomidae	5	8	19	16
Rhagionidae				
Atherix varigata	0	0	0	0
Simuliidae				
Prosimulium sp.	3	8	13	0
Tipulidae				
Tipula sp.	0	0	0	0
Coleoptera				
Dytiscidae				
nr. *Agabus*	0	0	0	0
Copepoda				
Harpacticoida	0	3	0	0
Oligocheta	32	45	13	21
Nematoda 11	3	0	0	

Date: 10-25-85
Sample site: SW-1

	Sample Number 1	2	3	4
Ephemeroptera				
Baetidae				
Baetis sp.	139	115	45	139
Heptageniidae				
Heptagenia sp.	5	5	0	3
Plecoptera				
Perlodidae				
Cultus sp.	5	11	0	8
Chloroperlidae				
Chloroperla sp.	19	13	0	0
Nemouridae				
Malenka sp.	8	0	0	0
Trichoptera				
Hydropsychidae				
Hydropsyche sp.	13	5	3	11
Brachycentridae				
Brachycentrus sp.	0	0	0	0
Limnephilidae	0	0	0	0
Diptera				
Chironomidae	5	12	11	24
Rhagionidae				
Atherix variqata	0	8	0	0
Simuliidae				
Prosimulium sp.	0	0	0	5
Tipulidae				
Tipula sp.	0	0	0	0
Coleoptera				
Dytiscidae				
nr. Agabus	0	0	0	0
Copepoda				
Harpacticoida	0	0	0	0
Oligocheta	19	29	53	35
Nematoda 0	0	3	0	

Date: 10-25-85
Sample site: SW-2

	Sample Number 1	2	3	4
Ephemeroptera				
Baetidae				
Baetis sp.	557	275	93	115
Heptageniidae				
Heptagenia sp.	0	8	3	0
Plecoptera				
Perlodidae				
Cultus sp.	27	16	5	0
Chloroperlidae				
Chloroperla sp.	12	0	3	0
Nemouridae				
Malenka sp.	0	0	0	0
Trichoptera				
Hydropsychidae				
Hydropsyche sp.	3	3	5	0
Brachycentridae				
Brachycentrus sp.	0	0	0	0
Limnephilidae	3	0	0	3
Diptera				
Chironomidae	5	275	83	261
Rhagionidae				
Atherix variqata	3	0	3	0
Simuliidae				
Prosimulium sp.	0	0	0	0
Tipulidae				
Tipula sp.	5	0	0	0
Coleoptera				
Dytiscidae				
nr. *Agabus*	0	0	3	0
Copepoda				
Harpacticoida	0	0	0	0
Oligocheta	77	45	3	64
Nematoda 8	0	0	0	

Final Report

Cottonwood Creek Macroinvertebrate Assessment

for the

Trail Mountain Coal Company

by

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Introduction and Purpose

The Utah Division of Oil, Gas and Mining and the United States Department of the Interior have required a study of the Cottonwood Creek macroinvertebrate community with the objective of documenting any negative impacts of the Trail Mountain Coal Company mining operations on the stream system. The instructions were to compare the faunal elements over three sampling periods at two stations on Cottonwood Creek. A total of four samples per station were recommended. This report details the results of the study and interprets the similarities and dissimilarities of the two communities and the habitat found at each station.

Description of Study Area

The study was conducted from two preestablished sampling stations in Cottonwood Canyon, Emery County, Utah. These sites are the surface water monitoring stations SW-1 and SW-2 of the Hydrologic Monitoring program established by the Trail Mountain Coal Company in compliance with requirements by the Utah Division of Oil, Gas & Mining and the United States Department of the Interior. SW-1 is above the Trail Mountain Coal Company mining facilities and represents a control, or non impact section. SW-2 is approximately one kilometer downstream from the facilities and represents the portion of the stream where mining impacts would be expected if such impacts occur.

The upstream station, SW-1 is located in a shaded portion of the stream, with a relatively dense overhead canopy of Cottonwood (*Populus sp.*) and a riparian of varied native shrubs. The stream passes through a narrow channel, confined by steep side walls. The substrate is large rubble with a sand matrix. SW-2 is in a more open setting, and has significantly less overstory cover. The stream bed is, for the most part, exposed to direct sunlight. The bank slopes gradually to the stream bed from the east, while the western bank is steep, similar to the banks at location SW-1. The substrate here is a small rubble with a matrix of sand. The matrix and rubble tended to be cemented together with a calcarious marl, and this marl was best developed during the summer sampling period.

Materials and Methods

Sampling Methods

Samples were taken three times during the year: July 31, 1985; October 25, 1985 and February 9, 1986. Four replicate samples were taken per station using a one square foot surber sampler with a net mesh of 351 microns. The positioning of each sample was determined with random numbers to avoid any bias by the investigator. Once the sample position was determined, the surber sampler was centered directly over the sampling point. Large rocks found within the sample area were washed and measured in the field, but were not retained for laboratory processing. The volume of each rock was used to determine its approximate weight for sediment analysis. The remaining substrate in each sample was removed to a depth of 4 inches (10 cm.) and placed in a polyethylene jar. Excess water was removed by filtering through a 64 micron mesh sieve. The contents of the surber sampler net was also washed into the sieve and then transferred into the jar. Samples were preserved with ten percent formalin. Rose bengal stain was added to aid in laboratory processing.

Samples were transported to the laboratory where the sediments were separated from the benthic invertebrates using elutriation (Shiozawa 1986). The elutriated organic residue was collected with a 65 micron mesh sieve, washed into a jar, and preserved with a 10% formalin - rose bengal solution. The inorganic residual was retained for sediment analysis. The samples were picked under a stereo dissecting scope and the recovered invertebrates were sorted and separated by genus or species when possible. The sediments were oven dried at 120 degrees centigrade to a constant weight. The dried material was then placed in a series of nested sieves sized according to the phi scale (Cummins, 1962; Cummins and Lauff, 1969), beginning at 250 microns mesh diameter. The sieves were then placed on a Tyler sediment shaker for 20 minutes. The size fractions were weighed and the resulting percents were used to characterize the sediments distribution in each sample.

Samples were sorted with a dissecting microscope using fiber optics lighting. Organisms were enumerated and placed into vials. The sorted invertebrates were preserved with 70% ethyl alcohol. The preserved samples were later sorted to Order and Family and the Genus and Species were determined when possible using standard keys for aquatic invertebrates (Baumann, Gaufin and Surdick, 1977; Edmondson, 1959; Edmunds, Jensen and Berner, 1976; Hitchcock, 1974; Merritt and Cummins,1978; Ross, 1944; Usinger, 1971; Wiggens, 1977). Identifications were made under a dissecting microscope and occasionally with slide mounted specimens viewed with a compound microscope.

Results and Discussion

Analysis of aquatic impact data has traditionally focused on either the invertebrate community or the water chemistry of the stream areas in question. Water chemistry (which has been monitored separately and is not of consideration in this report) has the advantage of giving direct levels of potential contaminants reaching a given site and, in that sense, simplifies management decisions when pre-established toxicant levels are exceeded. However water chemistry varies regionally as well as seasonally (Hem 1970), and the conditions present in one system can remove or neutralize materials which might be toxic or stressful under other conditions. In addition a serial water sampling program represents point data and does not detect pollutants which may enter the system for only short periods of time, such as immediately following a storm (storm runoff) or materials that are only periodically discharged into the stream system. Materials which may enter the stream in sublethal quantities can still impact the aquatic community yet not exceed established standards and some materials may be difficult or prohibitively expensive to measure and assess chemically. The use of the biotic community is advantageous under such conditions. Lotic organisms will respond to stress if it exceeds their tolerance limits. Thus a single slug flow of a toxicant may result in the elimination or reduction of certain species and favor the multiplication or survival of other more tolerant species. The resulting shift in community structure can be detected long after the stressing factor(s) have left the system. This initially led investigators to develop the concept of indicator species

(Gaufin and Tarzwell, 1956; Tarzwell and Gaufin, 1953) where certain species were considered to be indicative of stress, especially organic pollution. If these indicators were present, then pollution was likely.

Later with the adaptation of information theory to ecology (Margalef 1957) an additional tool was made available for such evaluation. Information theory predicted that the number of pathways available for information transfer was directly correlated with the stability of information systems. A direct adaptation of this concept to that of trophic associations and food web connectivity led to the widespread use of diversity indices as a measure of the stability of natural and perturbed systems (Margalef, 1957; MacArthur, 1972; Patrick, 1963; Pielou, 1975). The Shannon-Weiner (Shannon and Weaver 1949) index of diversity became widely used in evaluating impacts in the early 1970's. This index for diversity is:

$$H' = \mathrm{sum}(pi*\log(p_i))$$

where H' = the Shannon Weiner Index of diversity
p_i = the proportion of species i in the sampled community

This function is maximum when $p_i = 1/S$ for all S species in the sample. That is:

$$H'max = S((1/S)*\log(1/S))$$

where H'max = the maximum diversity
S = the total number of species in the sample

Assuming that the ideal community would have maximum diversity, the nearness to this ideal state could be calculated. This measure of nearness to the ideal is called evenness and is found with the formula:

$$E = H'/H'max$$

where E = evenness
H' = the Shannon-Weiner Diversity Index
H' = the maximum diversity index defined above

Evenness ranges between 0 and 1 where 1 is maximum evenness.

As more was understood about natural communities the connection between diversity and stability began to come under question (see Pielou, 1975) and the use of diversity and evenness alone as an index of environmental stress became limited. An association between diversity and stability may exist (May, 1974) but that association is in no way as simplistic as the original users of information theory had assumed. The most reasonable use of diversity indices now are for comparisons of adjacent sites, such as is the case in this study where two stations on the same stream are being compared. Regional and broad geographical comparisons are likely to be less valid, especially when interpretations associated with the condition or quality of various systems are being considered.

In 1972 Chutter recommended the use of a biotic index to assess the impact of perturbations on aquatic systems. This index was designed to allow a quantitative evaluation of the indicator species concept. All species in the sampled station are enumerated and each is assigned a value according to it's importance as an indicator. The higher the value, the higher the tolerance is to stressful conditions. Species values range from zero to ten and the density of each species is included in the computation of the index. The index is:

$$BI = (Sum(n_i * s_i))/N$$

where BI = the biotic index
n_i = the importance value of the ith species
s_i = the density of species i in the sample being evaluated
N = the total number of organisms in the sample

Here values of unperturbed systems are generally considered to be in the range of 0-2, while values of 2-4 indicate slightly enriched (stressed) situations, 4-7 are typical of enriched waters and 7-10 are characteristic of polluted waters (Hilsenhoff 1977).

Additional factors can be useful when interpreting the relative conditions of several sites. One is the influence of substrate on community structure (DeMarch, 1976) and another is the functional grouping of stream organisms (Cummins 1974). In this report these various techniques were used in extracting information relative to the impact of the Trail Mountain Coal company operations on Cottonwood Creek.

Sediment Characterization

The sediment size frequencies for each sample taken during the study are listed in Tables I, II and III. Sediments have been shown to undergo a seasonal change in structure associated with annual changes in discharge in some stream systems (DeMarch, 1976; Shiozawa, 1986). This has implications for community structure since the substrate essentially establishes the template on which the community is structured (Shiozawa 1983). Differences in sediment dynamics or in sediment structure at the two stations could induce differences in the community structure and thus complicate the interpretation of the data. Station SW-1 shifts from slightly higher percentages in the 64+mm size range to more in the 32-8 mm sizes between July and October of 1985. These particles are in the gravel sizes, and indicate selective erosion of sands from the substrate. Essentially no change in substrate size frequency occurred between October and the February samples at SW-1. Station SW-2 underwent an increase in the coarse material greater than 64 mm in size between July and October. This implies the erosion of sands and gravels from the substrate. Between October and February the proportion of gravels increased in the samples and deposition is the likely source of materials. It appears that the stations are undergoing different sediment dynamics. If annual sediment deposition - erosion cycles occur, then station SW-1 is undergoing a change from a depositional environment in the early-mid summer to an erosional one in the fall. Over the winter it stabilizes and in the spring runoff it should become erosional again. Once water levels stabilize the stream becomes depositional, replacing the materials lost to the spring floods. Station SW-2 underwent an erosional period between July and October with

Table I. Sediment size frequency data for samples collected on 7-31-85

Station: SW-1

Sample	64+	32-64	8-32	4-8	2-4	1-2	.5-1	.25-.5
				Percent Composition				
1	82.1	8.3	7.6	0.8	0.4	0.2	0.2	0.4
2	62.8	16.9	12.9	3.1	1.7	0.8	0.5	1.3
3	75.8	13.0	7.7	1.2	0.7	0.3	0.2	1.1
4	75.9	0.0	14.4	3.5	2.2	1.1	0.8	2.1
Mean	74.15	9.55	10.65	2.15	1.25	0.60	0.43	1.23
Std. Deviation	7.03	6.30	3.05	1.17	0.73	0.37	0.25	0.61

Mean Sediment Diversity: 0.929741
Mean Sediment Evenness: 0.447111

Station: SW-2

Sample	64+	32-64	8-32	4-8	2-4	1-2	.5-1	.25-.5
				Percent Composition				
1	34.2	33.7	19.7	7.8	1.7	0.9	0.6	1.4
2	16.0	28.0	17.9	9.6	6.3	4.9	5.7	11.6
3	0.0	0.0	75.9	8.8	5.7	3.1	2.1	4.4
4	0.0	43.3	45.6	4.9	2.3	1.0	0.6	2.3
Mean	12.55	26.25	39.78	7.78	4.00	2.48	2.25	4.93
Std. Deviation	14.10	26.25	23.56	1.79	2.02	1.65	2.05	4.00

Mean Sediment Diversity: 1.630813
Mean Sediment Evenness: 0.784255

Table II. Sediment size frequency data for samples collected on 10-25-85

Station: SW-1

Sample	Percent Composition							
	64+	32-64	8-32	4-8	2-4	1-2	.5-1	.25-.5
1	55.3	16.9	21.9	3.0	0.8	0.4	0.3	1.4
2	79.9	14.7	2.6	1.1	0.6	0.3	0.2	0.6
3	76.9	7.1	9.7	2.3	1.3	0.7	0.5	1.5
4	45.3	13.8	21.5	10.5	2.4	1.3	1.2	4.0
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Mean	64.35	13.13	13.93	4.23	1.28	0.68	0.55	1.88
Std. Deviation	14.53	3.66	8.17	3.69	0.70	0.39	0.39	1.28

Mean Sediment Diversity: 1.150947
Mean Sediment Evenness: 0.553958

Station: SW-2

Sample	Percent Composition							
	64+	32-64	8-32	4-8	2-4	1-2	.5-1	.25-.5
1	0.0	35.9	43.6	13.1	3.1	1.5	0.9	1.9
2	71.2	14.4	10.9	1.5	0.6	0.3	0.2	0.9
3	55.9	7.5	32.8	1.3	0.9	0.4	0.3	0.9
4	84.6	0.0	12.7	0.9	0.3	0.3	0.3	0.9
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Mean	52.93	14.45	25.00	4.20	1.23	0.63	0.43	1.15
Std. Deviation	32.20	13.39	13.76	5.14	1.10	0.51	0.28	0.43

Mean Sediment Diversity: 1.256215
Mean Sediment Evenness: 0.604112

Table III. Sediment size frequency data for samples collected on 2-9-86

Station: SW-1 — Percent Composition

Sample	64+	32-64	8-32	4-8	2-4	1-2	.5-1	.25-.5
1	46.2	12.5	21.8	7.6	3.9	2.2	1.9	3.9
2	85.0	3.6	6.1	1.9	1.0	0.7	0.7	1.0
3	72.8	11.8	10.2	2.5	0.9	0.4	0.3	1.1
4	58.0	22.0	16.6	1.9	0.7	0.3	0.2	0.3
	---	---	---	---	---	---	---	---
Mean	65.50	12.48	13.68	3.48	1.63	0.90	0.78	1.58
Std. Deviation	14.68	6.52	6.00	2.39	1.32	0.76	0.68	0.38

Mean Sediment Diversity: 1.138008
Mean Sediment Evenness: 0.547266

Station: SW-2 — Percent Composition

Sample	64+	32-64	8-32	4-8	2-4	1-2	.5-1	.25-.5
1	0.0	39.3	42.0	5.8	2.8	2.0	2.2	5.9
2	79.2	5.3	8.9	3.3	1.8	0.9	0.4	0.2
3	0.0	9.8	77.1	7.7	2.8	1.2	0.6	0.8
4	13.5	14.7	58.0	6.5	2.8	1.3	0.9	1.9
	---	---	---	---	---	---	---	---
Mean	23.18	17.28	46.60	5.83	2.55	1.35	1.03	2.20
Std. Deviation	32.81	13.14	25.06	1.61	0.43	0.40	0.70	2.22

Mean Sediment Diversity: 1.446200
Mean Sediment Evenness: 0.695475

even more coarse materials being removed than in station SW-1. From October to February deposition occurred. In the spring the runoff would again be expected to act as an erosional factor. The difference in the size of particles deposited is indicative of the stream velocity in the two sites. Station SW-2 has a higher gradient than does station SW-1 and higher velocity water will carry larger particles. However the sediment determinations were based upon the four replicate random samples. Other studies (DeMarch, 1976; Shiozawa, 1986) relied upon more replicates per station and sampled much more frequently when deriving the seasonal patterns. Thus the three sampling periods used here can give only partial support of such seasonal trends existing in Cottonwood Creek. It is obvious that the substrates at the two sites are quite different, especially during the July and February sampling periods.

Some of the differences between the sediments at SW-1 and SW-2 are associated with the high carbonate content at location SW-2. The open exposure of the eastern bank of the stream at SW-2 and the lack of an overhead canopy combine to favor photosynthesis of algae. Under condition of very active photosynthesis, algae can switch from utilizing dissolved CO_2 in the water to utilizing carbon dioxide in the bicarbonate form. Extraction of CO_2 from the bicarbonate, HCO_3^-, leaves a hydroxide group (OH^-) which then reacts with other bicarbonates to form insoluble carbonate complexes. These complexes cement the substrate together in the form of a calcareous marl. The benthos of SW-2 was cemented in place by such a marl when samples were taken in July. Less cementing was noted when sampling in November and February. The lower marl presence in the fall and winter may be due to lower primary production associated with shorter days in the narrow canyon in which the sampling stations are located, or it may be an artifact resulting from the initial disturbance of the stream channel by the July sampling. The answer to this cannot be determined without further sampling. Station SW-1 did not have marl deposits during any of the sampling periods. This was to be expected because of the overhead canopy which would reduce the rate of algal photosynthesis.

The differences in the sediments collected from the two stations are summarized in Table IV. A comparison of sediment weight based on both modal and median weight frequencies also indicates the differences between stations SW-1 and SW-2. SW-2 samples in general had a smaller modal and median size although this difference is not apparent in the October samples. Diversity and evenness of each sample is also listed in Table IV. The diversity value gives a relative picture of the distribution of the sediment weights. The lower the diversity, the more a single size class dominates the sample. Again both diversity and evenness indicate that the sediments in station SW-1 are more skewed in distribution than are those in station SW-2 with the exception of the October sampling series.

Benthic Invertebrate Community

The benthic invertebrate community consisted of 15 taxa representing eight orders. The distributions of the invertebrates resulted in a high variance to mean ratio which implies a contagious distribution. Such patterns are typical of stream systems and the currently accepted treatment of such data is to utilize the geometric confidence limits based on a log(x+1) transformation on the arithmetic mean (Elliott, 1977; Shiozawa and Barnes, 1977). For that reason the confidence limits about each species will not be symmetrical. It is important to recognize that contagious distributions predominate in most benthic groups, and that this distributional pattern further limits the accuracy of small numbers of replicate samples.

The predominant benthic invertebrate groups collected included the mayflies, especially Baetis, perlodid and nemourid stoneflies, hydropsychid caddisflies, chironomids, simuliids and oligochaetes. These taxa can be placed into functional group designations (Cummins, 1974; Merritt and Cummins, 1978) which can add insight into the functional structures of the two sites. The stations can be compared over time as well as between each other for differences in functional groupings. The functional group concept of Cummins (1974) is based on the processing of food in the stream system. Most streams have a considerable portion of their energetic budget supplied by the surrounding riparian vegetation. The resulting food web is thus detrital based, and the functional groups correspond to the role which various species play in processing food within the system. Whole leaves, after being conditioned by bacteria and fungi are broken into smaller particles by shredders. The finer particles are collected from the flowing water by filterers, and those particles which settle out onto the stream bed are fed upon by the collector-gatherers. Grazers are those species which actively feed on living plant materials, algae being the main food source, while those designated as grazer/scrapers may also feed on epilithic detritus. Predators are those species which feed upon other benthic invertebrates.

In July SW-1 (Table V) had abundant collector-gatherers (Baetis, Chironomids, oligochaetes) and filter feeders (Brachycentrus, Hydropsyche and Prosimulium. Predators were represented by the plecopterans Cultus and Choloroperla, rhagionid fly larvae and the dytiscid beetle larvae, Agabus. The only shredder at SW-1 was Melanka (Plecoptera). The October (Table VI) samples had a decrease in shredder (still the one plecopteran species) and predator densities. The grazer/scraper Heptagenia (Ephemeroptera) occurred, possibly as a partial response to the open canopy following leaf drop and to the increased organic flocculates on the rock surfaces. The collector gatherers were in slightly lower densities. By February (Table VII) the collector gatherer Baetis was in low density but the chironomids, also collector gatherers, had increased to over ten times their October densities. The grazer Heptagenia was still present and the shredders were predominantly represented by Tipula and limnephilid caddisflies. The filterers were still present but the hydropsychid caddisflies decreased in density and the simuliid larvae became more abundant.

The July (Table VIII) samples from Station SW-2 had collector gatherer densities virtually identical to that of SW-1. The filter feeders were lower in density than those at station SW-1, but this difference was strongly influenced by the substrate size distribution. Filter feeders require a substratum for attachment and from the sediment analysis for SW-2 (Table I) it is apparent that the dominant substrate in July was gravel, too unstable for the development of a high filter feeder density. Shredders were also in lower densities in the SW-2 July samples, but with the high variance associated with the contagious distributions of this group the difference is not significant. The only predator in station SW-2 for July was the plecopteran Cultus. Its densities were approximately one fourth

Table IV. Sediment Data Summary

Date: 7-31-85	modal size	median size	Diversity	Evenness
SW-1 1	64+	64+	0.67201	0.323172
SW-1 2	64+	64+	1.15532	0.555594
SW-1 3	64+	64+	0.83994	0.403928
SW-1 4	64+	64+	0.85902	0.413103
mean conditions:	64+	64+	0.92974*	0.447111*
SW-2 1	32-64	64+	1.45463	0.699529
SW-2 2	8-32	32-64	1.91767	0.922209
SW-2 3	8-32	8-32	0.91271	0.438922
SW-2 4	8-32	8-32	1.11856	0.537914
mean conditions	8-32	8-32	1.63081*	0.784255*
Date: 10-25-85				
SW-1 1	64+	64+	1.20374	0.578878
SW-1 2	64+	64+	0.69688	0.335131
SW-1 3	64+	64+	0.88353	0.424889
SW-1 4	32-64	64+	1.52695	0.734307
mean conditions	64+	64+	1.15095*	0.553958*
SW-2 1	8-32	8-32	1.28434	0.617639
SW-2 2	64+	64+	0.92844	0.446487
SW-2 3	64+	64+	1.06578	0.512532
SW-2 4	64+	64+	0.54062	0.259986
mean conditions	64+	64+	1.25622*	0.604112*
Date 2-9-86				
SW-1 1	32-64	32-64	1.55692	0.748722
SW-1 2	64+	64+	0.66529	0.319939
SW-1 3	64+	64+	0.93986	0.451978
SW-1 4	64+	64+	1.10446	0.531136
mean conditions	64+	64+	1.13801*	0.547266*
SW-2 1	8-32	8-32	1.32584	0.637594
SW-2 2	64+	64+	0.81747	0.393120
SW-2 3	8-32	8-32	0.84808	0.407840
SW-2 4	8-32	8-32	1.33412	0.641577
mean conditions	8-32	8-32	1.446208*	0.695475*

* note that these values are based on the mean percent composition values from Tables I,II,III and are not arithmetic means of the individual diversity and evenness values.

Table V. Invertebrate density, diversity, evenness and biotic index for site SW-1, July 31, 1985.

	no./sq. meter	95% confidence interval lower	upper
Ephemeroptera			
Baetidae			
Baetis sp.	1754.52	716.11	4276.38
Heptageniidae			
Heptagenia sp.	0.0	-	-
Plecoptera			
Perlodidae			
Cultus sp.	185.68	76.12	433.37
Chloperlidae			
Chloroperla sp.	8.07	-4.51	45.98
Nemouridae			
Melanka sp.	51.13	0.93	316.72
Trichoptera			
Hydropsychidae			
Hydropsyche sp.	59.20	19.91	148.82
Brachycentridae			
Brachycentrus sp.	8.07	-4.51	45.98
Limnephillidae	0.0	-	-
Diptera			
Chironomidae	142.62	24.69	652.80
Rhagionidae			
Athrix varigata	8.07	-4.51	45.98
Simuliidae			
Prosimulium sp.	271.79	4.14	5347.37
Tipulidae			
Tipula sp.	0.0	-	-
Coleoptera			
Dytiscidae			
Agabus sp.	8.07	-4.51	45.98
Crustacea			
Copepoda			
Harpacticoida	0.0	-	-
Annellida			
Oligochaeta	274.48	60.42	1132.24
Nematoda	0.0	-	-
Total Invertebrates	2771.70		

Number of Taxa 11
H' Max 2.397895
Diversity, H' 1.303748
Evenness 0.543705
Biotic Index (Hilsenhoff 1977) 2.0748

Table VI. Invertebrate density, diversity, evenness and biotic index for site SW-1, October 25, 1985.

	no./sq. meter	95% confidence interval lower	upper
Ephemeroptera			
Baetidae			
Baetis sp.	1178.65	498.96	2764.67
Heptageniidae			
Heptagenia sp.	34.98	4.11	65.86
Plecoptera			
Perlodidae			
Cultus sp.	64.58	2.00	433.92
Chloperlidae			
Chloroperla sp.	86.11	-3.56	1291.33
Nemouridae			
Melanka sp.	21.53	-5.14	174.67
Trichoptera			
Hydropsychidae			
Hydropsyche sp.	86.11	27.19	236.51
Brachycentridae			
Brachycentrus sp.	0.0	-	-
Limnephillidae	0.0	-	-
Diptera			
Chironomidae	139.93	48.78	370.63
Rhagionidae			
Athrix varigata	21.53	-5.14	174.67
Simuliidae			
Prosimulium sp.	13.45	-4.94	89.97
Tipulidae			
Tipula sp.	0.0	-	-
Coleoptera			
Dytiscidae			
Agabus sp.	0.0	-	-
Crustacea			
Copepoda			
Harpacticoida	0.0	-	-
Annellida			
Oligochaeta	365.97	184.75	715.17
Nematoda	8.07	-4.51	45.98
Total Invertebrates	2020.92		

Number of Taxa 11
H' Max 2.397895
Diversity, H' 1.410172
Evenness 0.588087
Biotic Index (Hilsenhoff 1977) 2.0719

Table VII. Invertebrate density, diversity, evenness and biotic index for site SW-1, February 9, 1986.

	no./sq. meter	95% confidence interval lower	upper
Ephemeroptera			
Baetidae			
Baetis sp.	861.11	161.00	4414.80
Heptageniidae			
Heptagenia sp.	45.75	10.44	81.05
Plecoptera			
Perlodidae			
Cultus sp.	26.91	-0.17	53.99
Chloperlidae			
Chloroperla sp.	24.22	-1.47	49.91
Nemouridae			
Melanka sp.	8.07	-4.51	45.98
Trichoptera			
Hydropsychidae			
Hydropsyche sp.	69.97	17.75	217.80
Brachycentridae			
Brachycentrus sp.	0.0	-	-
Limnephillidae	16.15	-4.83	37.12
Diptera			
Chironomidae	4039.15	1675.14	9718.06
Rhagionidae			
Athrix varigata	0.0	-	-
Simuliidae			
Prosimulium sp.	91.49	2.94	752.20
Tipulidae			
Tipula sp.	29.60	1.20	58.00
Coleoptera			
Dytiscidae			
Agabus sp.	8.07	-4.5	45.98
Crustacea			
Copepoda			
Harpacticoida	0.0	-	-
Annellida			
Oligochaeta	129.17	-3.24	2591.57
Nematoda	0.0	-	-
Total Invertebrates	5349.66		

Number of Taxa 12
H' Max 2.484906
Diversity, H' 0.880037
Evenness 0.354153
Biotic Index (Hilsenhoff 1977) 2.0645

Table VIII. Invertebrate density, diversity, evenness and biotic index for site SW-2, July 31, 1985.

	no./sq. meter	95% confidence interval lower	upper
Ephemeroptera			
Baetidae			
Baetis *sp.*	1716.84	763.14	3845.84
Heptageniidae			
Heptagenia *sp.*	0.0	-	-
Plecoptera			
Perlodidae			
Cultus *sp.*	45.75	0.43	274.62
Chloperlidae			
Chloroperla *sp.*	0.0	-	-
Nemouridae			
Melanka *sp.*	37.67	0.58	196.02
Trichoptera			
Hydropsychidae			
Hydropsyche *sp.*	29.60	-3.59	216.48
Brachycentridae			
Brachycentrus *sp.*	0.0	-	-
Limnephillidae	0.0	-	-
Diptera			
Chironomidae	129.17	46.62	330.47
Rhagionidae			
Athrix *variqata*	0.0	-	-
Simuliidae			
Prosimulium *sp.*	64.58	1.14	466.02
Tipulidae			
Tipula *sp.*	0.0	-	-
Coleoptera			
Dytiscidae			
Agabus *sp.*	0.0	-	-
Crustacea			
Copepoda			
Harpacticoida	8.07	-4.51	45.98
Annellida			
Oligochaeta	298.70	125.78	690.58
Nematoda	37.67	-3.63	318.25
Total Invertebrates	2368.06		

Number of Taxa 9
H' Max 2.197224
Diversity, H' 1.033331
Evenness 0.470289
Biotic Index (Hilsenhoff 1977) 2.3216

of that of the same species at SW-1.

In October (Table IX) the invertebrate density in SW-2 was double that of SW-1. Baetis was 2.5 times more abundant and the midge larvae (Chironomidae) were approximately ten times more abundant. Both the predacious stoneflies and the grazer Heptagenia were present in approximately the same density as in SW-1. The grazer was not present in SW-2 in July, and the change to more favorable substrate size classes are associated with its October occurrence. Filter feeders were less abundant. The simuliids appear to have undergone a fall emergence prior to the October sampling date and therefore were absent. The hydropsychid caddisflies were significantly lower in density than those in SW-1 for October, and were about the same density as they were in the previous SW-2 samples taken in July. The cause of this difference is not clear and the data taken in this project will not allow a resolution of this problem. One factor which could be influential is the lower drift rates of later instar hydropsychid caddisflies which slows dispersal and would therefore imply that later instar hydropsychids would be slow in colonizing newly opened habitat. However the ability of such behavioral factors to control densities several months later seems unlikely.

The February samples from SW-2 (Table X) are indicative of the stressful conditions which exist in the stream during the winter. At the time of sampling frazzle ice was present and it appeared that anchor ice had occurred as well. Invertebrate densities were approximately one eighth the October level. The location of SW-2 with its open exposure would increase the likelihood of anchor ice formation. In addition the sediments collected in February had shifted back to gravel (Table IV) which would also favor reduced numbers of species. The total invertebrate density in SW-2 was also about one eighth of that of SW-1 on that same sampling date. The functional groups present include mostly collector gatherers. A few filterers (hydropsychids) and shredders (Tipula) were collected, but in general the community appeared as a vagrant benthos with opportunistic species being dominant.

Diversity, evenness and the biotic index were also computed for the benthic communities. Highest diversity for SW-1 and SW-2 occurred during October. The lowest diversity for both stations occurred in February. SW-2 had the lowest diversity value in July and October samples but in February SW-1 was found to have the lowest diversity. At this time SW-2 had 6 taxa and SW-1 had 12 taxa but the evenness of SW-1 was much lower than that of SW-2. Wilhm (1970) proposed diversity indices less than one to be indicative of stressed or polluted systems while values above 3 represented clean water conditions. On this basis both stations are borderline polluted or polluted. Neither would fall into the clean water categories.

The biotic index, based on the computed values of Hilsenhoff (1972) was also used to compare the benthic communities. SW-2 had consistently higher biotic index values throughout the three sampling periods, averaging 2.3493 while SW-1 averaged 2.0704. Values between 0-2 are indicative of clean water conditions and values between 2 and 3 are indicative of sightly stressed conditions (Hilsenhoff 1972). Thus SW-1 is at worst very slightly stressed on the biotic index rating and SW-2 is only slightly but significantly more so. However much of the stress is can be attributed to the differences

Table IX. Invertebrate density, diversity, evenness and biotic index for site SW-2, October 25, 1985.

	no./sq. meter	95% confidence interval lower	upper
Ephemeroptera			
Baetidae			
Baetis *sp.*	2798.61	750.00	10363.83
Heptageniidae			
Heptagenia *sp.*	29.60	-3.59	216.48
Plecoptera			
Perlodidae			
Cultus *sp.*	129.17	2.66	1447.76
Chloperlidae			
Chloroperla *sp.*	40.36	-3.63	355.72
Nemouridae			
Melanka *sp.*	0.0	-	-
Trichoptera			
Hydropsychidae			
Hydropsyche *sp.*	26.91	0.35	116.96
Brachycentridae			
Brachycentrus *sp.*	0.0	-	-
Limnephillidae	16.16	-4.83	37.12
Diptera			
Chironomidae	1679.17	86.66	29303.24
Rhagionidae			
Athrix *varigata*	16.15	-4.83	37.12
Simuliidae			
Prosimulium *sp.*	0.0	-	-
Tipulidae			
Tipula *sp.*	13.45	-4.94	89.97
Coleoptera			
Dytiscidae			
Agabus *sp.*	8.07	-4.51	45.98
Crustacea			
Copepoda			
Harpacticoida	0.0	-	-
Annellida			
Oligochaeta	508.59	46.65	4687.38
Nematoda	21.53	-5.14	174.67
Total Invertebrates	5287.77		

Number of Taxa	12
H' Max	2.484906
Diversity, H'	1.192904
Evenness	0.480060
Biotic Index (Hilsenhoff 1977)	2.2651

Table X. Invertebrate density, diversity, evenness and biotic index for site SW-2, February 9, 1986.

	no./sq. meter	95% confidence interval lower	upper
Ephemeroptera			
Baetidae			
Baetis sp.	441.32	91.01	1997.33
Heptageniidae			
Heptagenia sp.	0.0	-	-
Plecoptera			
Perlodidae			
Cultus sp.	0.0	-	-
Chloperlidae			
Chloroperla sp.	8.07	-6.76	22.90
Nemouridae			
Melanka sp.	0.0	-	-
Trichoptera			
Hydropsychidae			
Hydropsyche sp.	8.07	-4.51	45.98
Brachycentridae			
Brachycentrus sp.	0.0	-	-
Limnephillidae	0.0	-	-
Diptera			
Chironomidae	123.78	-0.97	1837.34
Rhagionidae			
Athrix variqata	0.0	-	-
Simuliidae			
Prosimulium sp.	0.0	-	-
Tipulidae			
Tipula sp.	13.45	-4.94	89.97
Coleoptera			
Dytiscidae			
Agabus sp.	0.0	-	-
Crustacea			
Copepoda			
Harpacticoida	0.0	-	-
Annellida			
Oligochaeta	64.58	-3.56	776.95
Nematoda	0.0	-	-
Total Invertebrates	659.29		

Number of Taxa 6
H' Max 1.791759
Diversity, H' 0.997553
Evenness 0.556744
Biotic Index (Hilsenhoff 1977) 2.4612

of substrate size, a factor not fully considered in the derivation of the biotic index.

The final technique used to evaluate the samples was a form of multivariate analysis known as cluster analysis. Cluster analysis utilizes a similarity matrix based on comparisons of all possible pairs of samples in the study. The similarity can be measured with any index, including those based on presence and absence as well as on quantitative comparisons. In this study correlation coefficients were used as the measure of similarity. The resulting correlation matrices are listed in Tables XI and XII. Table XI lists the correlations of all possible pairs of sediment samples and Table XII lists the correlations for all pairs of benthic invertebrate samples. Cluster dendrograms for the sediments (Figure 1) and the benthic invertebrate communities (Figure 2) were prepared from the correlation matrices. The algorithm used was the unweighted pair-group arithmetic averaging method (Sokal and Sneath, 1963; Sneath and Sokal, 1973). The initial purpose of clustering was to check for associations between the sediments and samples. The high degree of sediment variability between the stations as well as within station SW-2 over time made it necessary to look for associations between the sediment structure of a sample and invertebrate community structure. That is, to determine if sediment-invertebrate community structure was tightly enough linked that community structure could be determined solely on the sediment structure of the sample. Discrete multivariate comparisons of categorized groupings showed no significant associations between sediment structure and community structure. This should not be interpreted to imply that no association exists. The earlier discussions of various functional groups did develop the concept of functional associations, but the results of the cluster analysis point to no general response to the sediment composition by the community as a unit. The various species involved in the system act independently of one another in their responses to the ambient conditions.

The clusters can also be used to distinguish patterns within the clustered samples. The sediment cluster (Figure 1) can be subdivided into three clusters at the similarity level of 0.55. The samples which make up the first cluster consist of SW-2 samples exclusively, and the third cluster is comprised of two samples from SW-2 taken in July. The second cluster contains all of the SW-1 samples as well as most of the October SW-2 samples. This indicates that the samples from SW-2 are much more variable than those from SW-1, and that the October SW-2 samples did converge towards the sediment distribution typical of the upstream site, SW-1. This interpretation confirms the earlier discussion of sediment size structure, with an additional observation that two of the July samples from SW-2 (sample #'s 1 and 2) were quite different from those taken from the same site in July and February.

The benthic invertebrate cluster (Figure 2) is more difficult to interpret. In general the July samples from SW-1 and SW-2 tend to be quite similar and the SW-2 February samples tend to also fall within this cluster. However the samples from SW-1 in February are very different from the patterns found at that station during the other two sampling periods. Since the samples all fall in a single discrete cluster, a seasonal succession in the community structure at SW-1 is implied. Such dynamics are not as

Table XI. Correlation matrix of percent sediment composition.

July 1985				July 1985				October 1985			
SW-1	SW-1	SW-1	SW-1	SW-2	SW-2	SW-2	SW-2	SW-1	SW-1	SW-1	SW-1
1	2	3	4	1	2	3	4	1	2	3	4
1.000											
0.984	1.000										
0.998	0.992	1.000									
0.987	0.961	0.976	1.000								
0.685	0.802	0.728	0.622	1.000							
0.288	0.445	0.347	0.212	0.869	1.000						
-0.129	-0.059	-0.137	-0.021	0.126	0.216	1.000					
-0.137	0.032	-0.090	-0.157	0.567	0.803	0.639	1.000				
0.945	0.981	0.954	0.936	0.845	0.523	0.130	0.188	1.000			
0.994	0.985	0.997	0.964	0.717	0.335	-0.207	-0.127	0.935	1.000		
0.999	0.983	0.996	0.992	0.680	0.282	-0.101	-0.133	0.948	0.990	1.000	
0.923	0.959	0.929	0.929	0.827	0.508	0.188	0.190	0.986	0.906	0.930	1.000
-0.176	-0.012	-0.135	-0.177	0.519	0.745	0.701	0.982	0.152	-0.175	-0.167	0.184
0.994	0.998	0.998	0.974	0.759	0.387	-0.091	-0.035	0.970	0.993	0.993	0.946
0.888	0.913	0.886	0.920	0.738	0.415	0.337	0.202	0.965	0.850	0.900	0.965
0.992	0.966	0.982	0.999	0.628	0.219	-0.051	-0.163	0.937	0.972	0.995	0.924
0.938	0.966	0.942	0.947	0.804	0.471	0.190	0.164	0.992	0.917	0.945	0.995
0.998	0.970	0.991	0.991	0.635	0.225	-0.143	-0.197	0.925	0.987	0.998	0.907
0.998	0.994	0.999	0.982	0.730	0.347	-0.099	-0.075	0.962	0.994	0.997	0.942
0.951	0.990	0.966	0.921	0.872	0.555	0.009	0.168	0.990	0.956	0.949	0.964
-0.172	-0.004	-0.125	-0.189	0.535	0.795	0.646	0.998	0.154	-0.162	-0.167	0.158
0.998	0.978	0.993	0.993	0.661	0.252	-0.108	-0.158	0.939	0.987	0.999	0.924
-0.113	-0.015	-0.108	-0.021	0.246	0.355	0.987	0.750	0.178	-0.175	-0.084	0.229
0.113	0.219	0.121	0.185	0.462	0.504	0.937	0.782	0.403	0.055	0.136	0.444

October 1985				February 1986				February 1986			
SW-2	SW-2	SW-2	SW-2	SW-1	SW-1	SW-1	SW-1	SW-2	SW-2	SW-2	SW-2
1	2	3	4	1	2	3	4	1	2	3	4
1.000											
-0.079	1.000										
0.186	0.905	1.000									
-0.190	0.979	0.912	1.000								
0.148	0.957	0.980	0.942	1.000							
-0.230	0.984	0.876	0.995	0.923	1.000						
-0.113	0.999	0.903	0.987	0.954	0.991	1.000					
0.118	0.978	0.919	0.926	0.968	0.928	0.968	1.000				
0.980	-0.070	0.173	-0.195	0.131	-0.231	-0.110	0.132	1.000			
-0.188	0.989	0.893	0.996	0.939	0.999	0.995	0.940	-0.193	1.000		
0.801	-0.057	0.357	-0.048	0.225	-0.134	-0.071	0.070	0.754	-0.096	1.000	
0.816	-0.174	0.550	0.161	0.440	0.082	0.156	0.307	0.778	0.121	0.970	1.000

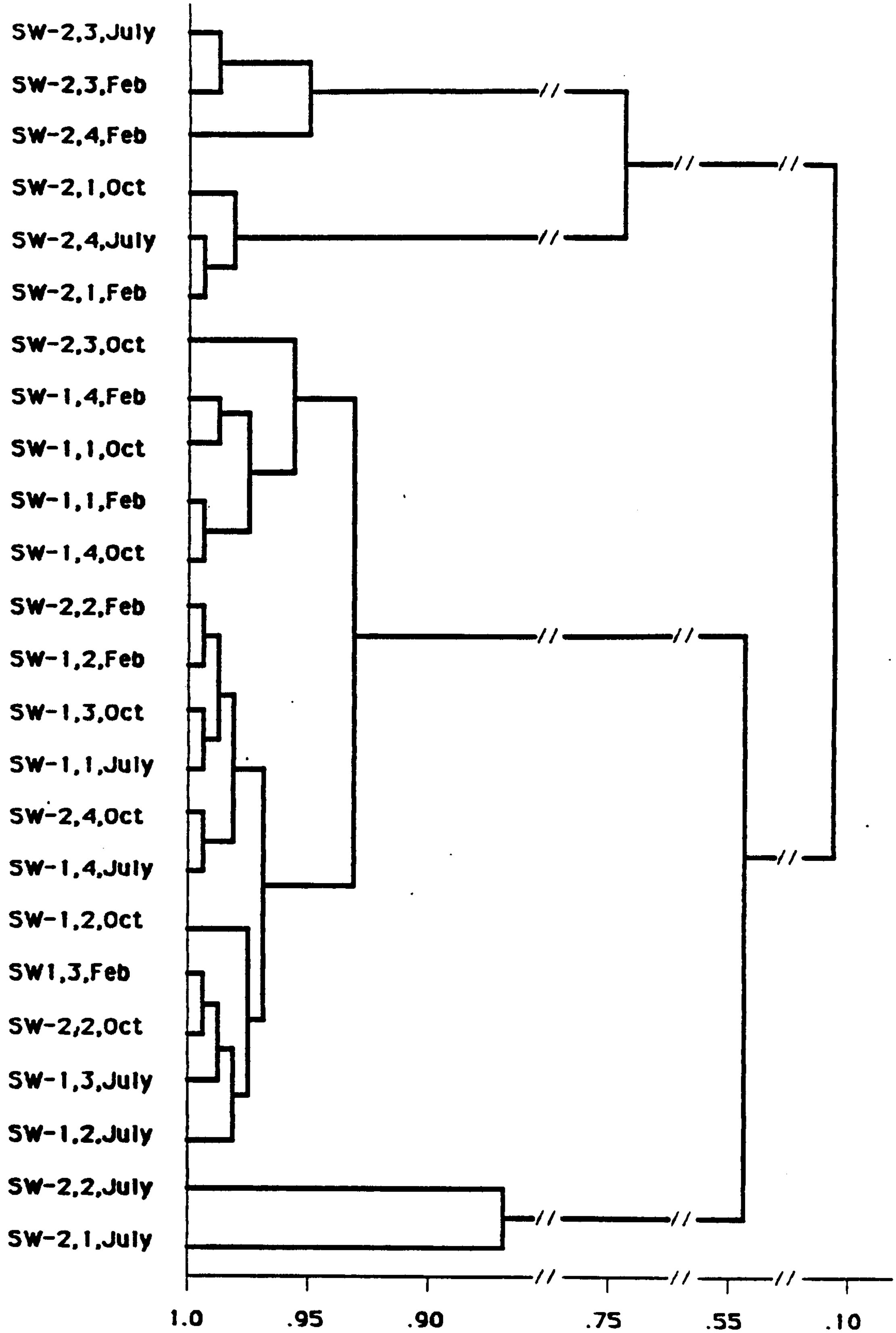
Table XII. Correlation matrix of the benthic communities.

July 1985				July 1985				October 1985			
SW-1	SW-1	SW-1	SW-1	SW-2	SW-2	SW-2	SW-2	SW-1	SW-1	SW-1	SW-1
1	2	3	4	1	2	3	4	1	2	3	4
1.000											
0.718	1.000										
0.987	0.729	1.000									
0.966	0.762	0.986	1.000								
0.958	0.786	0.980	0.990	1.000							
0.941	0.875	0.959	0.967	0.983	1.000						
0.976	0.752	0.997	0.990	0.989	0.971	1.000					
0.927	0.861	0.957	0.958	0.960	0.973	0.962	1.000				
0.942	0.779	0.966	0.983	0.985	0.967	0.976	0.956	1.000			
0.934	0.849	0.960	0.969	0.979	0.983	0.969	0.980	0.983	1.000		
0.612	0.953	0.637	0.645	0.698	0.808	0.665	0.789	0.684	0.765	1.000	
0.946	0.845	0.973	0.969	0.979	0.987	0.979	0.994	0.970	0.986	0.782	1.000
0.956	0.802	0.977	0.992	0.998	0.984	0.986	0.965	0.988	0.985	0.702	0.979
0.692	0.539	0.761	0.689	0.690	0.697	0.755	0.794	0.679	0.725	0.575	0.780
0.731	0.504	0.798	0.729	0.725	0.711	0.789	0.807	0.718	0.748	0.519	0.797
0.372	0.352	0.449	0.351	0.363	0.404	0.443	0.527	0.352	0.427	0.474	0.501
0.230	0.158	0.302	0.190	0.192	0.222	0.288	0.360	0.185	0.252	0.290	0.541
0.012	-0.060	0.084	-0.032	-0.034	-0.013	0.067	0.136	-0.038	0.024	0.089	0.332
0.466	0.265	0.539	0.437	0.432	0.430	0.523	0.559	0.425	0.468	0.346	0.104
0.140	0.027	0.216	0.104	0.099	0.111	0.199	0.261	0.094	0.151	0.156	0.231
0.849	0.791	0.902	0.866	0.884	0.910	0.909	0.948	0.869	0.913	0.796	0.946
0.942	0.737	0.982	0.967	0.972	0.954	0.985	0.969	0.960	0.962	0.677	0.980
0.935	0.684	0.957	0.967	0.969	0.930	0.962	0.907	0.983	0.956	0.580	0.929
0.958	0.705	0.985	0.989	0.989	0.953	0.989	0.940	0.984	0.966	0.606	0.960

October 1985				February 1986				February 1986			
SW-2	SW-2	SW-2	SW-2	SW-1	SW-1	SW-1	SW-1	SW-2	SW-2	SW-2	SW-2
1	2	3	4	1	2	3	4	1	2	3	4
1.000											
0.681	1.000										
0.715	0.992	1.000									
0.352	0.915	0.871	1.000								
0.418	0.840	0.798	0.977	1.000							
0.179	0.697	0.654	0.904	0.972	1.000						
-0.048	0.945	0.932	0.966	0.957	0.822	1.000					
0.085	0.785	0.751	0.941	0.989	0.990	0.938	1.000				
0.879	0.923	0.916	0.744	0.601	0.397	0.751	0.506	1.000			
0.968	0.829	0.858	0.547	0.399	0.185	0.621	0.315	0.947	1.000		
0.972	0.651	0.704	0.310	0.157	-0.055	0.410	0.078	0.825	0.944	1.000	
0.987	0.713	0.760	0.379	0.225	0.010	0.477	0.145	0.871	0.977	0.988	1.000

Figure I

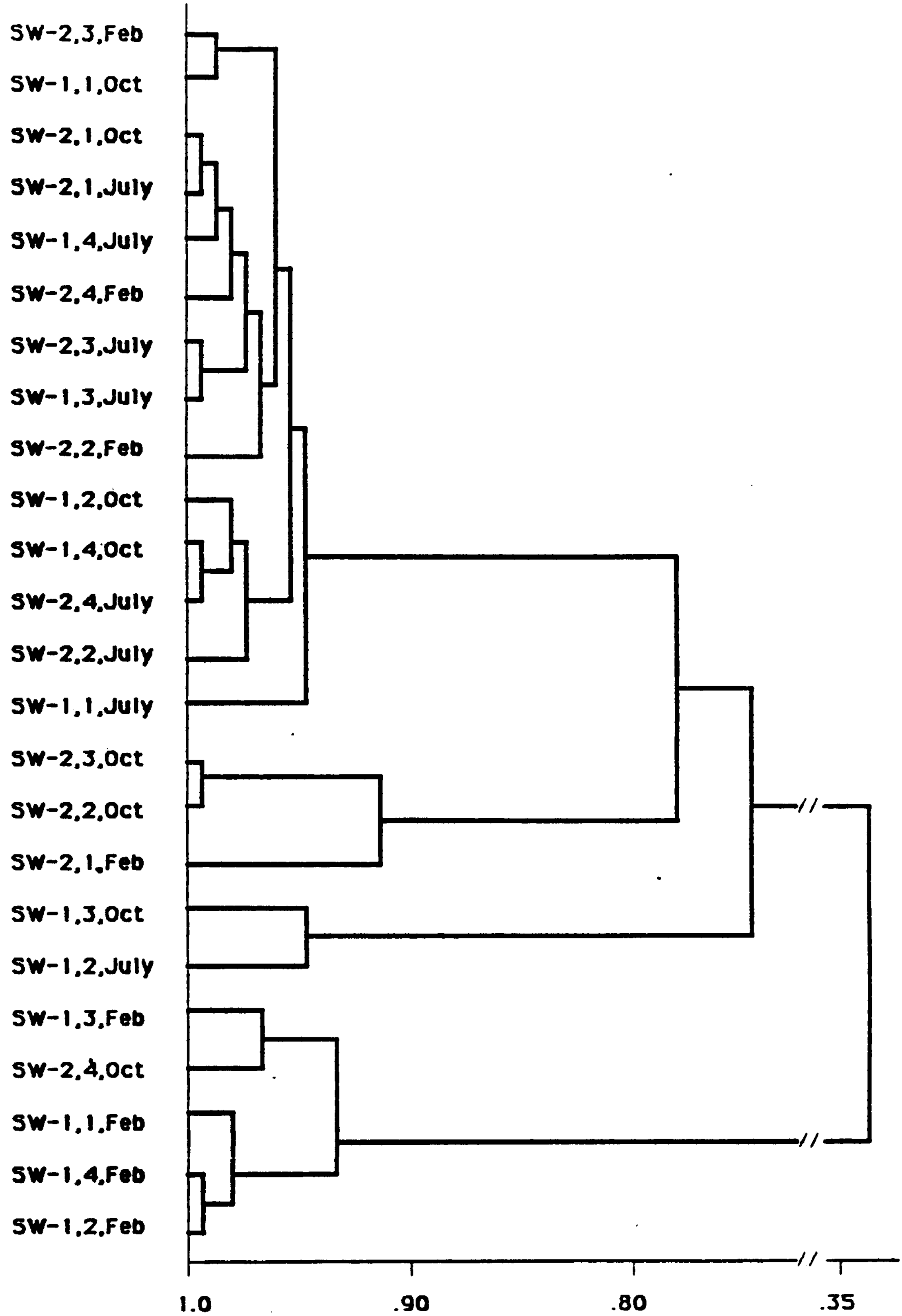
Sediment cluster



SW-2,3,July
SW-2,3,Feb
SW-2,4,Feb
SW-2,1,Oct
SW-2,4,July
SW-2,1,Feb
SW-2,3,Oct
SW-1,4,Feb
SW-1,1,Oct
SW-1,1,Feb
SW-1,4,Oct
SW-2,2,Feb
SW-1,2,Feb
SW-1,3,Oct
SW-1,1,July
SW-2,4,Oct
SW-1,4,July
SW-1,2,Oct
SW1,3,Feb
SW-2,2,Oct
SW-1,3,July
SW-1,2,July
SW-2,2,July
SW-2,1,July
1.0
.95
.90
.75
.55
.10

Figure II

Benthic community cluster


SW-2,3,Feb
SW-1,1,Oct
SW-2,1,Oct
SW-2,1,July
SW-1,4,July
SW-2,4,Feb
SW-2,3,July
SW-1,3,July
SW-2,2,Feb
SW-1,2,Oct
SW-1,4,Oct
SW-2,4,July
SW-2,2,July
SW-1,1,July
SW-2,3,Oct
SW-2,2,Oct
SW-2,1,Feb
SW-1,3,Oct
SW-1,2,July
SW-1,3,Feb
SW-2,4,Oct
SW-1,1,Feb
SW-1,4,Feb
SW-1,2,Feb
1.0
.90
.80
.35

clear from station SW-2, likely because of the sediment variability over time which complicates interpretation of any existing trends.

Conclusions

The data gathered for this study have not yielded discrete answers to the impact or degree of impact of the Trail Mountain Coal Company Mining operation on Cottonwood Creek but an evaluation of the various analytical methods used do allow a conclusion to be reached. The general trends shown by the diversity values and the biotic index do point towards some impact on the downstream station, however that impact, if real, is minor. Additional factors need to be considered. 1) Sediment analysis showed that the lower station underwent greater seasonal changes than did the upper station. It is significant that the predominant sediment type at SW-2 was gravel. This substrate size is less stable than the rubble habitat found at station SW-1, and thus the differences seen between SW-1 and SW-2 communities could be a function of the sediment structure and completely independent of any mining impact. 2) It is also notable that in February the diversity value at SW-1 was actually lower than that at SW-2, implying that if diversity alone were the judgement tool, SW-2 at that time was in better condition than is the upstream SW-1. The location of a road paralleling Cottonwood Creek above SW-1 will also stress the stream independently of the Trail Mountain Mining operation. 3) Observations made when sampling began in July included the presence of a calcarious marl in the sediments at SW-2. Whether sampling sufficiently disturbed this marl and thus initiated the shift in sediment structure observed in October is not known, but must be retained as a possibility. 4) The degree of development of various functional groups differed between the two sites. In particular the filter feeders and grazers are strongly influenced by substrate size since unstable substrates have a lower standing crop of algae and are not good anchoring sites for filter feeders. Different substrate sizes will also influence the settling and retention of different sizes of detrital particles and thus influence the densities and species composition of the shredder groups in the substrate.

In general the differences between the two stations can be sufficiently explained by differences in sediment structure. The higher biotic index values of SW-2, while consistently above that of SW-1, are associated with the microhabitat created in a gravel environment as opposed to a rubble area. The benthic inhabitants of gravel tend to be those which have been given higher biotic index values. This relates to their ability to live under less turbulent (and thus less oxygenated) conditions. The biotic index does not consider variations in substrate type, other than assuming that samples will be taken from the most coarse substrate available. This results in an index which is robust and more reliable than diversity indices, but which can confound the effects of sediment structure and thus give biased results.

Therefore I am concluding that the impact of the Trail Mountain mining operation on the Cottonwood Creek invertebrate community is negligible as determined by the prescribed sampling program. Because of various confounding factors unanticipated in the original design of the study, a more direct conclusion is not possible. It does not appear that additional studies need to be conducted, however if further sampling is required I recommend that several changes be made in the prescribed methodology. First, care should be taken to select a downstream station with canopy cover, sediments and slope conditions comparable to that at station SW-1. This will allow the elimination of the marl as a confounding variable. The taking of four replicate samples is often standard, but usually results in too few samples to give strong statistical confidence in the results of the study. More samples should be taken per station. More frequent sampling will allow a more accurate assessment of seasonal events, and in some ways reduce the extrapolation necessary to interpret results, but monthly sampling is probably not necessary. It also appears that winter samples may not be as useful as samples taken during the warmer months.

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APPENDIX 7-F

PROBABLE HYDROLOGICAL CONSEQUENCE DETERMINATION (PHC) FOR TRAIL MOUNTAIN COAL COMPANY**

**Ch 7-Rev 2-04-87

PROBABLE HYDROLOGIC CONSEQUENCES OF MINING AT THE TRAIL MOUNTAIN MINE, EMERY COUNTY, UTAH

Prepared for

TRAIL MOUNTAIN COAL COMPANY
Orangeville, Utah

Prepared by

EARTHFAX ENGINEERING, INC.
Salt Lake City, Utah

January 1987

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PROBABLE HYDROLOGIC CONSEQUENCES OF MINING AT THE TRAIL MOUNTAIN MINE, EMERY COUNTY, UTAH

1.0 INTRODUCTION

Trail Mountain Coal Company recently submitted a Permit Application Package (PAP) to the Utah Division of Oil, Gas & Mining (the Division) to expand their underground mining operations to the west. This expansion area was termed in the PAP as Tract 2.

The purpose of this document is to present an assessment of the probable hydrologic consequences of the Tract 2 mining operation. Where appropriate, the potential cumulative impacts of both the Tract 2 and the existing Tract 1 operations will be addressed, along with impacts from potential future expansions of the Trail Mountain Mine.

This document is divided into five sections, including this introduction. Section 2.0 presents probable groundwater impacts and proposed groundwater monitoring plans. A similar discussion of surface water is provided in Section 3.0. Conclusions and references are listed in Sections 4.0 and 5.0, respectively.

2.0 GROUNDWATER

2.1 Probable Impacts

2.1.1 Background Information. Information presented in Chapters 6 and 7 of the PAP indicate that groundwater in the mine plan and adjacent areas occurs within the Blackhawk Formation (the coal-bearing formation) and the underlying Star Point Sandstone. These two formations are jointly considered an aquifer in the region (Lines, 1985).

According the Doelling (1972), the Blackhawk Formation consists of interbedded layers of sandstone, siltstone, shale, and coal, all of marine origin. The Star Point Sandstone consists of massive medium- to fine-grained sandstone with minor interbedded layers of shale and siltstone near its base. The Star Point also interfingers locally with the Blackhawk in the vicinity of the mine (Lines, 1985).

Lines (1985) tested core samples of the Blackhawk Formation and the Star Point Sandstone taken from a drill hole located approximately 1.5 miles west of the western Tract 2 boundary. Results of these analyses are presented in Table 2-1. According to these results, the sandstone units within the Blackhawk Formation are five to six orders of magnitude more permeable than the shale and siltstone units. The Star Point Sandstone is one to two times more permeable than the sandstone units of the Blackhawk Formation.

Aquifer tests were conducted by Lines (1985) on selected wells in the vicinity of the Trail Canyon Mine. Due to the low yield of most bedrock in the area, these tests could be performed only as recovery tests following pumping at rates of 5 to 10 gallons per minute for periods less than 5 hours. Nonetheless, the data are useful in determining approximate hydraulic characteristics of bedrock in the mine vicinity.

Based on the transmissivity and thickness data presented by Lines (1985), a hydraulic conductivity of 1.1x10-2 foot per day was calculated for a well completed in the Blackhawk Formation and the Star Point Sandstone in Section 24, T. 17 S., R. 6 E., approximately one-quarter mile north of the Tract 1 permit area. Another test was conducted in a well completed in the Blackhawk-Star Point aquifer in Section 27, T. 17 S., R. 6 E., about 1.5 miles west of the Tract 2 area (the same well from which core was obtained to determine the laboratory hydraulic conductivities provided in Table 2-1). Results of this test indicated a hydraulic conductivity of 1.4x10-2 foot per day. Both of these values compare favorably with the laboratory results reported in Table 2-1.

Table 2-1. Results of laboratory analyses of selected core samples (from Lines, 1985).

[Determinations by Core Laboratories, Inc., Dallas, Texas]

Lithology: Sh, shale; Slt, siltstone; Ss, sandstone; f, fine grained; m, medium grained.
Hydraulic conductivity: I, impermeable to water even at a pressure of 5,000 pounds per square inch.

Geologic unit	Lithology	Depth below land surface (feet)	Porosity (percent)	Hydraulic conductivity (feet per day)	
				Horizontal	Vertical
Blackhawk Formation	Ss, f	1,521	14	$1.5x10^{-2}$	$3.7x10^{-3}$
	Slt	1,545	3	$9.3x10^{-8}$	$1.2x10^{-7}$
	Sh	1,786	2	I	I
	Ss, f	1,792	14	$1.1x10^{-2}$	$3.9x10^{-3}$
	Sh	2,170	4	$1.1x10^{-8}$	---
	Slt	2,265	2	$2.0x10^{-7}$	$2.2x10^{-6}$
Star Point Sandstone	Ss, m	2,466	17	$3.1x10^{-2}$	$1.1x10^{-2}$
	Ss, m	2,493	11	$1.5x10^{-2}$	$6.6x10^{-3}$

Lines (1985) also reported the results of a constant-drawdown and recovery test conducted in a since-abandoned flowing well located in Straight Canyon (Section 4, T. 18 S, R. 6 E.) approximately 2.5 miles east-southeast of the southeast corner of the proposed Tract 2 permit area. This well was located near the center of the Straight Canyon Syncline immediately east of the Joes Valley Fault in an area of suspected fracturing (Lines, 1985). The hydraulic conductivity of the Blackhawk-Star Point aquifer at this location (as determined from the measured transmissivity and the thickness) was calculated to be 1.6x10-1 foot per day, approximately one order of magnitude more permeable than the unfractured Blackhawk-Star Point aquifer as determined from previously mentioned laboratory and field tests. Lines (1985) attributed the relatively high value to fracturing.

No major fractures are known to exist within the mine plan and adjacent areas (see Section 6.4.2) that might increase the permeability of the Blackhawk-Star Point aquifer. Thus, based on the remaining laboratory and field tests, this aquifer is assumed to have a hydraulic conductivity ranging from about 0.01 to 0.03 foot per day.

Data presented in the PAP (as developed initially by Lines, 1985 and modified using local data from the mine area) indicate that the flow of groundwater in the Blackhawk-Star Point aquifer is primarily to the south-southwest toward Straight Canyon. The hydraulic gradient within this aquifer varies in the eastern portion of the permit area from about 0.029 to 0.055 foot per foot, averaging 0.039 foot per foot. In the western portion of the permit area, the hydraulic gradient ranges from about 0.046 to 0.061 foot per foot, averaging 0.048 foot per foot.

2.1.2 Potential Dewatering Impacts. Potential inflows to underground workings at the Trail Canyon Mine were determined from modeling studies conducted by Lines (1985) using a three-dimensional finite-difference model developed by McDonald and Harbaugh (1984). Lines (1985) considered the mine inflow and drawdown estimates determined as a result of these modeling studies to be "more reliable than those that could be made with other more simplified analytical techniques." In light of the fact that rigorous analytical techniques that apply to the local conditions are not available (Freeze and Cherry, 1979), the results of Lines' modeling efforts are considered adequate for inflow and drawdown estimation.

Lines assumed that the Blackhawk-Star Point aquifer could be simulated with three layers (two in the Blackhawk and one in the Star Point) and that the aquifer was isotropic and infinite in areal extent. Drawdown effects were modeled for various mine widths, mine lengths, pre-mining hydraulic gradients, and hydraulic conductivities.

Figure 2-1 shows the effect of mine size on expected inflow rates as determined by Lines (1985). Results presented in this figure are base on hydraulic conductivities of 0.01 foot per day for the Blackhawk Formation and 0.02 foot per day for the Star Point Sandstone. These values are very similar to the laboratory hydraulic conductivities reported by Lines (1985) for sandstone units within the Blackhawk Formation and for the Star Point Sandstone, respectively. They are also similar to the hydraulic conductivities calculated in Section 2.1.1 for the Blackhawk-Star Point aquifer from transmissivity and thickness data reported by Lines (1985) from local aquifer tests. Thus, the results are considered representative of local conditions.

According to Figure 7-3 of the PAP, the Tract 1 and Tract 2 mine workings will have a maximum length of 9000 feet. Figure 2-2 was prepared from Figure 2-1 using this mine length, showing potential mine inflows for various mine widths and two premining hydraulic gradients.

Comparing Figure 7-3 of the PAP with Figure 7-1 of the PAP and Figure 5 of Lines (1985), the maximum width of the potentially saturated Tract 1 and Tract 2 workings will be 6000 feet. Utilizing a premining hydraulic gradient of 0.041 foot per foot as being most representative of local conditions, Figure 2-2 indicates a potential steady-state inflow of approximately 70 gallons per minute. Using a premining hydraulic gradient of 0.065 foot per foot to represent a worst-case scenario, Figure 2-2 indicates a potential steady-state inflow of about 165 gallons per minute. Inflow rates are likely to be more near the lower end of the range except perhaps in the western portion of the permit area where hydraulic gradients are steeper and heads are greater.

If areas of significant fracturing are encountered in the saturated portion of the mine workings, inflows to the mine would increase. However, as noted previously, no significant fracturing is known to exist in the mine area that would result in increased inflows above the predicted range.

Future mining within the Trail Mountain Mine (beyond Tract 2) could conceivably extend approximately 3000 feet to the west of Tract 2 and 4000 feet south of Tracts 1 and 2. Mining to the south should not significantly increase potential inflows to the mine workings since much of this area is unsaturated (based on a comparison of Figure 7-1 of the PAP with Figure 5 of Lines, 1985). However, mining to the west would continue into the saturated zone, thus increasing potential mine inflows. By extrapolation of the curves in Figure 2-2, increasing the width of the mine from 6000 to 9000 feet should increase inflows by less than 10 gallons per minute under either premining hydraulic gradient condition.

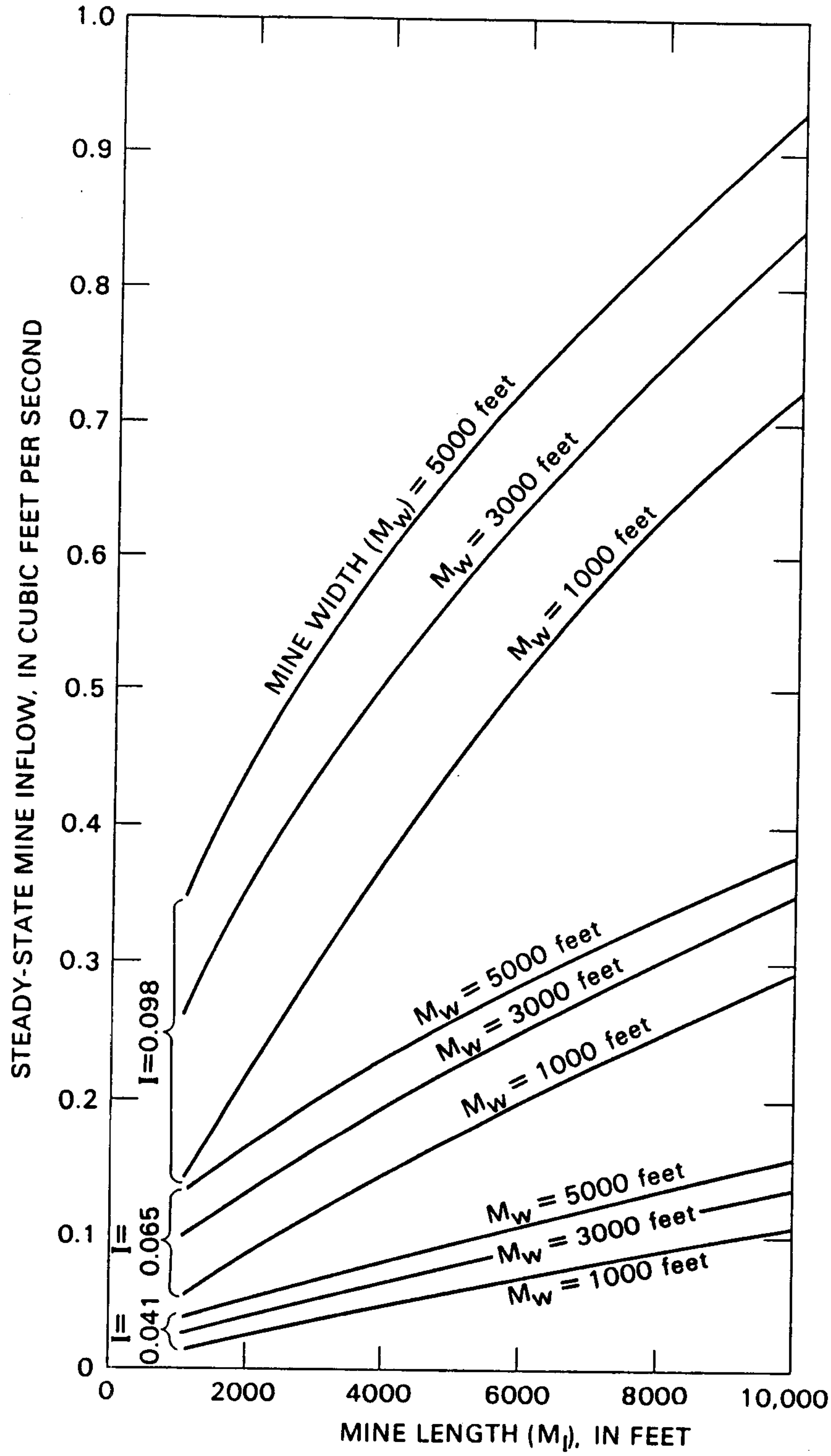

Figure 2-1. Effect of mine size and premining hydraulic gradient on mine inflow (from Lines, 1985).

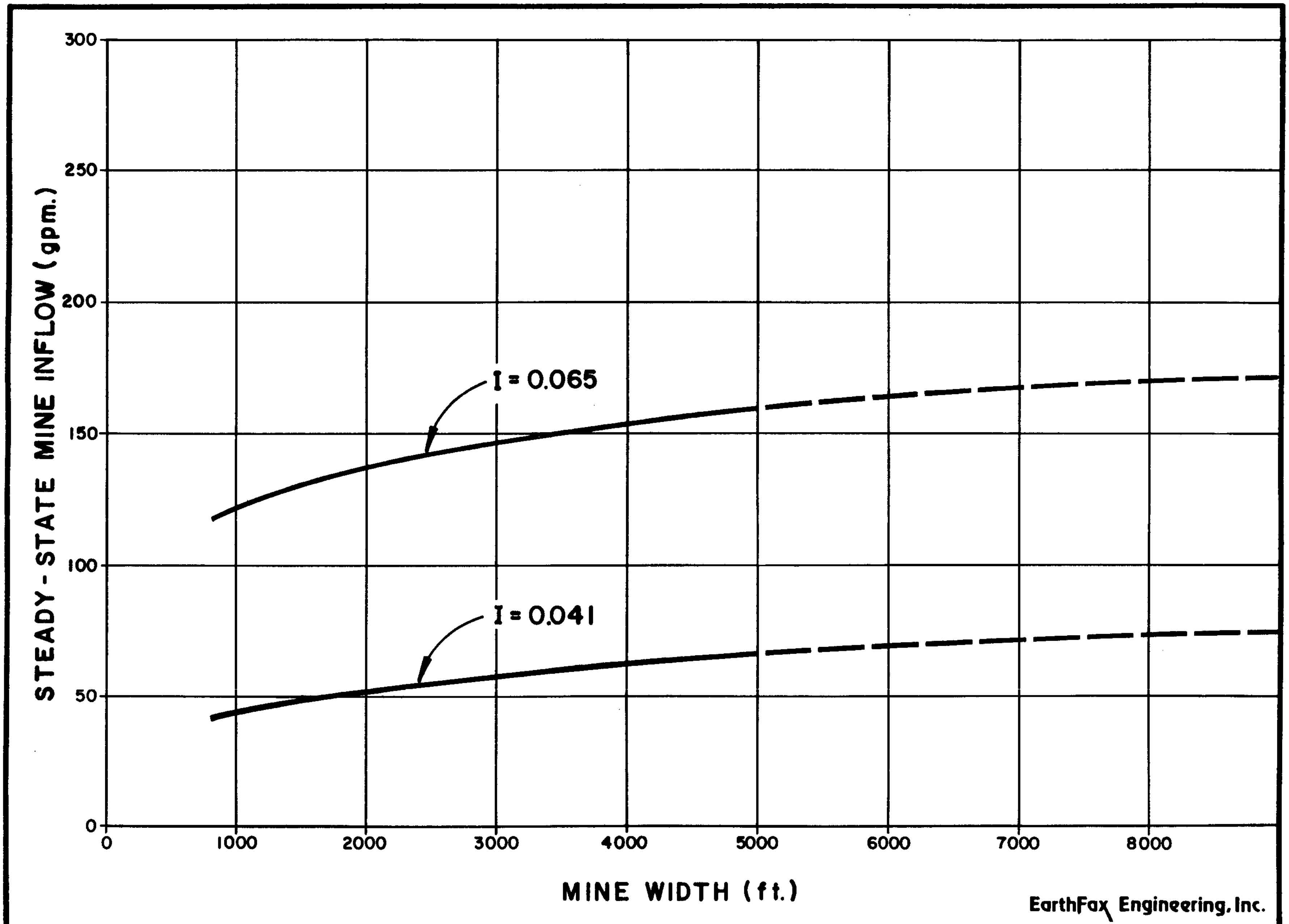

Figure 2-2. Effect of mine width on steady-state inflow for a mine length of 9000 feet.

As noted in Section 7.1.3.2 of the PAP, in-mine water requirements are projected to amount to approximately 100 gallons per minute. As a result, water that naturally flows into the mine workings will probably all be used underground, except potentially when mine workings are concentrated near the western portion of the permit area. Thus, during most of the mining period, the need for pumping mine water to the surface will be eliminated. Similarly, the use of water that flows into the mine to satisfy underground requirements will preclude the need to pump that quantity of water from Cottonwood Creek (the current source of water for underground use).

Lines (1985) modeled potential drawdown due to mine dewatering for a hypothetical mine with a length of 10,000 feet, a width of 1000 feet, and a premining hydraulic gradient of 0.065 foot per foot. Curves developed from these modeling results are presented in Figure 2-3 for hydraulic conductivities of 0.01 and 0.02 foot per day for the Blackhawk Formation and Star Point Sandstone, respectively. Since the premining hydraulic gradient used to develop these curves is generally greater than the gradient in the mine area, the impacts predicted using these curves will be conservatively high.

Since the Trail Mountain Mine will be wider than 1000 feet, actual drawdowns near the center of the mine will be greater than predicted by Figure 2-3 (due to the law of superposition). However, the curves are reliable in predicting the maximum extent of drawdown effects near the mine (since superposition does not affect the outer limit of the impact). Under a worst-case condition (i.e., all water encountered in the mine is pumped to the surface), data presented in Figure 2-3 indicate that, after 50 years of mining and accompanying dewatering (a probable maximum period of mining), the cone of depression resulting from dewatering can be expected to extend about two miles from the mine in the direction of the mine length (Dy) and five miles from the mine in the direction of the mine width (Dx). These effects will be most notable to the north and west of the mine since the Blackhawk Formation is typically unsaturated to the east and south.

Unless subsidence fractures extend vertically to overlying perched aquifers, inflow to the mine workings will be derived totally from the Blackhawk-Star Point aquifer. According to Lines (1985), only perched groundwater systems exist above the Blackhawk Formation. Thus, springs in overlying formations are not hydraulically connected to the Blackhawk and will not be impacted by mine inflows.

Data presented in Chapter 7 of the PAP (Appendix 7-1) and by Lines (1985) indicate that only three springs issue from the Blackhawk Formation within the zone of potential influence from dewatering. No other seeps or springs issuing from the Blackhawk

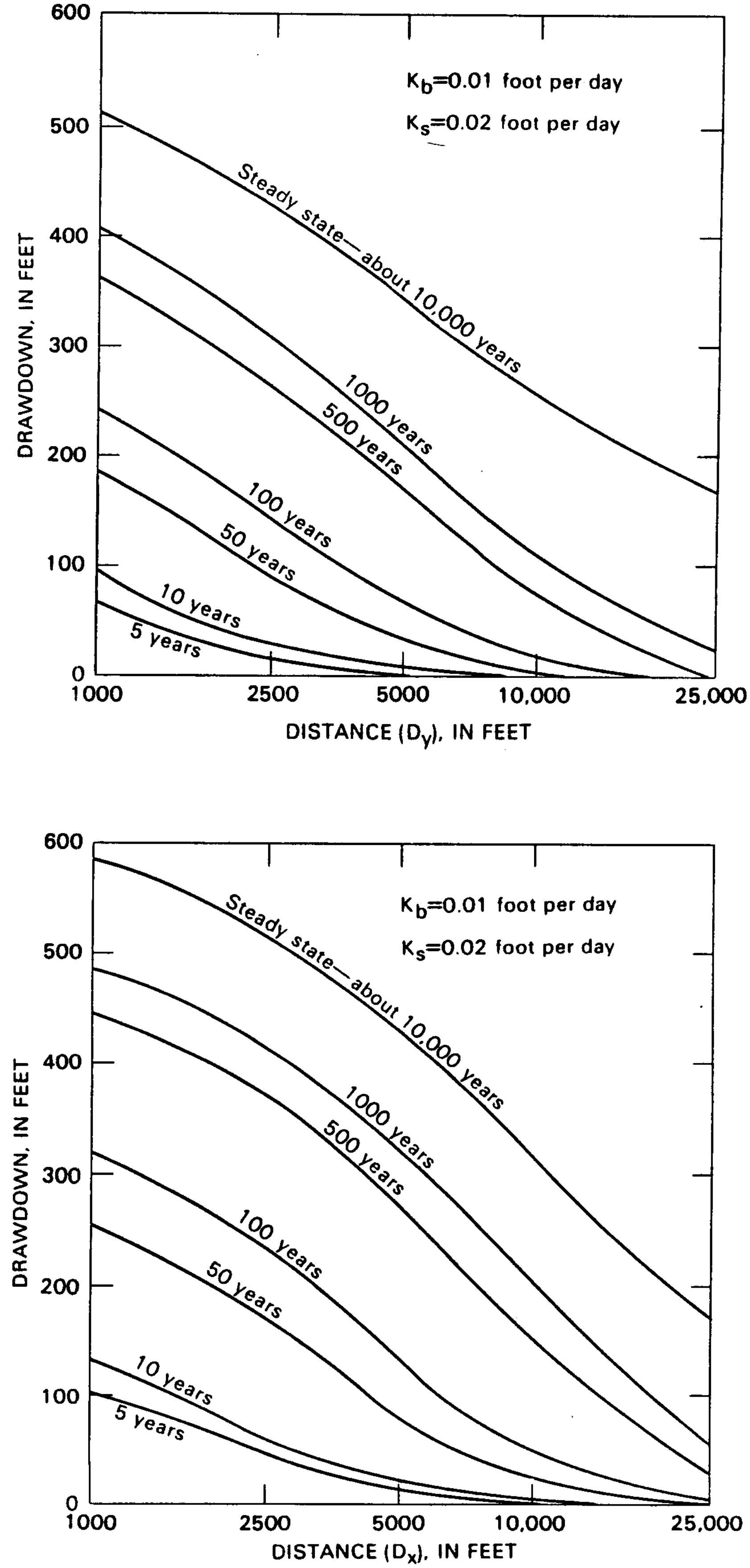

Figure 2-3. Effect of mine size and time on drawdown in the Blackhawk-Satr Point aquifer (from Lines, 1985).

Formation have been noted in the area adjacent to the mine plan area.

Spring TM-23 (discussed in the PAP) is located immediately adjacent to Cottonwood Creek, with flow from this spring comprising a portion of the baseflow of the stream. Flows from this spring were reported in the PAP as ranging from 4 to 110 gallons per minute during the period of record.

Springs (D-18-6)4bbc-S1 and (D-18-6)5abd-S1 (both discussed by Lines, 1985) issue in the bottom of Straight Canyon, immediately downstream from Joes Valley Reservoir. These springs also contribute to the baseflow of Cottonwood Creek via Straight Canyon. Lines (1985) reported that the flow of the former spring has been less than 2 gallons per minute during the period of observations. The latter spring had measured discharge rates of 180 and 200 gallons per minute during two observations in 1982.

Since other springs in the mine plan and adjacent areas are located above the regional water table, the primary impact from mine dewatering will probably be a decrease in the flow of Cottonwood Creek (diverting water either from one of the indicated springs or from diffuse inflow to Cottonwood Creek and Straight Canyon). Based on an average annual flow of Cottonwood Creek near Orangeville of 70,700 acre-feet (see Section 7.2.2.1 of the PAP), the potential annual flow reduction of Cottonwood Creek (70 to 165 gallons per minute) is approximately 0.2 to 0.4 percent of the average flow (assuming none of the inflowing water is used underground). These flow changes will decrease the amount of water available for downstream irrigation, stockwatering, and wildlife usage.

2.1.3 Potential Subsidence Impacts. The maximum area of potential surface expression of subsidence due to mining in the Tract 1 and Tract 2 areas is presented in Figure 7-3 of the PAP. Only two springs exist within this area. Data presented in Appendix 7-1 of the PAP indicate that spring T-10 issues from the North Horn Formation with a maximum measured flow of 2 gallons per minute. Spring T-14 issues from the Price River Formation with a maximum measured flow of 1.5 gallons per minute. Flows at each spring have been measured only during early autumn, suggesting that flows during the spring and summer period may be higher.

Subsidence fractures may potentially divert flow from the North Horn and Price River Formations to deeper formations. Such fractures could create a hydraulic connection between the upper perched layers (from which T-10 and T-14 issue) and deeper zones, including the Blackhawk-Star Point aquifer. If this occurred, flow from the perched springs would decrease. Water that is diverted to the Blackhawk-Star Point aquifer may increase inflows to the mine workings beyond that predicted in Section 2.1.2.

If flow from springs T-10 and/or T-14 is decreased as a result of mining, wildlife that currently utilize the springs will be displaced. Displacement would probably be to the west where additional springs exist.

According to data presented by Lines (1985), water quality is similar in all aquifers in the Trail Mountain area. Thus, subsidence should not degrade the quality of groundwater. Some improvement of groundwater quality may even occur since flow rates through the bedrock would increase and residence time in the bedrock would decrease. This would decrease dissolution and lower the dissolved concentrations of various constituents below current concentrations.

2.2 Groundwater Monitoring Plan

A groundwater monitoring plan has been previously submitted to the Division by Trail Mountain Coal Company. This plan includes monitoring of selected springs, monitoring wells, and an underground drill hole in the permit and adjacent areas. Details of this plan can be found in Section 7.1.6 of the PAP.

3.0 SURFACE WATER

3.1 Probable Impacts

3.1.1 Background Information. According to Chapter 7 of the PAP, the Trail Mountain Mine is located within the Cottonwood Creek watershed. Cottonwood Creek has had an average annual flow of 70,700 acre-feet, approximately 60 percent of which occurs during the period of May through July as snowmelt runoff. The quality of water in Cottonwood Creek is good near the mine, with total dissolved solids concentrations generally less than 400 milligrams per liter.

The Tract 2 area is drained entirely by ephemeral and intermittent streams. Watersheds tend to be steep and well vegetated.

3.1.2 Potential Water-Quality Impacts. Expansion of the mining operations into Tract 2 will not require the addition of any surface facilities. Existing runoff and sediment-control facilities were designed in accordance with applicable Division regulations and are maintained to minimize sediment concentrations from the surface facilities to Cottonwood Creek. Thus, no increase in impacts will occur to local water quality as a result of the Tract 2 operations.

3.1.3 Potential Water-Quantity Impacts. Water for in-mine use is currently diverted from Cottonwood Creek. As the mine workings expand to the west (into the saturated zone), it is suspected that most water required for underground use will be derived from mine inflows, thus decreasing the need to pump water from the creek.

Under a worst-case scenario, mine inflows would be insufficient to meet underground water requirements. Under this condition, water would be continually diverted from Cottonwood Creek for underground use. As noted in Section 7.1.3.2 of the PAP, expected in-mine water requirements are 100 gallons per minute when the mine is fully developed. Assuming a 250-day work year, this quantity amounts to approximately 110 acre-feet per year. This quantity represents 0.2 percent of the average annual flow of Cottonwood Creek. A reduction in the flow of the stream would decrease the amount of water available for downstream irrigation, stockwatering, and wildlife usage.

3.2 Surface-Water Monitoring Plan

A surface-water monitoring plan has been previously submitted to the Division by Trail Mountain Coal Company. Details of this plan can be found in Appendix 7-D of the PAP.

4.0 CONCLUSIONS

The following conclusions have been presented in this document in relation to potential hydrologic impacts from mining at the Trail Mountain Mine:

- o Inflow of water to the underground workings at the Trail Canyon Mine are expected to range between 70 and 165 gallons per minute. Inflows are predicted to be lowest in the eastern portion of the mine and highest to the west, where hydraulic gradients are steeper and heads are greater. Inflow to the mine workings will be derived primarily from the Blackhawk Formation.

- o Expansion of the mine workings 3000 feet west and 4000 feet south of Tract 2 would increase inflows to the mine by less than 10 gallons per minute.

- o Most water encountered underground will be used underground during mining.

- o The cone of depression resulting from mine dewatering will extend a maximum of two miles north and south of the mine and five miles east and west of the mine. These effects will be most notable to the north and west where the bedrock is saturated.

- o The primary potential impact due to a drawdwon of the potentiometric surface near the mine is a decrease in the baseflow of Cottonwood Creek. The maximum potential decrease in the average annual flow of Cottonwood Creek near Orangeville is 0.2 to 0.4 percent.

- o Due to the limited number of springs in the immediate vicinity of the mine, subsidence is predicted to have little impact on local spring flow. Springs that are diverted as a result of subsidence will displace wildlife to the west where additional springs exist.

- o No adverse impacts to surface or groundwater quality are anticipated as a result of mining at the Trail Mountain Mine.

- o If insufficient water is encountered in the mine to meet underground water needs, a maximum of 100 gallons per minute would need to be diverted from Cottonwood Creek for underground use. This quantity represents 0.2 percent of the average annual flow of the stream.

5.0 REFERENCES

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McDonald, M.G. and A.W. Harbaugh. 1984. A Modular Three-Dimensional Finite Difference Ground-Water Flow Model. U.S. Geological Survey Open-File Report 83-875.

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APPENDIX 7-G

CALCULATIONS AND RATIONAL USED TO CALCULATE MINE INFLOW FOR TRAIL MOUNTAIN COAL COMPANY TRACT 2 MINE PLAN AREA**

**Ch 7-rev 1-10-87

EarthFax Engineering, Inc.
Engineers/Scientists

December 19, 1986

C-54

Mr. Allen P. Childs
Trail Mountain Coal Company
P.O. Box 370
Orangeville, Utah 84537-0370

Dear Allen:

Pursuant to your request, we have reviewed the statement made in Chapter 7 of the Tract 2 permit application package (PAP) regarding potential inflows to the mining operations. Apparently, an important figure used to determine the expected inflow rate was inadvertently omitted from the PAP. This figure (reproduced herein as Figure 1) was developed by Lines (1985) based on the results of analyses using a three-dimensional, finite-difference model (McDonald and Harbaugh, 1984) to determine drawdown effects from mining operations in the Trail Mountain area.

As noted by Lines (1985), his modeling results are based on assumed hydraulic conductivities of 0.01 and 0.02 foot per day for the Blackhawk Formation and the Star Point Sandstone, respectively. He further assumed that the formations acted as a single aquifer and that the aquifer was isotropic. Drawdown effects were modeled for various mine widths and lengths based on selected premining hydraulic gradients.

According to Lines (1985) and data presented in Figure 7-1 of the PAP, the premining hydraulic gradient in the vicinity of the Trail Mountain Mine is 0.04 foot per foot. Entering Figure 1 with this gradient and a mine length and width of 9000 feet and 5000 feet, respectively, the steady-state mine inflow was determined to be 0.15 cfs (approximately 70 gpm).

Lines (1985) indicates that the model results represent "order-of-magnitude estimates of mine inflow . . ." but that "the estimates are more reliable than those that could be made with other more simplified analytical techniques." Thus, although the actual inflow may vary slightly due to local changes in the hydraulic properties of the aquifer, the inflow estimate of 70 gpm is considered adequate for this investigation.

7324 South 1300 East, Suite 100 Midvale, Utah 84047 (801) 561-1555

It was noted in the PAP that the 70 gpm estimate is based on the mine workings encountering fully saturated bedrock. Since this will not be case throughout the mine, the estimated inflow probably represents a maximum value. Additionally, the lack of known fractures in the vicinity of the mine reduces the potential for major unanticipated inflows.

If you have any questions regarding our explanation, please contact us.

Sincerely,

Rich

Richard B. White, P.E.
Principal Hydrologist

Enclosure (Figure 1)

References

Lines, G.C. 1985. The Ground-Water System and Possible Effects of Underground Coal Mining in the Trail Mountain Area, Central Utah. U.S. Geological Survey Water-Supply Paper 2259.

McDonald, M.G. and A.W. Harbaugh. 1984. A Modular Three-Dimensional Finite-Difference Ground-Water Flow Model. U.S. Geological Survey Open-File Report 83-875.

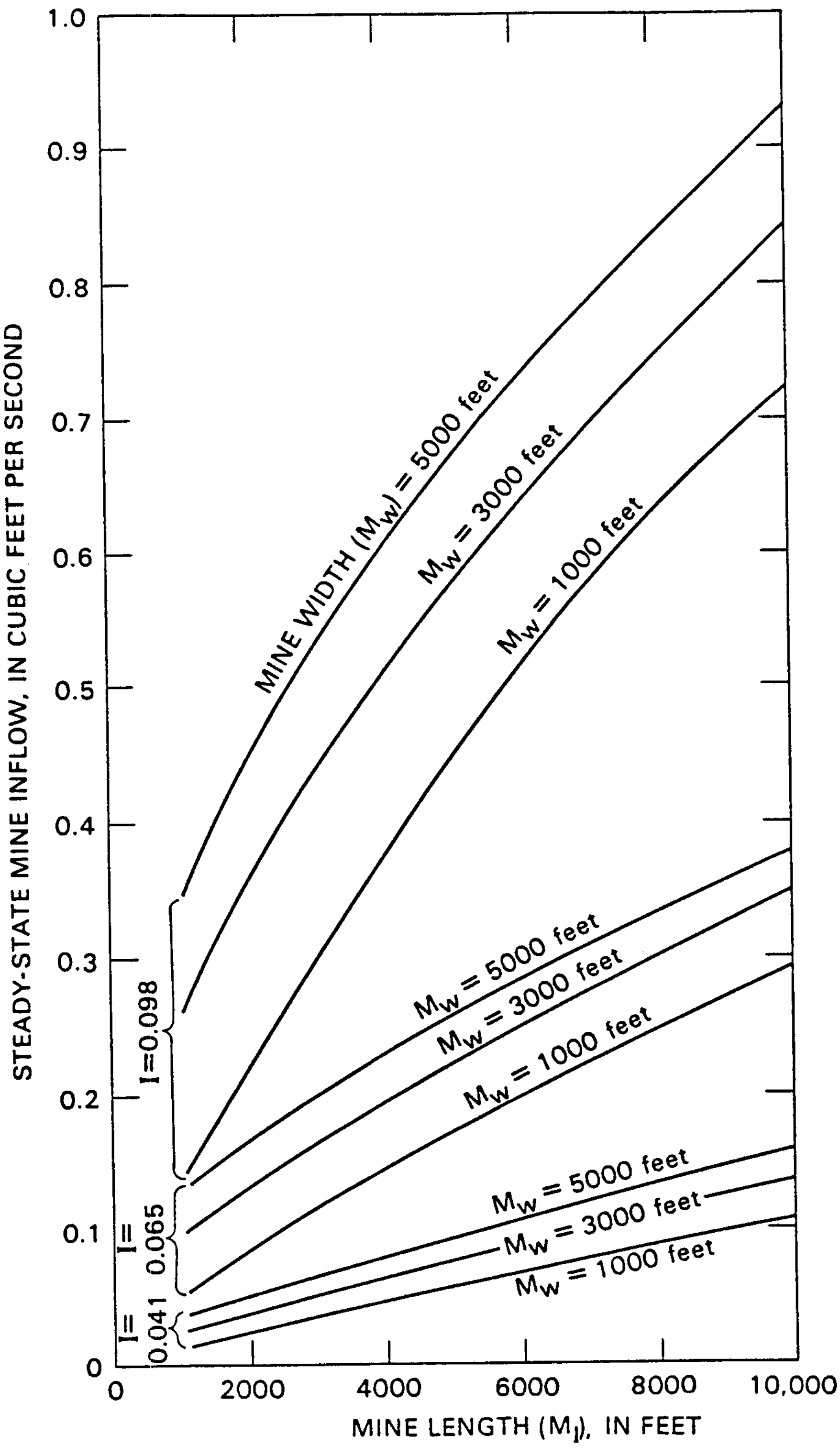

Figure 1. Variation in mine-water inflow rates in the Trail Mountain area (from Lines, 1985).

APPENDEX 7-H

MINE INFLOW DETERMINATION

(TRACT I MINE PLAN AREA) **

**Ch 7-Rev. 3-4-87

INFLOW DETERMINATION

Trail Mountain Coal Company isolated a 64 acre section of the Trail Mountain Mine (See figure 7-4). This section was isolated for 65 days and mine inflows were allowed to collect at the bottom of the section At the end of 65 Days, all mine inflow that was collected at the bottom of the section was pumped to an in-mine sump to determine the amount of inflow.

A 5 HP pump was used to pump inflow. The 5 HP pump pumped water at a rate of 390 gallons per minute. The pump was in service for 24 hours and pumped 561,000 gallons of water. From this data it was determined that .0938 gpm of inflow was produced from each acre of reserve.

A total of 57 gpm of inflow was determined for the Tract I area. (See the following calculations.)

CALCULATIONS USED TO DETERMINE TRACT I INFLOW

Section was pumped for 65 days;

65 days	=	1,560 hours
1,560 hours	=	93,600 minutes
93,600 minutes	=	65 days

Section was pumped for 24 hours;

24 hours	=	1,440 minutes
5 HP rating	=	390 gpm
1,440 min. x 390 gpm	=	561,600 gallons

Total amount of water pumped from 64 acres = 561,600 gallons.

During a 65 day (93,600 minutes) period, 561,600 gallons of inflow was collected from a 64 acre area.

561,600 gallons/93,600 minutes = 6.0 gpm

6.0 gpm inflow from 64 acres (.0938 gpm/acre)

Total reserve area of Tract I is approximately 605 acres.

605 acres x .0928 gpm/acre = 57 gpm total mine inflow.

APPENDIX 7-I**

ADDITIONAL GROUND WATER MONITORING

ASSOCIATED WITH TRACT 2

1. PONDS
2. ADDITIONAL GROUNDWATER
3. ADDITIONAL WELLS

**CH 7-Rev. 3-26-87

1. PONDS

Trail Mountain Coal Company has implemented a monitoring plan for monitoring the effects of subsidence on the runoff-fed ponds on and adjacent to Trail Mountain Coal Company Tract 2 Mine Plan Area. (See Figure 7-3 for list and location of ponds.)

Monitoring will consist of quarterly physical inspections, as accessable, of the pond sites. During these inspections a log will be kept noting the states of each pond and the presence on any subsidence related impacts. In addition to a log, Trail Mountain Coal Company will keep a pictorial diary of all ponds.

2. ADDITIONAL GROUNDWATER MONITORING

Trail Mountain Coal Company plans to monitor locations T-18 and T-19. T-19 is a regional aquifer down gradient from Tract 2 in the Straight Canyon area. (See Figure 7-3) This location will be monitored in accordance with the water monitoring guidelines contained in Appendix 7-3. This location will be monitored four times per annum as accessible. This will be a baseline monitoring location.

T-18 is in mine discharge from the abandoned and sealed Oliphant Mine located down gradient from Tract 2 in the Straight Canyon area. (See Figure 7-3)

This location will also be monitored in accordance with Appendix 7-3 guidelines. T-18 will be monitored four times per annum, as accessible, and will be a baseline monitoring location. T-18 is a postmining discharge and should be useful in gauging the post mine water quality of the Trail Mountain Mine.

3. ADDITIONAL MONITORING WELLS

Trail Mountain Coal Company commits to develop an additional in mine groundwater monitoring well. This proposed well will be identified as TM-3 (See Figure 7-3). TM-3 will be located at the western extent of the 6th West Main and will be drilled upon completion of the development of the 6th West Mains. In conjunction with the drilling of this observation well, roof and floor rock samples with be drilled and collected for analysis. This analysis will better characterize the pyritic content and potential alkalinity of the strata within Tract 2.

TM-3 will be monitored quarterly in accordance with the water monitoring guidelines contained in Appendix 7-3. TM-3 will be a baseline monitoring well used to monitor the regional aquifer (Starpoint Aquifer).