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Changes in Groundwater Chemistry and Groundwater Elevation in Response to Peak Hydrograph Conditions

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1.0 Introduction

1.1 Background

Tailings material deposited in some parts of the Clark Fork River floodplain can become saturated when groundwater elevations increase as river stage increases, providing a potential load source of constituents of concern to the Clark Fork River. The changes in shallow groundwater chemistry and the shallow groundwater gradient and flow direction near the Clark Fork River must be quantified to determine if there is any load of constituents of concern (arsenic, cadmium, copper, lead, and zinc) associated with peak stage and high groundwater conditions during spring runoff and snowmelt processes. Several monitor wells were installed within two small watersheds along the Clark Fork River floodplain as part of the Governor's Demonstration Project Monitoring (Schafer & Associates, 1997). This report examines shallow groundwater flux and shallow groundwater chemistry at the control and treated microwatersheds during peak river stage and shallow groundwater elevations, and how they change when river stage decreases to base flow levels.

1.2 Approach

The hydraulic properties of the soil, tailings, and aquifer materials were examined along with changes in shallow groundwater chemistry. Hydraulic properties of alluvium were determined using pumping tests, slug tests, and bore hole permeameter tests. Groundwater samples were collected from shallow groundwater monitoring wells and drive point piezometers completed at the Governor's Demonstration Project control and treated microwatersheds, located in the river floodplain, during base flow and during the climbing limb, peak, and declining limb portions of the river hydrograph.

The seasonal variation in groundwater chemistry and elevation was examined at the Governor's Demonstration Project control and treated microwatersheds, depicted on Figure 1.1. The treated microwatershed was reclaimed by incorporating lime using deep plow methods and revegetating. A detailed description of the reclamation work can be found in the Final Report on the Clark Fork River Governor's Demonstration Project (1991). The control microwatershed has not been reclaimed. Both watersheds have been instrumented to observe climatic conditions, measure surface water run off, and measure changes in volumetric water content in the near surface soil. Monitor wells and drive point piezometers have been installed to measure groundwater elevation and to collect groundwater samples.

A large quantity of groundwater chemistry and hydrologic data were available at the Governor's Demonstration Project control and treated microwatersheds as a result of aquifer testing and extensive water quality sampling. Therefore, the analysis of potential changes in shallow groundwater chemistry and groundwater elevation in response to spring peak hydrograph conditions was conducted at the two microwatersheds. Detailed maps of the two microwatersheds, displaying monitor well, observation well, and drive point piezometer locations, are presented in Figures 1.2 and1.3.

The spring peak hydrograph is associated with water entering the Clark Fork River from annual snowmelt processes and from precipitation during snow melt. Changes in river stage and groundwater elevation associated from a single precipitation event are not analyzed in this report.

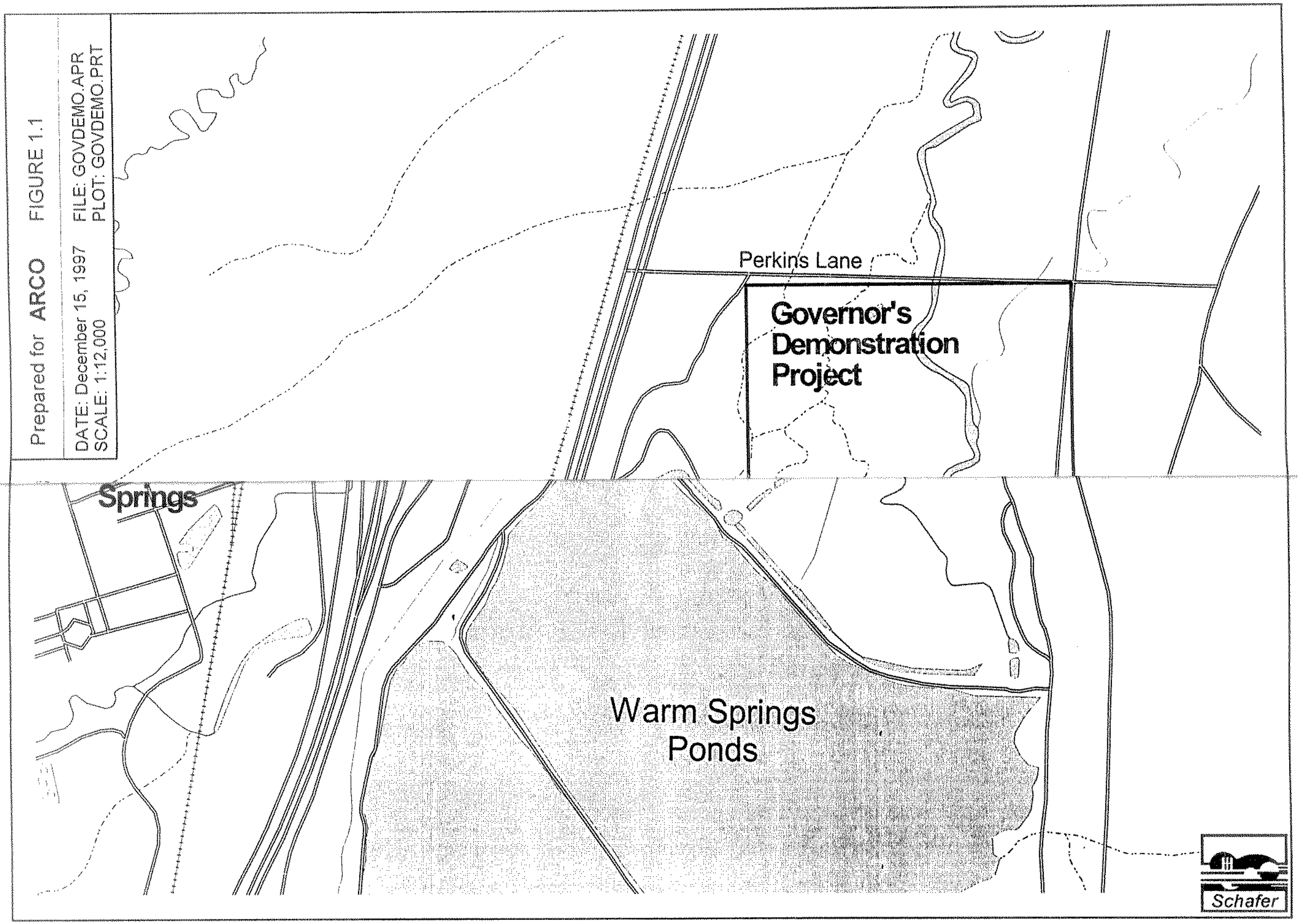
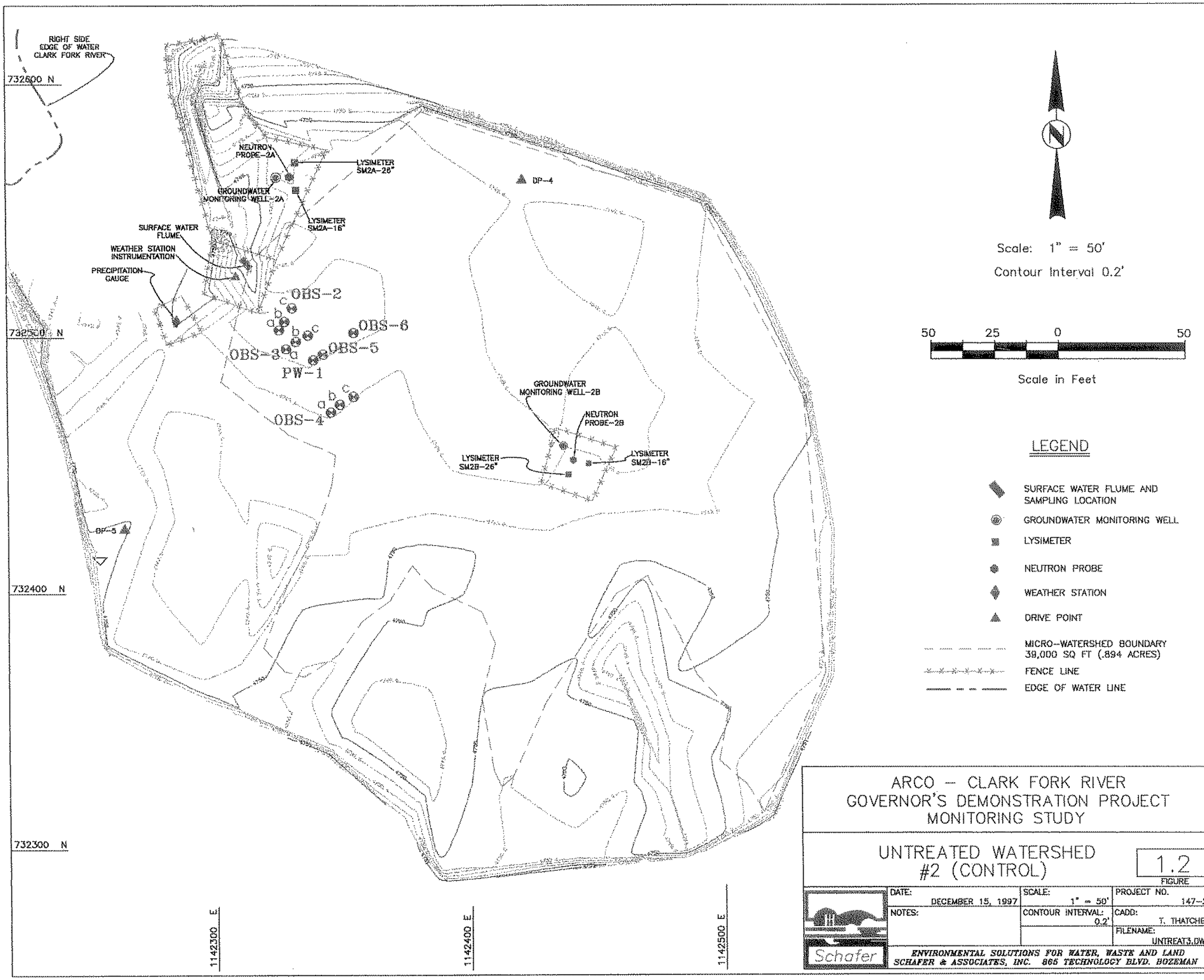


Figure 1.1 Location of Clark Fork River Governor's Demonstration Project.



ARCO — CLARK FORK RIVER
GOVERNOR'S DEMONSTRATION PROJECT
MONITORING STUDY

UNTREATED WATERSHED
#2 (CONTROL)

FIGURE 1.2

DATE: DECEMBER 15, 1997	SCALE: 1" = 50'	PROJECT NO. 147-22
NOTES:	CONTOUR INTERVAL: 0.2'	CADD: T. THATCHER
		FILENAME: UNTREAT3.DWG

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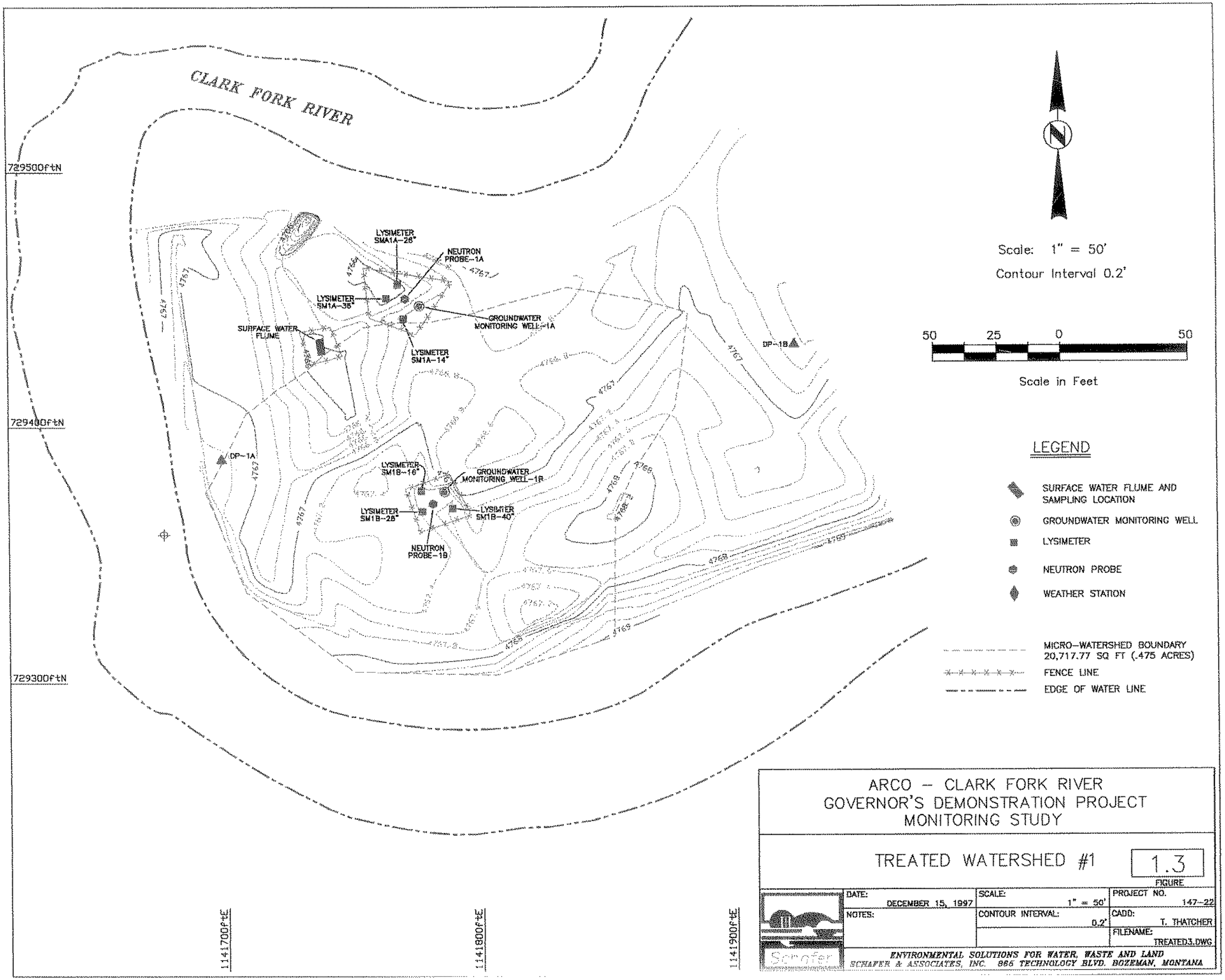

ARCO – CLARK FORK RIVER
GOVERNOR'S DEMONSTRATION PROJECT
MONITORING STUDY

TREATED WATERSHED #1

FIGURE 1.3

DATE: DECEMBER 15, 1997	SCALE: 1" = 50'	PROJECT NO. 147-22
NOTES:	CONTOUR INTERVAL: 0.2'	CADD: T. THATCHER
		FILENAME: TREATED3.DWG

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2.0 Hydrogeologic Conceptual Model

The majority of the tailings mapped in the floodplain (Schafer and Associates, 1988) are overbank deposits. A majority of these deposits formed during previous flood events and are underlain by "point bar" deposits. Along the Clark Fork River the upper point bar deposits have had one or more episodes of tailings deposits representing historic flooding (Nimmick, 1990). The topographic position of most floodplain tailings deposits is in a well-drained location at least 1 to 4 feet above the base flow groundwater elevation (Schafer and Associates, 1997).

Drill log and soil pit characterization indicated that the shallow groundwater system could be separated into three layers (Figure 2.1) with distinct hydrologic and soil properties. The top layer (layer 1) is generally tailings material, soil or a combination of both and contains a large quantity of fine material. A sand and gravel material with fines dominates the middle layer (layer 2). Layer 3 consists of clean heaving sand or a cobble and gravel mix. The three-layer hydrologic/soil model appeared to be pervasive in the shallow groundwater system in the Clark Fork River floodplain.

The hydrologic boundaries of the shallow groundwater system, along with the physical arrangement of layers, determine the groundwater flow rate and direction (Figure 2.2). The three-layer shallow groundwater system is connected to the Clark Fork River channel in a downgradient direction. The shallow groundwater system is recharged laterally by regional groundwater at the edge of the package of alluvial deposits paralleling the Clark Fork River. Finally, a small amount of groundwater recharge may occur seasonally when water flows through the vadose zone. Changes in the elevation of the Clark Fork River, and the rate of lateral and vertical recharge will determine the shallow groundwater levels.

Seasonal changes in groundwater level will be caused by variations in river stage. Because shallow groundwater and tailings in the variably saturated zone contain higher metal concentrations than the permeable gravel layer, these changes in groundwater elevation may induce changes in metal flux through the groundwater pathway. The hydrochemical model for the Clark Fork alluvial groundwater system is determined by the layer sequence within the shallow groundwater system, differences in hydraulic conductivity, seasonal variation in head, and variable chemistry between layers. As a consequence of the hydrochemical model, the expected pattern of change in metal flux due to variation in river stage can be predicted (Figure 2.3). If seasonal variation in the hydrograph increases metal flux to the river, the highest metal concentrations should be observed in layer 3 (gravels) during the falling limb of the hydrograph.

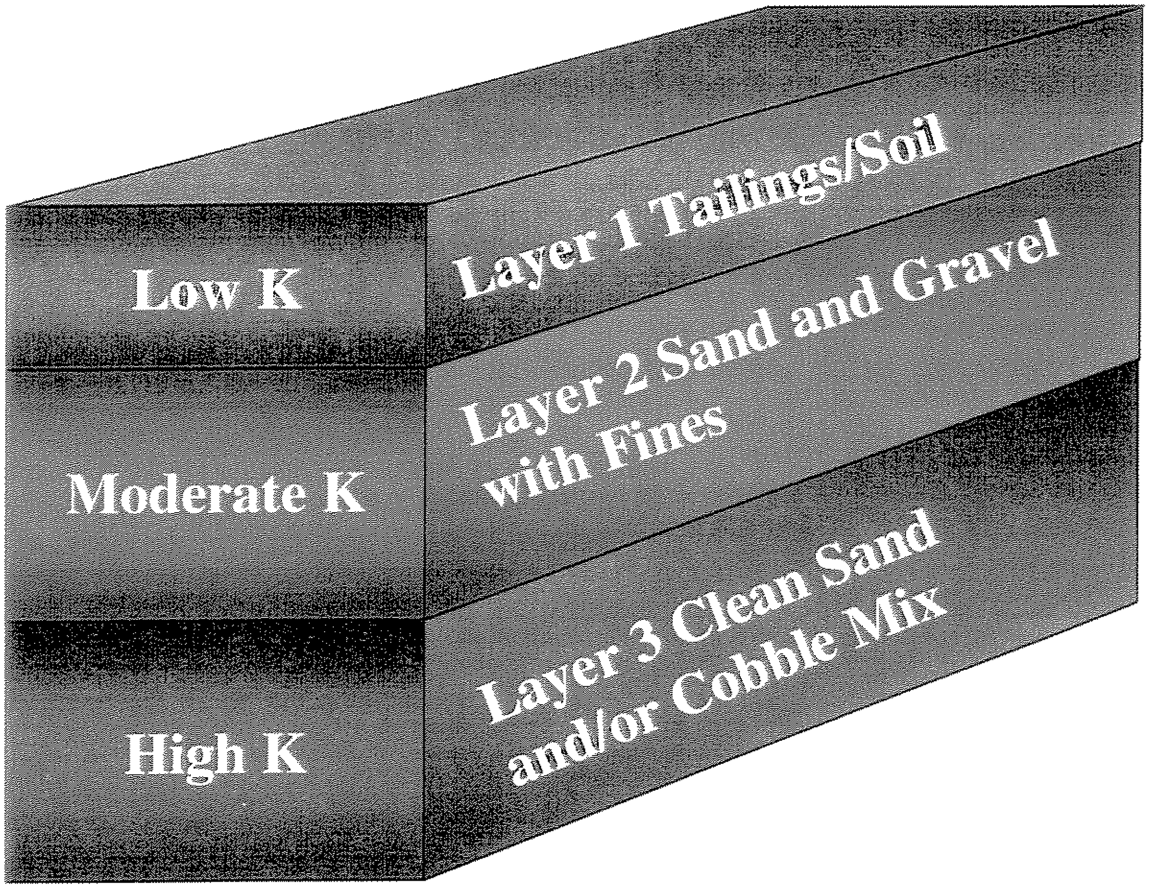

Figure 2.1. Conceptual model of the three hydrologic/soil units.

3.0 Methods

Aquifer characteristics were determined using a variety of methods, including pumping tests, slug tests, and bore hole permeameter tests. The hydraulic gradient and flow direction was determined by measuring water elevation in monitor wells and drive point piezometers. Samples were collected from monitor wells and drive point piezometers several times during the year to determine seasonal changes in shallow groundwater chemistry.

3.1 Hydraulic Conductivity

Pumping tests and slug tests were used to determine the hydraulic characteristics of conceptual model layers 2 and 3 and bore hole permeameter tests were used to determine the near surface hydraulic properties, layer 1. Results of the tests were used to characterize groundwater movement in the control and treated sites.

A 48-hour constant-rate pumping test was completed at the control site during the summer of 1996. The aquifer test was conducted with one pumping well, seventeen observation wells, and five drive point piezometers. A detailed description of the pumping test and analysis is provided by Schafer and Associates (1997a).

Slug tests were performed on five observation wells at the control site (OBS-1B, OBS-2B, OBS-3B, OBS-4B, and OBS-5) and 2 monitoring wells at the treated site (MW-1A and MW-1B). Slug tests were completed and analyzed as described by Schafer and Associates (1997b).

A bore hole permeameter was used to measure in situ saturated hydraulic conductivity of the unsaturated tailings material (control site) and amended tailings material (treated site) overlying the shallow alluvial aquifer material. Measurements were completed at 0.6 and 1.3 feet at the control site and at 0.3, 1.0, and 1.7 feet at the treated site. Gradient and Direction of Groundwater Flow

Static water levels were measured in each monitor well, observation well, and drive point piezometer using an electronic water level probe. Measurements were made to the nearest 0.01 feet. A level-line survey was conducted at each site prior to static water level measurements. Combining the level-line survey with the static water level measurements allowed the calculation of actual groundwater elevations in each well and drive point. A staff gauge installed at each site allowed for direct comparison between groundwater elevation and river stage.

3.2 Groundwater Chemistry

Shallow groundwater chemistry samples were collected from select monitor wells, observation wells, and drive point piezometers during base flow and during the climbing limb, peak, and declining limb of the river and shallow groundwater spring hydrograph. Samples were collected in accordance with Standard Operating

Procedures (CFR SOP). Drive point piezometers had 2 feet of well screen and were installed so that the top of the well screen would be approximately level with the groundwater surface. Both 2-inch and 1¼-inch diameter drive points were installed. The analytical results of samples collected from drive point piezometers were for observing trends in groundwater chemistry only, since drive points were not installed using the same protocols as monitor wells, outlined in the CFR SSI SOP.

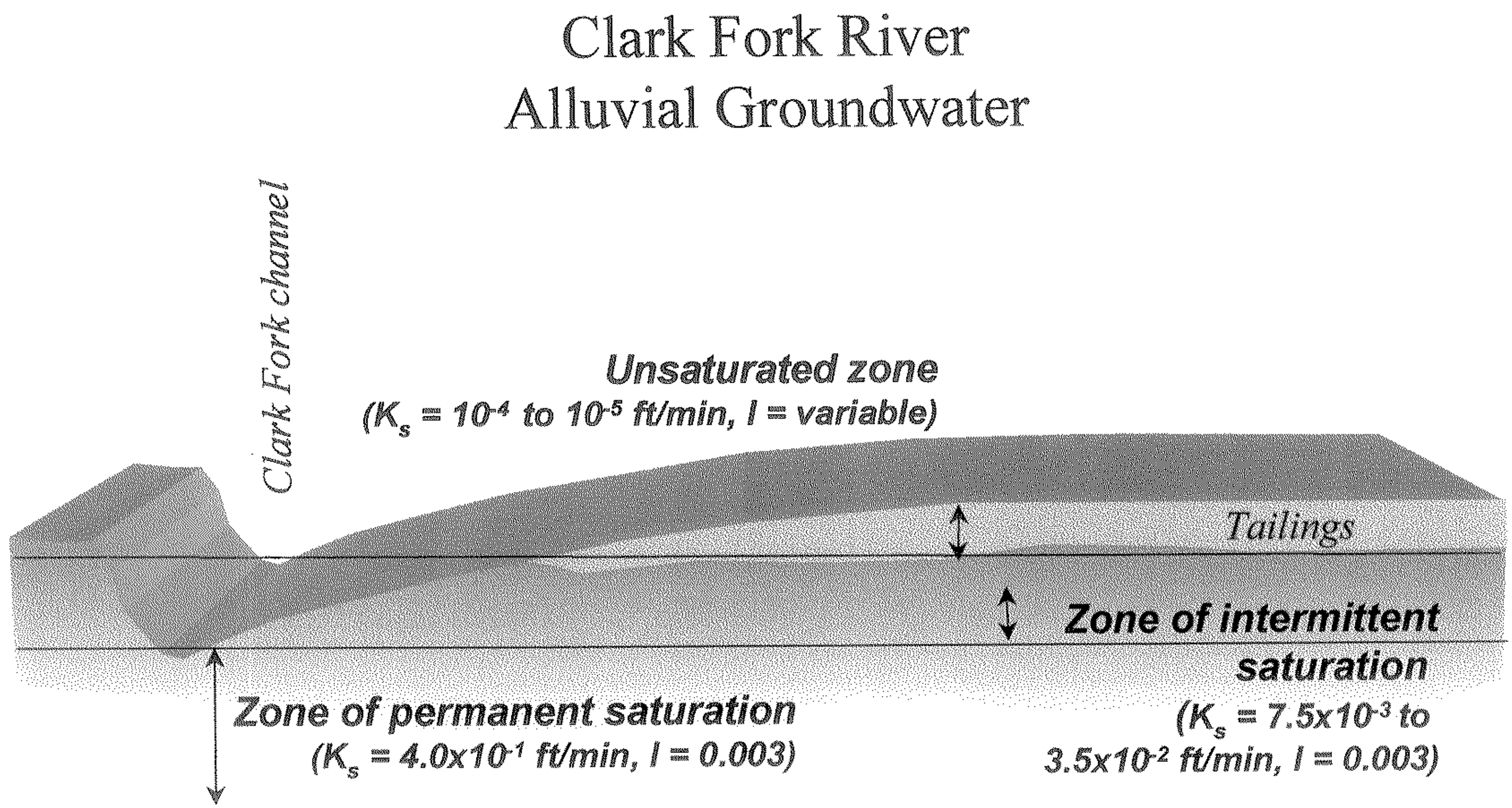

Figure 2.2. Typical cross section through the Clark Fork River floodplain showing variable materials.

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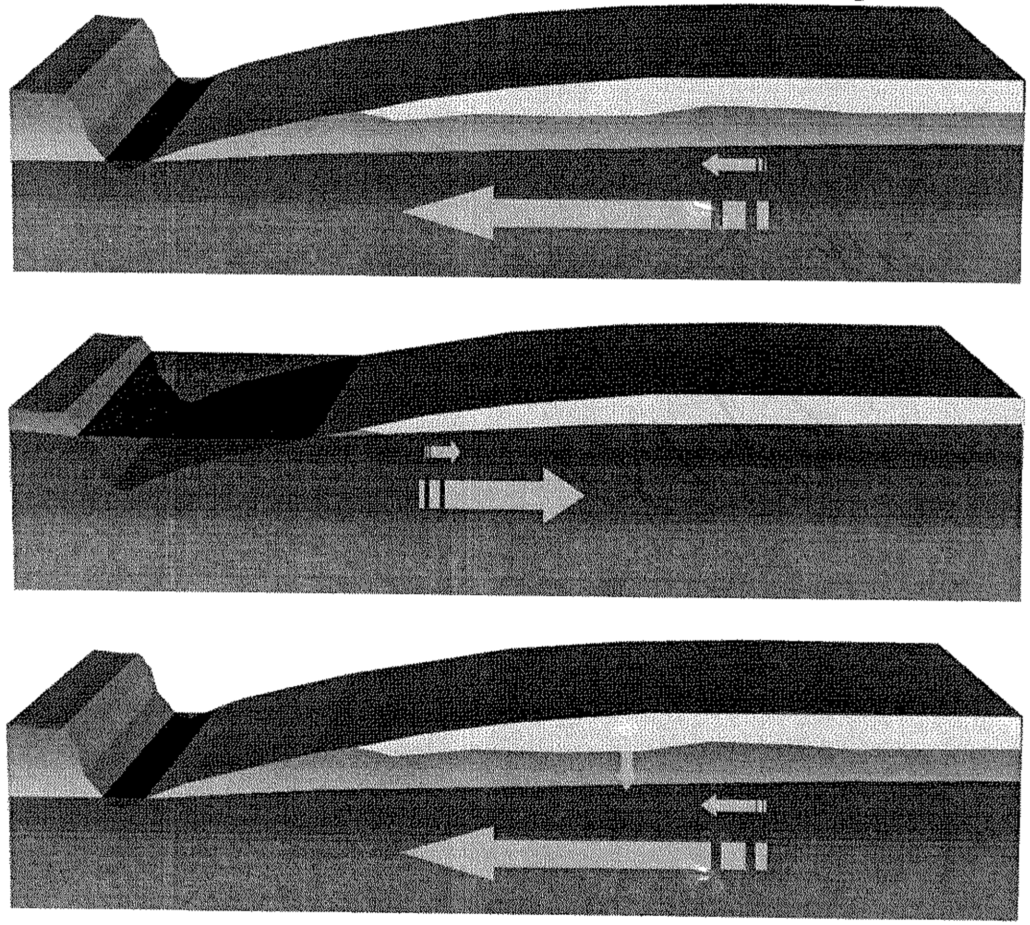
Clark Fork River-Bank Storage and Metal Transport



Baseflow - alluvial groundwater flowing in gravel layer low in metal concentration. Low levels of metals transported in shallow groundwater due to low hydraulic conductivity of upper saturated layer. Metals contained in water recharged through tailings are mostly attenuated.

Peak flow - rising groundwater levels force groundwater laterally into banks and upward into metal-enriched tailings. Groundwater flux of metals to river negligible due to reversed gradient.

Declining limb - as shallow groundwater system desaturates, water containing metals may flow downward into gravel aquifer and be carried toward the river. Evidence of this transport mechanism would be elevated metal concentrations in shallow groundwater during peak flow and elevated metals in gravel layer during falling limb.

Figure 2.3. Expected changes in groundwater chemistry during variation in river stage.

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4.0 Results and Discussion

4.1 Hydrostratigraphic Units

Drill logs from the installation of monitor wells, observation wells, and suction lysimeters were used to describe the hydrostratigraphic units of the shallow groundwater system in the Clark Fork River floodplain. In addition, observations made in soil pits were also utilized.

4.1.1 Control Microwatershed

Drill logs indicated that the shallow alluvial groundwater system included three distinct hydrologic/soil units (i.e. layers), each with distinct hydrologic and soil properties. The top unit, or layer, is comprised primarily of tailings material. This layer was only partially and seasonally saturated at the control site, with saturated conditions occurring only at bottom of the unit. The control site did not have a well developed buried soil beneath the tailings material, which was dissimilar to most observed soil profiles in the CFR floodplain where tailings are present. The second layer consisted of a sand and gravel mix with fines, and often the top portion of the layer was not saturated. The third layer was dominated by clean heaving sand and in some areas was a gravel and cobble mix.

4.1.2 Treated Microwatershed

Drill logs from monitor well and suction lysimeter installation indicated three distinct hydrologic/soil units also exist at the treated microwatershed. The top layer consisted of approximately 1 to 3 feet of amended tailings mixed with natural soil through plowing. The bottom portion of the amended tailings and soil was generally only saturated seasonally. Layer 2 and 3 material was similar to that observed at the control site and described in the conceptual hydrologic/soil model. The microwatershed had been revegetated with grasses

The upper layer at the control and treated microwatersheds are similar. However, the materials at the treated site were plowed when lime was incorporated, creating a homogeneous material.

The three layer system observed at the control and treated sites is similar to the description of sediment units presented in Brooks, (1988). Layer 3 (clean heaving sand and Gravel and Cobble mix) is similar to the Brooks gravel and boulder aquifer material and layer 2 (sand and gravel with fines) is similar to the coarse quartz sand with dark fines and gravel described by Brooks. Layer 1 (tailings material) incorporates the top three sediment units outlined by Brooks as tailings, transition unit, and cohesive silt. The transition unit and cohesive silt are discontinuous and thin, where present at the control site. The unit described by Brooks as topsoil is not present at the control site.

4.2 Hydraulic Characteristics

The shallow groundwater system in the Clark Fork River floodplain was characterized with a combination of pumping tests, slug tests, and bore hole permeameter tests.

4.2.1 Control Microwatershed

Results of bore hole permeameter testing at the control site indicate that the tailings material has a hydraulic conductivity of approximately $1x10^{-5}$ feet per min (ft/min). The bore hole permeameter tests conducted at the control site are described by ARCO (1997a). The average hydraulic conductivity of layer 2, the sand and gravel with fines, was $7.5x10^{-3}$ ft/min and was estimated with slug tests using wells OBS-1B, OBS-2B, OBS-3B, and OBS-4B. The observation wells were completed from 2.2 to 4.2 feet below the ground surface. Results of slug tests completed at the control site are described by ARCO (1997b). An analysis of the pumping test results completed at the control site indicates that the hydraulic conductivity of the clean sands and gravel and cobble mix averages approximately $4x10^{-1}$ ft/min. Additional pumping test analysis and the semi-confined conditions observed suggest that vertical hydraulic conductivity is two to tree orders of magnitude less than horizontal hydraulic conductivity (ARCO, 1997a).

4.2.2 Treated Microwatershed

Results from tests completed at the treated site indicate that the hydraulic conductivity of the amended tailings material increases below a depth of approximately 12 inches, with values at 4, 12, and 20 inches of $8.5x10^{-5}$, $6.5x10^{-5}$, and $7.1x10^{-4}$ ft/min, respectively. Results of bore hole permeameter tests conducted at the treated site are presented in Appendix A. Slug tests completed in monitor wells MW-1A and MW-1B indicate the average hydraulic conductivity of layer 2, sand and gravel with fines, was $3.5x10^{-2}$ ft/min. Monitor wells MW-1A and MW-1B were completed between 5 and 10 feet below the ground surface. Data describing the results of slug tests conducted at the treated site are presented in Appendix A.

The amended and revegetated tailings material at the treated microwatershed have somewhat different hydraulic properties than tailings material at the control microwatershed. The amendment process, which mixed the materials, and roots from vegetation appear to slightly increase hydraulic conductivity of the material and create a relatively homogenous material which should have similar vertical and horizontal hydraulic conductivity. The vertical hydraulic conductivity of the fluvially deposited tailings material, at the control site, and the fluvially deposited layer 2 and 3 material at both sites is significantly less than horizontal hydraulic conductivity.

The three-layer hydrologic conceptual model appears to accurately describe the hydrologic characteristics estimated at the control and treated microwatersheds. Overall, data from aquifer testing suggests that hydraulic conductivity increases with depth, and that vertical groundwater flux is not significant when compared to horizontal groundwater flux.

4.3 Groundwater Flow and Direction

Water level measurements were collected from monitor wells MW-1A and MW-1B at the treated site and from MW-2A and MW-2B during quarterly sampling since 1994. Figures 4.1 and 4.2 display changes in groundwater elevation and river stage, measured at the United States Geological Survey gauging station located at the Perkins Lane Bridge (Clark fork River at Galen), during the period of record for the treated and control microwatersheds, respectively. The figures represent absolute groundwater elevation, with the control site located downstream and the treated site located upstream of the gauging station.

The figures indicate that the shallow groundwater system in the Clark Fork River floodplain responds quickly to changes in river stage.

In general, groundwater elevations respond quickly to changes in river stage. Groundwater flow at the control and treated microwatersheds is towards the Clark Fork River. The direction of groundwater flow and the general gradient of the shallow groundwater system in the Clark Fork River flood plain do not change significantly when river stage and groundwater elevation change.

In order to more precisely detail changes in the shallow groundwater elevation, in response to changes in the peak stage hydrograph, additional static water level measurements were collected at the control and treated sites during sample collection on 17 May 1997, 31 July 1997, and 21 August 1997. Measurements were also collected on 24 September, 1997 during base river flow conditions at the control site.

4.3.1 Control Microwatershed

Exhibit A displays the potentiometric surface during base flow conditions (24 September 1996) and during the declining limb of the peak hydrograph on 31 July 1997 and 21 August 1997 The figures indicate that groundwater flow direction and gradient do not change significantly as river stage and groundwater elevation changes.

Neutron probe and depth to water measurements collected at the control site indicate that the depth to water is less than 0.5 ft below the ground surface, with the volumetric water content of the tailings material ranging from 30% to 33%, approximately the effective saturation point. The tailings material is capable of moving water vertically through capillary action, creating near saturated material conditions near the surface. Water moves up towards the surface to replace water lost to evaporation, often leaving a salt precipitate at the surface. Changes in water level and soil moisture are displayed in cross section Exhibit C.

4.3.2 Treated Microwatershed

Exhibit B displays the potentiometric surface during base flow conditions (28 October 1996) and during the declining portion of the hydrograph (31 July 1997 and 21 August 1997). Again, the figures indicate that groundwater flow direction and gradient do not change significantly when river stage and groundwater elevation change.

The water level at the treated site is approximately 2 feet below the ground surface on 31 July 1997 and approximately 3 feet below the ground surface on 21 August 1997, in the sand and gravel material with fines. The sand and gravel with fines material does not have the strong capillary action of the tailings material and neutron probe measurements indicate that soil moisture in the amended tailings material does not significantly change and is not at saturated levels. Changes in water level and soil moisture are displayed in cross section, Exhibit D.

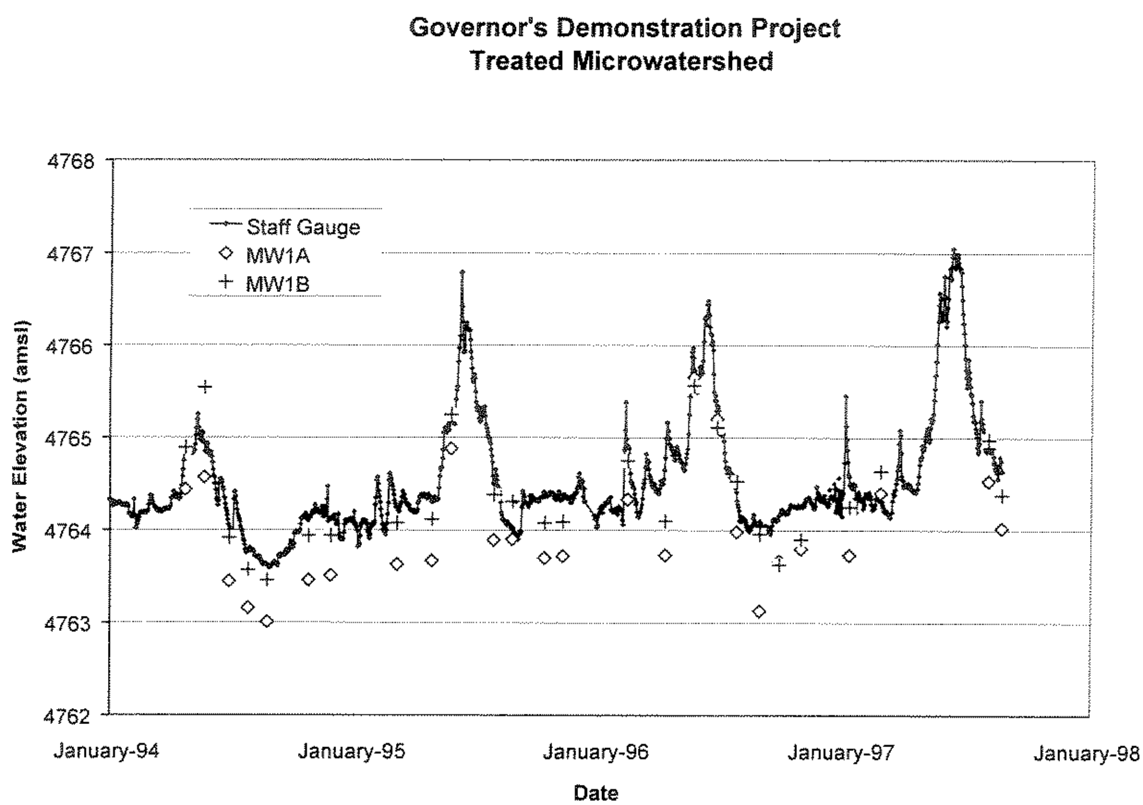


Figure 4.1. Groundwater elevation at the Governor's Demonstration Project treated microwatershed and river stage at the Clark Fork River near Galen USGS gauging station.

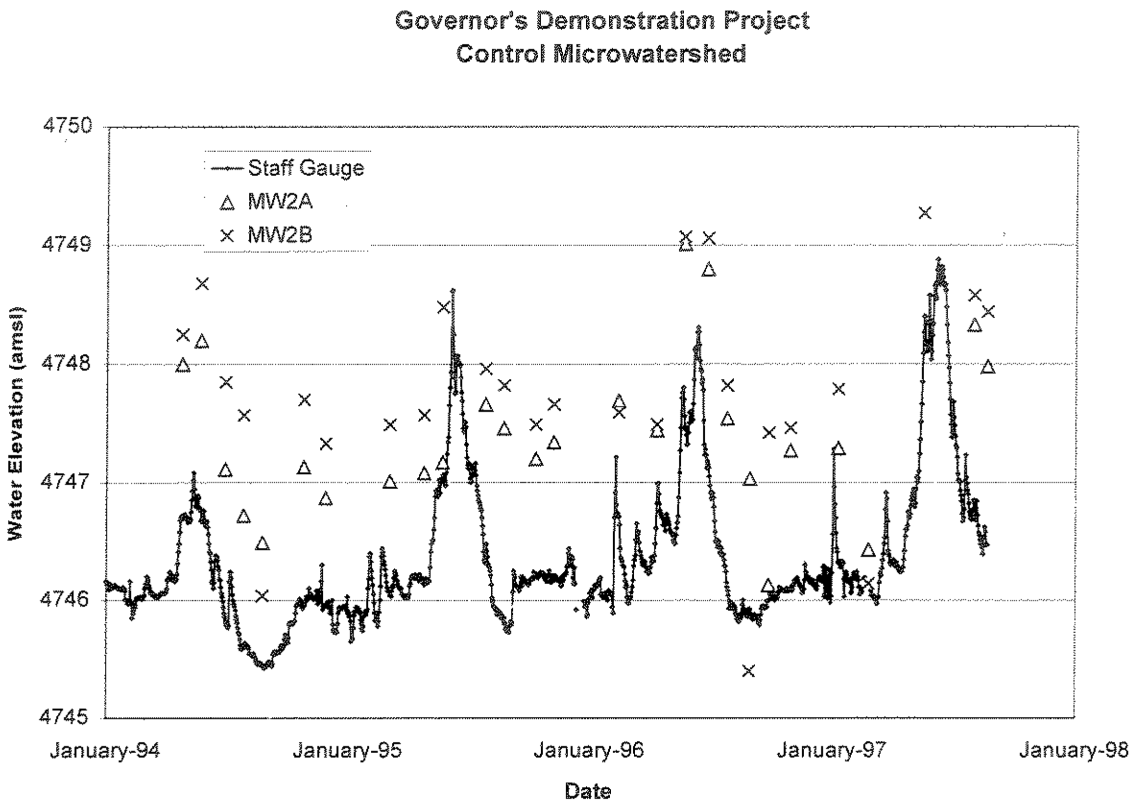


Figure 4.2. Groundwater elevation at the Governor's Demonstration Project control microwatershed and river stage at the Clark Fork River near Galen USGS gauging station.

4.4 Groundwater chemistry Characterization

Concentrations of arsenic, copper, and zinc have been monitored at monitor wells MW-1A and MW-1B at the treated microwatershed and MW-2A and MW-2B and the control microwatershed since 1994, with Figures 4.3 through 4.5 displaying changes in concentration. Many values were below detection and a relative change in concentration displayed in the figures were often caused by changes in the detection limit. Recent sampling has also included cadmium and lead. Groundwater chemistry data are presented in Appendix B, with concentrations of constituents of concern presented in Table 4.1. All lead values were below the detection limit for wells MW-1A, MW-1B, MW-2A, and MW-2B and only 2 cadmium values above the detection limit were available, wells MW-1A and MW-2A, and are presented in Table 4.1.

There does not appear to be a significant correlation between the concentrations of constituents of concern and groundwater elevation. Generally, only small changes in chemistry were observed. Downgradient wells had higher copper and zinc than upgradient wells at the control site. At the tested site, zinc and possibly arsenic were higher in downgradient wells.

In general, no significant change in concentration was observed with changes in river stage. Arsenic, copper, and zinc values were significantly greater at the control microwatershed at all portions levels of river stage.

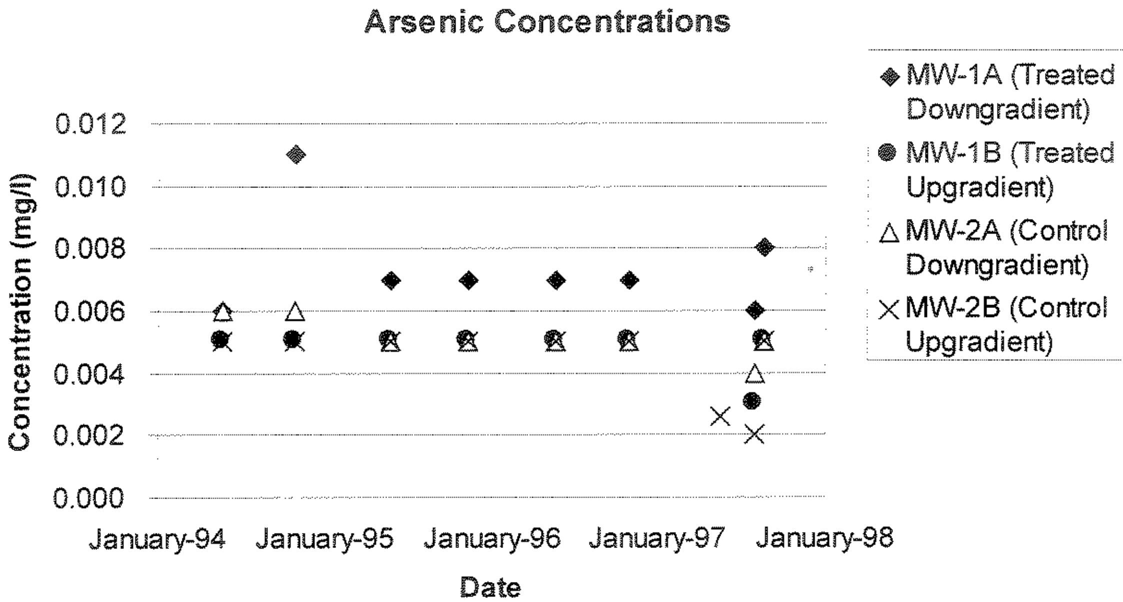


Figure 4.3. Arsenic concentrations at Governor's Demonstration Project treated and control microwatersheds for the period of record.

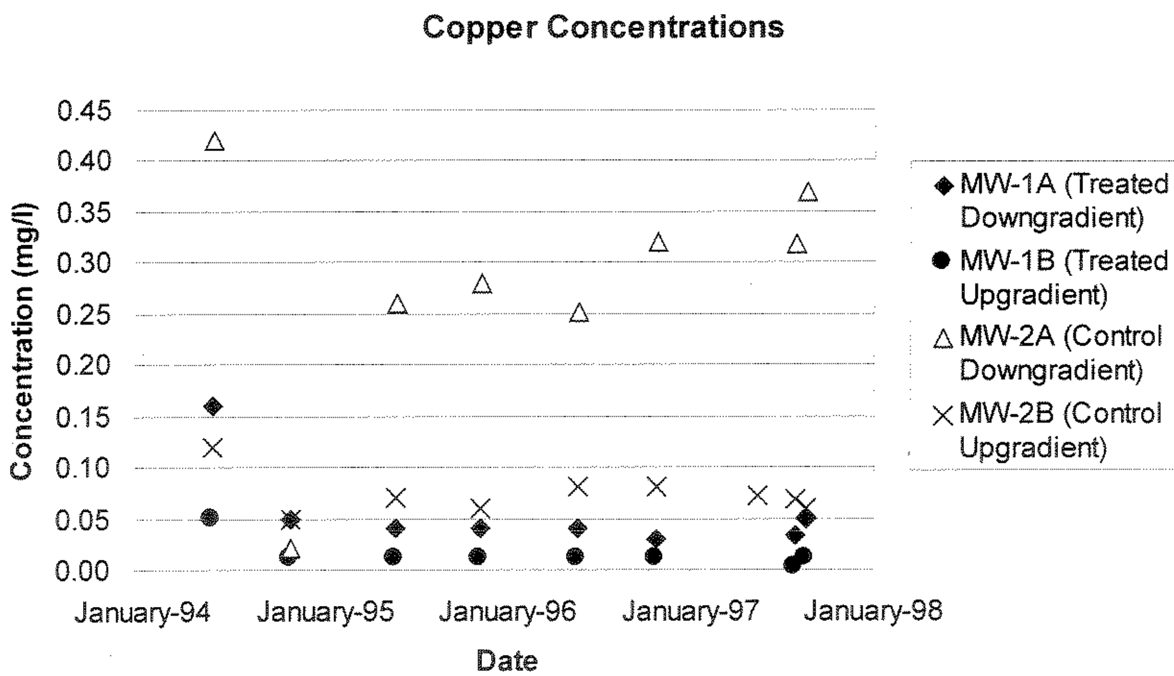


Figure 4.4. Copper concentrations at Governor's Demonstration Project treated and control microwatersheds for the period of record.

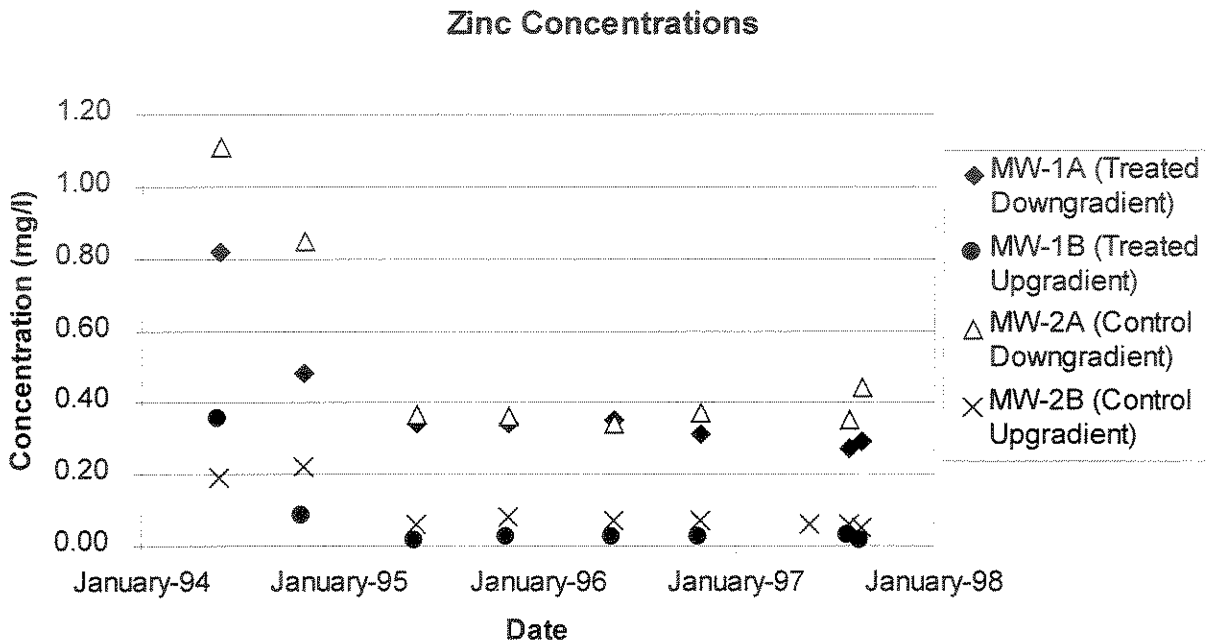


Figure 4.5. Zinc concentrations at Governor's Demonstration Project treated and control microwatersheds for the period of record.

Table 4.1. Concentrations of constituents of concern for monitor wells MW-1A, MW-1B, MW-2A, and MW-2B.

WELL NUMBER	SAMPLE DATE	As (mg/l)		Cd (mg/l)		Cu (mg/l)		Pb (mg/l)		Zn (mg/l)	
MW-1A	5/23/94	0.006				0.16				0.82	D
MW-1A	10/26/94	0.011				0.05				0.48	U
MW-1A	5/24/95	0.007				0.04				0.34	U
MW-1A	11/8/95	0.007	U			0.04	U			0.34	U
MW-1A	5/21/96	0.007				0.04				0.35	D,U
MW-1A	10/28/96	0.007	U			0.04	U			0.35	D,U
MW-1A	7/31/97	0.006		0.0013		0.034		0.002	B	0.272	
MW-1A	8/21/97	0.008		0.001		0.05		0.01	B	0.29	
MW-1B	5/23/94	0.005	B			0.05				0.35	
MW-1B	10/26/94	0.005	B			0.01	B			0.08	U
MW-1B	5/24/95	0.005	B			0.01	B			0.01	B,U
MW-1B	11/8/95	0.005	B,U			0.01	B,U			0.02	U
MW-1B	5/21/96	0.005	B			0.01	B			0.02	D,U
MW-1B	10/28/96	0.005	B,U			0.01	B,U			0.02	U
MW-1B	7/31/97	0.003		0.001	B	0.001	B	0.002	B	0.023	
MW-1B	8/21/97	0.005	B	0.001	B	0.01	B	0.01	B	0.01	B
MW-2A	5/23/94	0.006				0.42				1.11	
MW-2A	10/26/94	0.006				0.02				0.85	U
MW-2A	5/24/95	0.005	B			0.26				0.37	U
MW-2A	11/8/95	0.005	U			0.28	U			0.36	U
MW-2A	5/21/96	0.005				0.252				0.34	D,U
MW-2A	10/28/96	0.005	B,U			0.32	U			0.37	U
MW-2A	7/31/97	0.004		0.0024		0.318		0.002	B	0.351	
MW-2A	8/21/97	0.005	B	0.003		0.37		0.01	B	0.44	
MW-2B	5/23/94	0.005	B			0.12				0.19	
MW-2B	10/26/94	0.005	B			0.05				0.22	U
MW-2B	5/24/95	0.005	B			0.07				0.06	U
MW-2B	11/8/95	0.005	B,U			0.06	U			0.08	U
MW-2B	5/21/96	0.005	B			0.08				0.07	D,U
MW-2B	5/17/97	0.0026	B	0.003	B	0.072		0.001	B	0.0597	
MW-2B	10/28/96	0.005	B,U			0.07	U			0.06	U
MW-2B	7/31/97	0.002		0.003		0.069		0.002	B	0.058	
MW-2B	8/21/97	0.005	B	0.001	B	0.06		0.01	B	0.05	

B = Constituent concentration below detection.

U = Constituent concentration undefendable, spike standard analysis out o range.

D = Relative percent difference > 25% for duplicate sample analysis.

5.0 Conclusion

The shallow groundwater system in the Clark Fork River floodplain is dominated by three distinct hydrologic/soil units. The upper unit (layer 1) is primarily tailings, soil, or a mixture of tailings material and soil. The middle layer is primarily sand and gravel with fines, and layer 3 is a clean heaving sand or a gravel and cobble mix.

Analysis of the aquifer test results and the semi-confined conditions observed during aquifer testing suggest that vertical hydraulic conductivity is two to three orders of magnitude less than horizontal hydraulic conductivity, indicating that the flux of water from tailings material to the underlying shallow groundwater system is not significant when compared to horizontal shallow groundwater flux. The hydraulic conductivity increases at deeper depths, with layer 1 having significantly lower hydraulic conductivity than layer 2, and layer 2 having significantly lower hydraulic conductivity than layer 3.

Groundwater elevations vectors, near the river, indicate that groundwater flows downriver (North) with a component of flow towards the Clark Fork River. The shallow groundwater flow direction and gradient does not change significantly when the shallow groundwater elevations change in response to changes in river stage. Groundwater gradients generally reflect the river gradient.

Samples collected from shallow groundwater monitor wells suggest that concentrations of constituents of concern are not affected by changes in river stage and groundwater elevation. Downgradient wells had higher copper and zinc at the control and zinc at the treated microwatershed than did upgradient wells. Concentrations of copper are greater downgradient of the treated site during all portions of the river hydrograph.

Since groundwater gradients and groundwater flux do not increase and since concentrations of constituents of concern do not appear to increase when river stage and groundwater elevation increase during spring peak flow conditions, no significant increase in load is expected, due to changes in river stage. Therefore, load of constituents of concern during high flow conditions is expected to be similar to those estimated during base flow conditions at either the control or treated microwatershed.

6.0 References

ARCO, 1997a. Technical Memo: Aquifer Test Analysis, prepared for ARCO by Schafer and Associates.

ARCO, 1997b. Technical Memo: Near -Stream Gradients and Slug Tests, prepared for ARCO by Schafer and Associates.

Brooks, R., 1988. Distribution and Concentration of Metals in Sediments and Water of the Clark Fork River Floodplain, Montana, M.S. Thesis, University of Montana, Missoula, Montana.

Nimick, D. A., 1990. Stratigraphy and Chemistry of Metal-Contaminated Floodplain Sediments, Upper Clark Fork River Valley, Montana, M.S. Thesis, University of Montana, Missoula, Montana.

Schafer and Associates, 1991. Final Report on the Clark fork River Demonstration Project, Warm Springs, Montana. Report submitted to the office of the Governor.

Schafer and Associates, 1997. Clark Fork River Governor's Demonstration Project Monitoring (1993-1996) Report submitted to the office of the Governor.

Appendix A

Hydraulic Data

Bank Full Storage - Governor's Demonstration Project Groundwater Elevation				
Well No	**10/28/97**	**5/17/97**	**8/1/97**	**8/21/97**
SITE 1 - TREATED MICROWATERSHED				
MW-1A	4763.80	-	4764.53	4764.02
MW-1B	4763.90	-	4764.98	4764.38
DP-1A		-	4764.99	4764.51
DP-1B		-	4764.72	4764.19
DP-1C		-	4764.76	4764.44
Staff Gauge		-	4765.40	4764.90
Well No	**9/24/96**	**5/17/97**	**8/1/97**	**8/21/97**
SITE 2 - UNTREATED MICROWATERSHED				
MW-2A	4747.00	-	4748.33	4747.98
MW-2B	4747.40	4749.27	-	4748.44
OBS-1A	-	-	-	4749.72
OBS-1B	4746.81	-	4748.22	4747.73
OBS-1C	4746.78	-	4748.24	4747.72
OBS-2A	4747.20	-	-	-
OBS-2B	4747.19	4749.65	4748.48	4748.19
OBS-2C	4747.16	-	4748.45	4748.16
OBS-3A	4747.22	-	-	-
OBS-3B	4747.21	4749.68	4748.49	4748.22
OBS-3C	4747.22	4749.16	4748.49	4748.24
OBS-4A	-	-	-	-
OBS-4B	4747.26	4749.22	4748.49	4748.25
OBS-4C	4747.25	-	-	-
OBS-5	4747.22	-	4748.50	4748.25
OBS-6	4747.22	-	4748.48	4748.24
PW-1	4747.19	-	4748.45	4748.23
DP-1	4746.71	-	-	-
DP-2	4746.71	-	-	-
DP-3	4746.69	-	-	-
DP-4	4747.23	-	4748.44	4748.25
DP-5	-	-	4748.58	4748.25
Staff Gauge	4746.70	-	4747.84	4746.73

GP FIELD DATA SHEET

SECTION 2: STANDARDIZED PROCEDURE FOR PERMEAMETER READINGS AND CALCULATIONS

Date 7/31/97 Investigator Tiede

Reservoir Constants: (See label on Permeamter)

Combined Reservoirs X	cm²	✓ CHECK RESERVOIR USED
Inner Reservoir Y	cm²	✓

Depth of Well Hole 20"

Note: In standardized procedure the radius of the well hole is always 3.0 cm

1st Set of Readings with height of water in well (H_1) set at 5 cm

READING NUMBER	TIME	TIME INTERVAL (MIN)	WATER LEVEL IN RESERVOIR, (CM)	WATER LEVEL CHANGE, (CM)	RATE OF WATER LEVEL CHANGE, R_1, (CM/MIN)
	18:13	START			
1	18:15	2	1.10	—	
2	18:17	2	6.00	4.90	2.45
3	18:19	2	11.35	5.35	2.675
4	18:21	2	17.20	5.85	2.925
5	18:23	2	23.30	6.10	3.05
6	18:28	5	38.70	15.40	3.08
7	18:33	5	54.00	15.30	3.06
8	18:38	5	69.40	15.40	3.08
9	18:43	5			

RESERVOIR CONSTANT 2.15

2nd Set of Readings with height of water in well (H_2) set at 10 cm

$\bar{R}_1$ 3.1 $\bar{R}_{10}$ 3.7

READING NUMBER	TIME	TIME INTERVAL (MIN)	WATER LEVEL IN RESERVOIR, (CM)	WATER LEVEL CHANGE, (CM)	RATE OF WATER LEVEL CHANGE, R_2, (CM/MIN)
	18:50	START			
1	18:52	2	7.30	—	
2	18:54	2	7.70	0.40	0.20
3	18:56	2	8.20	0.50	0.25
4	18:58	2	8.75	0.55	0.275
5	19:00	2	9.30	0.55	0.275
6	19:05	5	10.90	1.60	0.32
7	19:10	5	12.90	2.00	0.40
8	19:15	5	14.90	2.00	0.40
9	19:20	5	16.80	1.90	0.38
					(0.39)

RESERVOIR CONSTANT 35.64

CALCULATIONS

$\bar{R}$, the steady state rate of flow, is achieved when R is the same in three consecutive time intervals.

For the 1st Set of Readings $\bar{R}_1$ = (3.073 [R_1])/60 = 0.0512 cm/sec

For the 2nd Set of Readings $\bar{R}_2$ = (0.393 [R_2])/60 = 0.00656 cm/sec

K_{fs} = [(.0041)(35.64 [RESERVOIR CONSTANT])(~~0.039~~ 0.0065 [$\bar{R}_2$-STEADY STATE RATE OF FLOW])] - [(.0054)(2.15 [RESERVOIR CONSTANT])(0.0512 [$\bar{R}_1$-STEADY STATE RATE OF FLOW])] = 3.6×10^{-4} cm/sec

FIELD SATURATED HYDRAULIC CONDUCTIVITY

ϕ_m = [(.0572)(2.15 [RESERVOIR CONSTANT])(0.0512 [$\bar{R}_1$ STEADY STATE RATE OF FLOW])] - [(.0237)(35.64 [RESERVOIR CONSTANT])(____ [$\bar{R}_2$ STEADY STATE RATE OF FLOW])] = ____ cm²/sec

MATRIC FLUX POTENTIAL

α = (____ [K_{fs}]) / (____ [ϕ_m]) = ____ cm⁻¹

ALPHA PARAMETER

Δθ = (____ [θ_{fs}, FIELD SATURATED WATER CONTENT OF SOIL, IN CM³/CM³]) - (____ [θ_i, AMBIENT WATER CONTENT OF SOIL, IN CM³/CM³]) = ____ cm³/cm³

DELTA THETA

ESTIMATED		CHECK ONE
MEASURED		

S = $\sqrt{2(\_\_\_\_)(\_\_\_\_)}$ [Δθ] [ϕ_m] = ____ cm sec^-1/2

SORPTIVITY

GP FIELD DATA SHEET

SECTION 2: STANDARDIZED PROCEDURE FOR PERMEAMETER READINGS AND CALCULATIONS

Date 07/31/97 Investigator TIEDE

Reservoir Constants: (See label on Permeamter)

Combined Reservoirs X	35.64	cm^2
Inner Reservoir Y	2.15	cm^2

CELL CONSTANTS

☐ CHECK RESERVOIR USED ☒

Depth of Well Hole 4 in

Note: In standardized procedure the radius of the well hole is always 3.0 cm

15:31 = 08:19
STOP WATCH ACTUAL

1st Set of Readings with height of water in well (H_1) set at 5 cm

READING NUMBER	TIME	TIME INTERVAL (MIN)	WATER LEVEL IN RESERVOIR, (CM)	WATER LEVEL CHANGE, (CM)	RATE OF WATER LEVEL CHANGE, R_1, (CM/MIN)
	15:31	START			
1	15:33	2	36.20	—	
2	15:35	2	37.48	1.28	0.64
3	15:37	2	38.62	1.14	0.57
4	15:39	2	40.40	1.78	0.89
5	15:41	2	41.86	1.46	0.73
6	15:46	5	45.80	3.94	0.79
7	15:51	5	49.80	4.00	0.80
8	15:56	5	54.00	4.20	0.84
9	15:61	5	58.10	4.10	0.82
10	15:67	5	62.50	4.40	0.88

2nd Set of Readings with height of water in well (H_2) set at 10 cm

READING NUMBER	TIME	TIME INTERVAL (MIN)	WATER LEVEL IN RESERVOIR, (CM)	WATER LEVEL CHANGE, (CM)	RATE OF WATER LEVEL CHANGE, R_2, (CM/MIN)
	16:13	START			
1	16:15	2	07.00		
2	16:17	2	09.30	2.30	1.15
3	16:19	2	12:00	2.70	1.35
4	16:21	2	14.78	2.78	1.39
5	16:23	2	17.35	2.57	1.29
6	16:28	5	23.96	6.55	1.31
7	16:33	5	30.64	6.74	1.35
8	16:38	5	37.53	6.89	1.38
9	16:43	5	44.50	6.97	1.39
10	16:48	5	51.45	6.95	1.39

CALCULATIONS

$\bar{R}$, the steady state rate of flow, is achieved when R is the same in three consecutive time intervals.

For the 1st Set of Readings $\bar{R}_1$ = (0.83 R_1)/60 = 0.0138 cm/sec

For the 2nd Set of Readings $\bar{R}_2$ = (1.39 R_2)/60 = 0.0231 cm/sec

K_{fs} = [(.0041)(2.15 RESERVOIR CONSTANT)(0.0231 $\bar{R}_2$-STEADY STATE RATE OF FLOW)] - [(.0054)(2.15 RESERVOIR CONSTANT)(0.0138 $\bar{R}_1$-STEADY STATE RATE OF FLOW)] = 4.34×10^{-5} cm/sec

FIELD SATURATED HYDRAULIC CONDUCTIVITY

ϕ_m = [(.0572)(2.15 RESERVOIR CONSTANT)(0.0138 $\bar{R}_1$ STEADY STATE RATE OF FLOW)] - [(.0237)(2.15 RESERVOIR CONSTANT)(0.0231 $\bar{R}_2$ STEADY STATE RATE OF FLOW)] = 5.20×10^{-4} cm^2/sec

MATRIC FLUX POTENTIAL

α = (4.34×10^{-5} K_{fs}) / (5.20×10^{-4} ϕ_m) = 0.0835 cm^{-1}

ALPHA PARAMETER

Δθ = (______ θ_{fs}, FIELD SATURATED WATER CONTENT OF SOIL, IN CM³/CM³) - (______ θ_i, AMBIENT WATER CONTENT OF SOIL, IN CM³/CM³) = ______ cm^3/cm^3

DELTA THETA

ESTIMATED	☐
MEASURED	☐

CHECK ONE

S = $\sqrt{2}$(______ Δθ)(______ ϕ_m) = ______ cm $sec^{-1/2}$

SORPTIVITY

GP FIELD DATA SHEET

SECTION 2: STANDARDIZED PROCEDURE FOR PERMEAMETER READINGS AND CALCULATIONS

Date 7/31/97 Investigator Tiese

Reservoir Constants: (See label on Permeamter)

Combined Reservoirs X	for 10cm	cm^2
Inner Reservoir Y	for 5cm	cm^2

CHECK RESERVOIR USED: [X]

Depth of Well Hole 12 in

Note: In standardized procedure the radius of the well hole is always 3.0 cm

1st Set of Readings with height of water in well (H_1) set at 5 cm

READING NUMBER	TIME	TIME INTERVAL (MIN)	WATER LEVEL IN RESERVOIR, (CM)	WATER LEVEL CHANGE, (CM)	RATE OF WATER LEVEL CHANGE, R_1, (CM/MIN)
	16:55	START			
1	16:57	2	5.30	—	
2	16:59	2	10.10	4.80	2.40
3	17:01	2	15.10	5.00	2.50
4	17:03	2	20.63	5.53	2.765
5	17:05	2	26.00	5.37	2.685
	~~17~~				
6	17:10	5	39.30	13.30	2.66
7	17:15	5	52.90	13.60	2.72
8	17:20	5	66.55	13.65	2.73
9	17:25	5			

CELL CONSTANT 2.15

2nd Set of Readings with height of water in well (H_2) set at 10 cm

READING NUMBER	TIME	TIME INTERVAL (MIN)	WATER LEVEL IN RESERVOIR, (CM)	WATER LEVEL CHANGE, (CM)	RATE OF WATER LEVEL CHANGE, R_2, (CM/MIN)
~~[illegible]~~	17:30	START			
1	17:32	2	10.40	—	
2	17:34	2	10.90	0.50	0.25
3	17:36	2	11.30	0.40	0.20
4	17:38	2	11.80	0.50	0.25
5	17:40	2	12.20	0.40	0.20
6	17:45	5	13.40	1.20	0.24
7	17:50	5	14.60	1.20	0.24
8	17:55	5	15.70	1.10	0.22
9	18:00	5	16.80	1.10	0.22

CELL CONSTANT 35.64

CALCULATIONS

, the steady state rate of flow, is achieved when R is the same in three consecutive time intervals.

For the 1st Set of Readings $\bar{R}_1$ = (2.725 R_1)/60 = 0.0454 cm/sec

For the 2nd Set of Readings $\bar{R}_2$ = (0.23 R_2)/60 = 0.00383 cm/sec

K_{fs} (FIELD SATURATED HYDRAULIC CONDUCTIVITY) = [(.0041)(35.64 RESERVOIR CONSTANT)(0.00383 $\bar{R}_2$-STEADY STATE RATE OF FLOW)] - [(.0054)(2.15 RESERVOIR CONSTANT)(0.0454 $\bar{R}_1$-STEADY STATE RATE OF FLOW)] = 3.256×10^{-5} cm/sec

ϕ_m (MATRIC FLUX POTENTIAL) = [(.0572)(2.15 RESERVOIR CONSTANT)(0.0454 $\bar{R}_1$ STEADY STATE RATE OF FLOW)] - [(.0237)(35.64 RESERVOIR CONSTANT)(0.00383 $\bar{R}_2$ STEADY STATE RATE OF FLOW)] = 2.348×10^{-3} cm^2/sec

α (ALPHA PARAMETER) = (3.256×10^{-5} K_{fs}) / (2.348×10^{-3} ϕ_m) = 0.0139 cm^{-1}

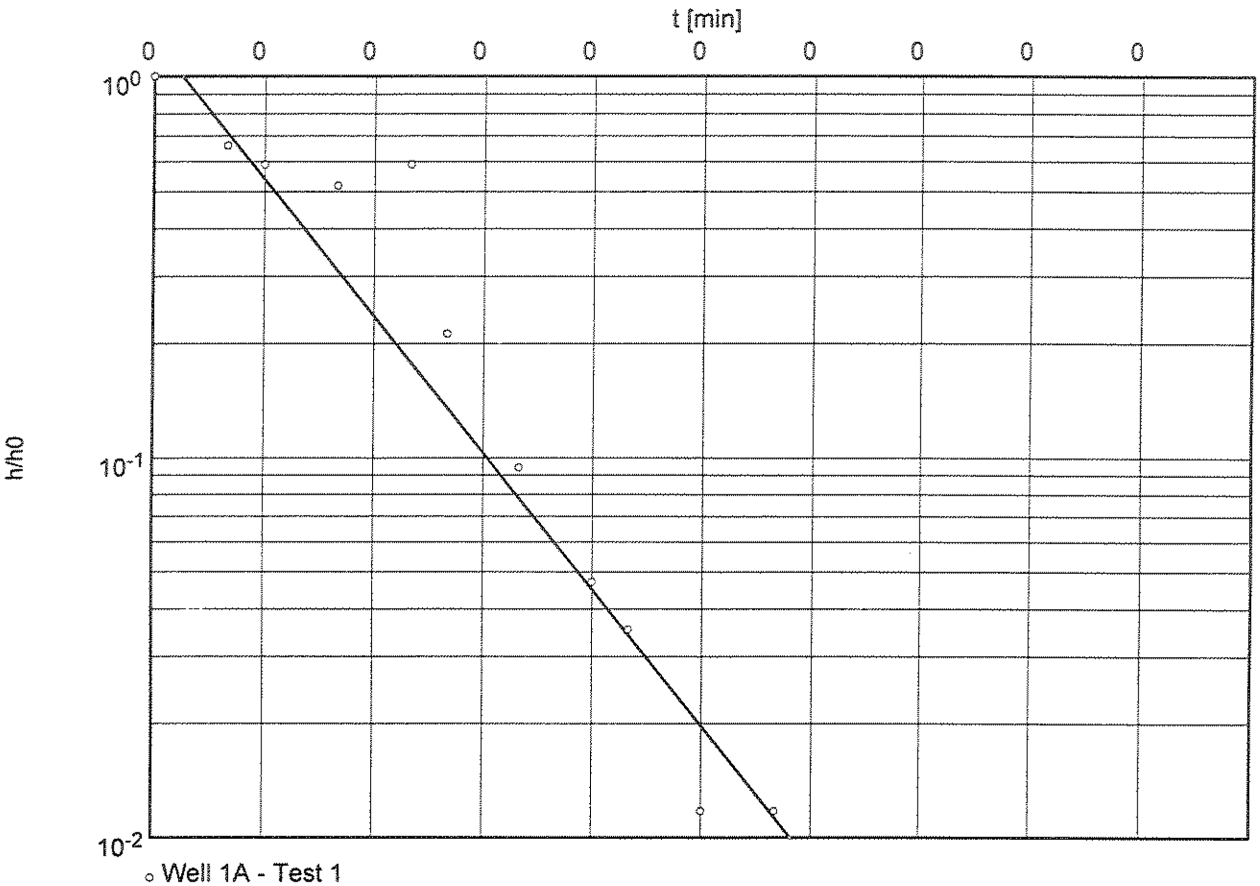
$\Delta\Theta$ (DELTA THETA) = (________ θ_{fs}, FIELD SATURATED WATER CONTENT OF SOIL, IN CM /CM) - (________ θ_i, AMBIENT WATER CONTENT OF SOIL, IN CM /CM) = ________ cm^3/cm^3

ESTIMATED		CHECK ONE
MEASURED		

S (SORPTIVITY) = $\sqrt{2}$(________ $\Delta\theta$)(________ ϕ_m) = ________ cm $sec^{-1/2}$

Schafer and Associates 865 Technology Blvd Bozeman, MT (406) 388-5192	slug/bail test analysis HVORSLEV's method	Page 1 Project: ARCO Clark Fork River Evaluated by: TM — Date:

Slug Test No. 1	Test conducted on: 7/31/97
MW-1A	



Hydraulic conductivity [ft/min]: 5.72×10^{-2}

Schafer and Associates 865 Technology Blvd Bozeman, MT (406) 388-5192	slug/bail test analysis HVORSLEV's method	Page 2 Project: ARCO Clark Fork River Evaluated by: TM · Date:

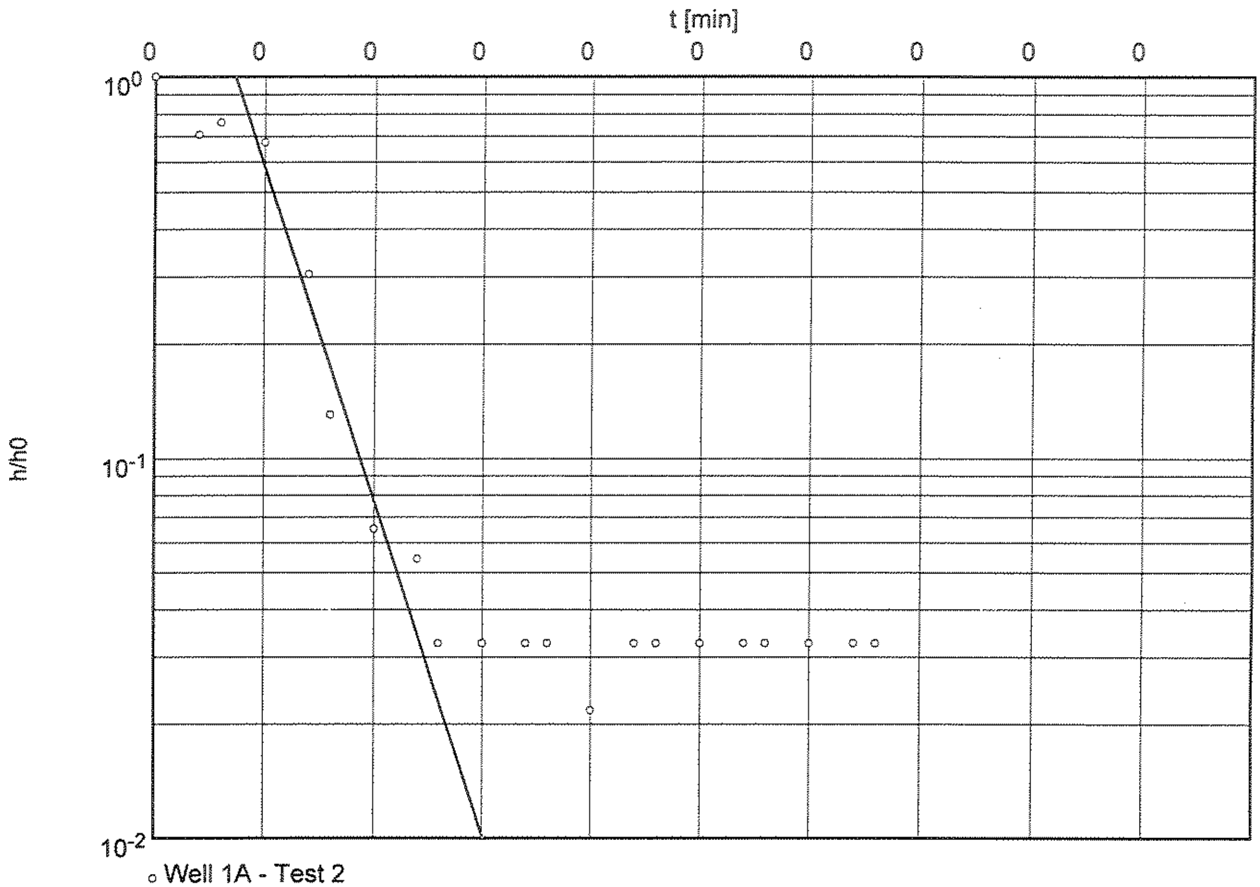
Slug Test No. 1	Test conducted on: 7/31/97
MW-1A	Well 1A - Test 1

Static water level: 7.76 ft below datum

	Pumping test duration [min]	Water level [ft]	Change in Waterlevel [ft]	
1	0.00	8.61	0.85	
2	0.02	8.32	0.56	
3	0.03	8.26	0.50	
4	0.05	8.20	0.44	
5	0.07	8.26	0.50	
6	0.08	7.94	0.18	
7	0.10	7.84	0.08	
8	0.12	7.80	0.04	
9	0.13	7.79	0.03	
10	0.15	7.77	0.01	
11	0.17	7.77	0.01	
12	0.18	7.76	0.00	
13	0.20	7.76	0.00	
14	0.22	7.76	0.00	
15	0.23	7.76	0.00	
16	0.25	7.76	0.00	

Schafer and Associates 865 Technology Blvd Bozeman, MT (406) 388-5192	slug/bail test analysis HVORSLEV's method	Page 1 Project: ARCO Clark Fork River Evaluated by: TM — Date:

Slug Test No. 2	Test conducted on: 7/31/97
MW-1A	



Hydraulic conductivity [ft/min]: 8.38×10^{-2}

Schafer and Associates 865 Technology Blvd Bozeman, MT (406) 388-5192	slug/bail test analysis HVORSLEV's method	Page 2 Project: ARCO Clark Fork River Evaluated by: TM · Date:

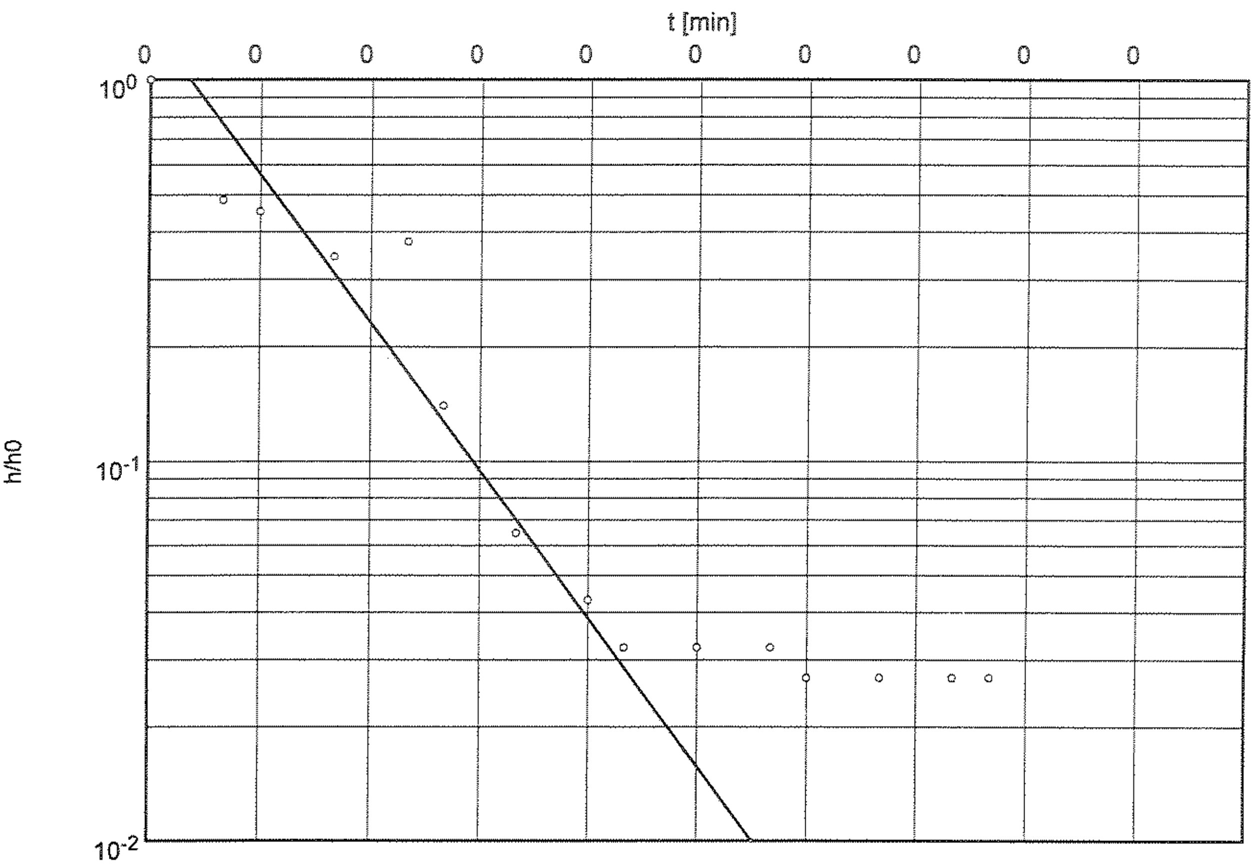
Slug Test No. 2	Test conducted on: 7/31/97
MW-1A	Well 1A - Test 2

Static water level: 7.76 ft below datum

	Pumping test duration [min]	Water level [ft]	Change in Waterlevel [ft]	
1	0.00	8.68	0.92	
2	0.02	8.41	0.65	
3	0.03	8.46	0.70	
4	0.05	8.38	0.62	
5	0.07	8.04	0.28	
6	0.08	7.88	0.12	
7	0.10	7.82	0.06	
8	0.12	7.81	0.05	
9	0.13	7.79	0.03	
10	0.15	7.79	0.03	
11	0.17	7.79	0.03	
12	0.18	7.79	0.03	
13	0.20	7.78	0.02	
14	0.22	7.79	0.03	
15	0.23	7.79	0.03	
16	0.25	7.79	0.03	
17	0.27	7.79	0.03	
18	0.28	7.79	0.03	
19	0.30	7.79	0.03	
20	0.32	7.79	0.03	
21	0.33	7.79	0.03	

Schafer and Associates 865 Technology Blvd Bozeman, MT (406) 388-5192	slug/bail test analysis HVORSLEV's method	Page 1 Project: ARCO Clark Fork River Evaluated by: TM Date:

Slug Test No. 3	Test conducted on: 7/31/97
MW-1A	



○ Well 1A - Test 3

Hydraulic conductivity [ft/min]: 6.19×10^{-2}

Schafer and Associates 865 Technology Blvd Bozeman, MT (406) 388-5192	slug/bail test analysis HVORSLEV's method	Page 2 Project: ARCO Clark Fork River Evaluated by: TM / Date:

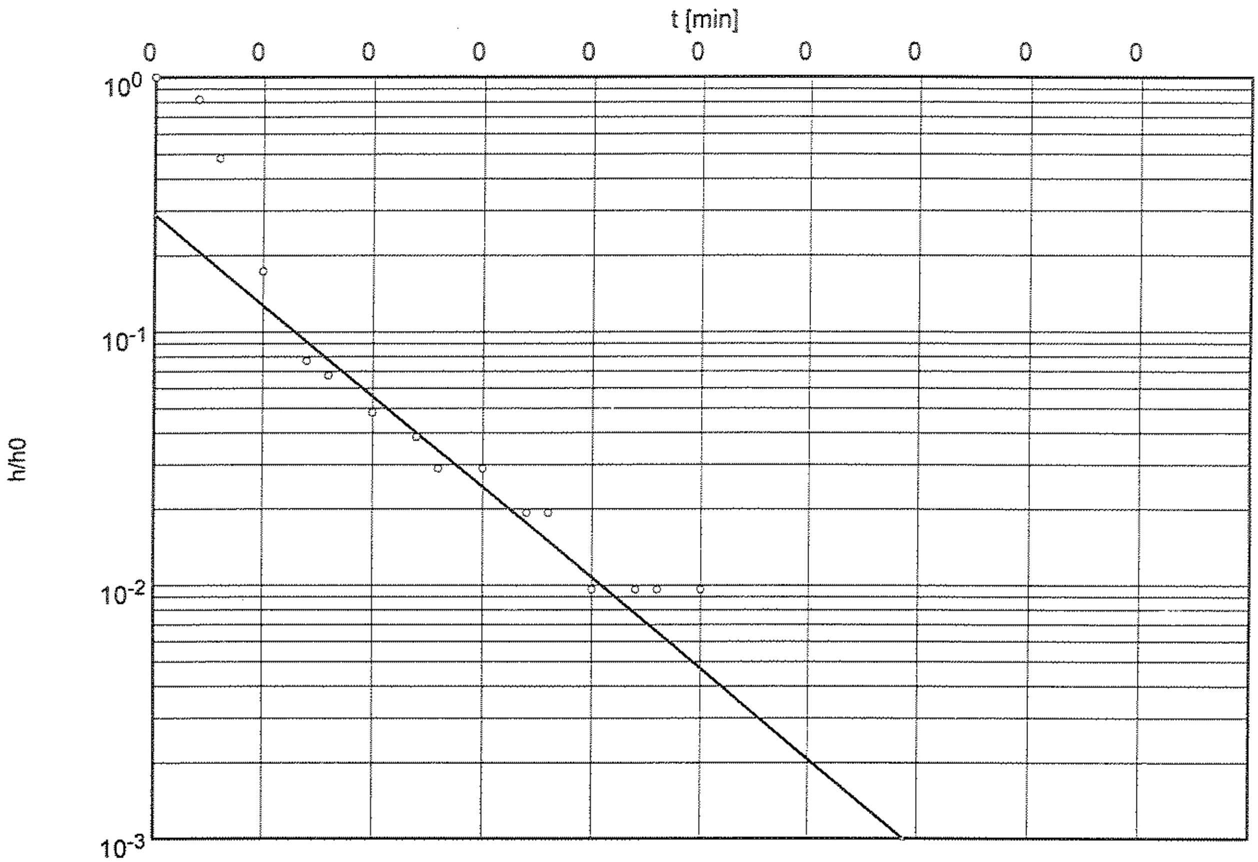
Slug Test No. 3	Test conducted on: 7/31/97
MW-1A	Well 1A - Test 3

Static water level: 7.76 ft below datum

	Pumping test duration [min]	Water level [ft]	Change in Waterlevel [ft]	
1	0.00	9.62	1.86	
2	0.02	8.66	0.90	
3	0.03	8.60	0.84	
4	0.05	8.40	0.64	
5	0.07	8.46	0.70	
6	0.08	8.02	0.26	
7	0.10	7.88	0.12	
8	0.12	7.84	0.08	
9	0.13	7.82	0.06	
10	0.15	7.82	0.06	
11	0.17	7.82	0.06	
12	0.18	7.81	0.05	
13	0.20	7.81	0.05	
14	0.22	7.81	0.05	
15	0.23	7.81	0.05	

Schafer and Associates 865 Technology Blvd Bozeman, MT (406) 388-5192	slug/bail test analysis HVORSLEV's method	Page 1 Project: ARCO Clark Fork River Evaluated by: TM Date:

Slug Test No. 1	Test conducted on: 7/31/97
MW-2B	



◦ Well 1B - Test 1

Hydraulic conductivity [ft/min]: 3.41×10^{-2}

Schafer and Associates 865 Technology Blvd Bozeman, MT (406) 388-5192	slug/bail test analysis HVORSLEV's method	Page 2 Project: ARCO Clark Fork River Evaluated by: TM Date:

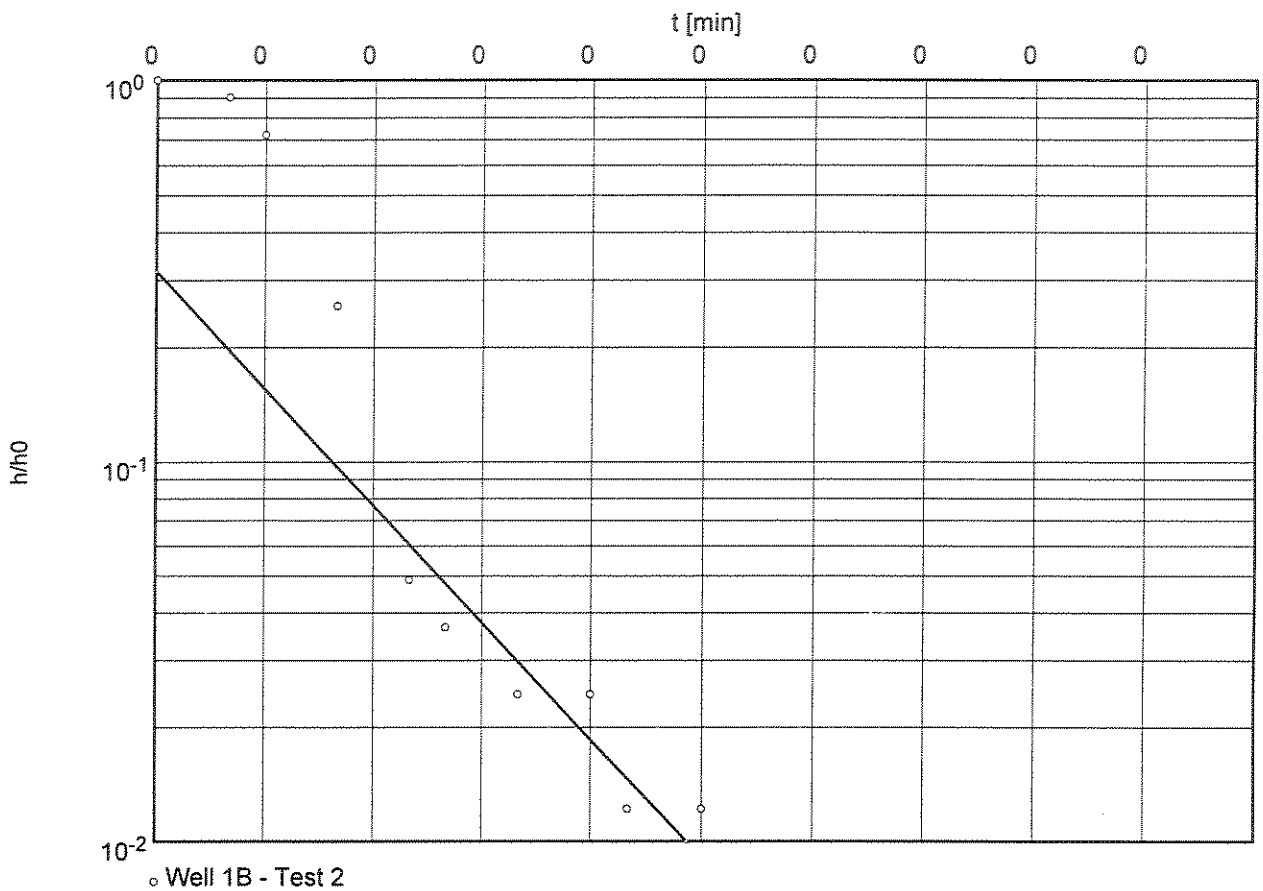
Slug Test No. 1	Test conducted on: 7/31/97
MW-2B	Well 1B - Test 1

Static water level: 6.71 ft below datum

	Pumping test duration [min]	Water level [ft]	Change in Waterlevel [ft]	
1	0.00	7.75	1.04	
2	0.02	7.56	0.85	
3	0.03	7.21	0.50	
4	0.05	6.89	0.18	
5	0.07	6.79	0.08	
6	0.08	6.78	0.07	
7	0.10	6.76	0.05	
8	0.12	6.75	0.04	
9	0.13	6.74	0.03	
10	0.15	6.74	0.03	
11	0.17	6.73	0.02	
12	0.18	6.73	0.02	
13	0.20	6.72	0.01	
14	0.22	6.72	0.01	
15	0.23	6.72	0.01	
16	0.25	6.72	0.01	
17	0.27	6.71	0.00	
18	0.28	6.71	0.00	
19	0.30	6.71	0.00	
20	0.32	6.71	0.00	
21	0.33	6.71	0.00	

Schafer and Associates 865 Technology Blvd Bozeman, MT (406) 388-5192	slug/bail test analysis HVORSLEV's method	Page 1 Project: ARCO Clark Fork River Evaluated by: TM / Date: 01.08.1997

Slug Test No. 2	Test conducted on: 7/31/97
MW-1B	



Hydraulic conductivity [ft/min]: 4.90×10^{-2}

Schafer and Associates 865 Technology Blvd Bozeman, MT (406) 388-5192	slug/bail test analysis HVORSLEV's method	Page 2 Project: ARCO Clark Fork River Evaluated by: TM — Date: 01.08.1997

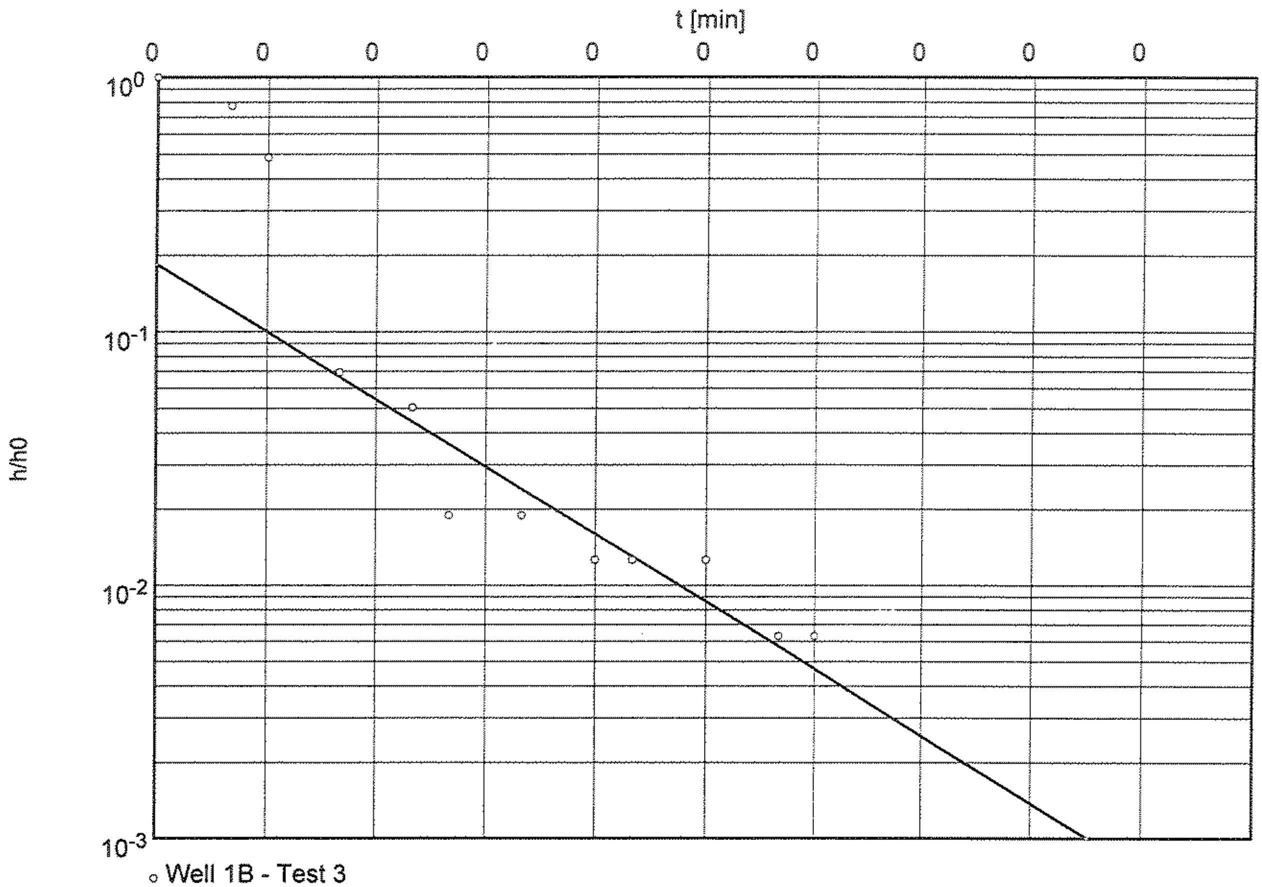
Slug Test No. 2	Test conducted on: 7/31/97
MW-1B	Well 1B - Test 2

Static water level: 6.75 ft below datum

	Pumping test duration [min]	Water level [ft]	Change in Waterlevel [ft]	
1	0.00	7.57	0.82	
2	0.02	7.49	0.74	
3	0.03	7.34	0.59	
4	0.05	6.96	0.21	
5	0.07	6.79	0.04	
6	0.08	6.78	0.03	
7	0.10	6.77	0.02	
8	0.12	6.77	0.02	
9	0.13	6.76	0.01	
10	0.15	6.76	0.01	
11	0.17	6.75	0.00	
12	0.18	6.75	0.00	
13	0.20	6.75	0.00	
14	0.22	6.75	0.00	
15	0.23	6.75	0.00	

Schafer and Associates 865 Technology Blvd Bozeman, MT (406) 388-5192	slug/bail test analysis HVORSLEV's method	Page 1 Project: ARCO Clark Fork River Evaluated by: TM Date:

Slug Test No. 3	Test conducted on: 7/31/97
MW-2B	



Hydraulic conductivity [ft/min]: 4.23×10^{-2}

Schafer and Associates
865 Technology Blvd
Bozeman, MT
(406) 388-5192

slug/bail test analysis
HVORSLEV's method

Project: ARCO Clark Fork River

Evaluated by: TM | Date:

Slug Test No. 3 | Test conducted on: 7/31/97

MW-2B | Well 1B - Test 3

Static water level: 6.74 ft below datum

	Pumping test duration [min]	Water level [ft]	Change in Waterlevel [ft]	
1	0.00	8.33	1.59	
2	0.02	7.97	1.23	
3	0.03	7.51	0.77	
4	0.05	6.85	0.11	
5	0.07	6.82	0.08	
6	0.08	6.77	0.03	
7	0.10	6.77	0.03	
8	0.12	6.76	0.02	
9	0.13	6.76	0.02	
10	0.15	6.76	0.02	
11	0.17	6.75	0.01	
12	0.18	6.75	0.01	
13	0.20	6.74	0.00	
14	0.22	6.74	0.00	
15	0.23	6.74	0.00	
16	0.25	6.74	0.00	

Appendix B-1

Control Chemical Data

CLARK FORK GOVERNORS PROJECT FOR CONTROL AND VEGETATED MICROWATERSHEDS

MONITORING WELL SAMPLING RESULTS (Organized by Well Number)

WELL	SAMPLE	FIELD PARAMETERS				LABORATORY ANALYSIS																				
		SWL		EC	T	MAJOR IONS mg/l															DISSOLVED METALS mg/l					
No.	DATE	(bgs)	pH	(uhos/cm)	(C)	K	Na	Ca	Mg	SO4	Cl	CO3	HCO3	F		NO3		Alk	P		As		Cu		Zn	
MW-1A	25-Apr-94	2.49	7.22	970	7.1																					
MW-1A	23-May-94	2.36	7.14	891	12.8	16	56	149	24	348	21	0	229	1.40		0.05	B	187	0.18	D	0.006		0.16		0.82	D
MW-1A	29-Jun-94	3.48	7.10	866	14.5																					
MW-1A	27-Jul-94	3.77	7.09	1115																						
MW-1A	25-Aug-94	3.92	6.94	863	19.9																					
MW-1A	23-Sep-94		7.10	1210	16.0																					
MW-1A	26-Oct-94	3.47	7.10	1340	8.0	17	60	148	24	397	25	0	234	1.50		0.05	B	192	0.50	D	0.011		0.05		0.48	D
MW-1A	28-Dec-94	3.42	6.28	1270	6.2																					
MW-1A	05-Mar-95	3.30	6.82	1024	10.6																					
MW-1A	26-Apr-95	3.26	7.02	1206	7.9																					
MW-1A	24-May-95	2.05	7.29	977	6.7	14	61	146	25	384	25	0	228	1.61		0.05	B	187	0.11	D	0.007		0.04		0.34	U
MW-1A	28-Jul-95	3.04	6.92	804	14.1																					
MW-1A	25-Aug-95	3.03	6.63	728	14.6																					
MW-1A	12-Oct-95	3.23	6.75	869	9.1																					
MW-1A	08-Nov-95	3.21	6.14	1072	8.6	21	66	163	28	408	24	0	238	1.51		0.05	B	195	0.22	D	0.007	U	0.04	U	0.34	U,D
MW-1A	13-Feb-96	2.6	6.81	1257	5																					
MW-1A	10-Apr-96	3.2	7.18	1125	3.5																					
MW-1A	21-May-96	1.28	7.21	1075	14.4	16	59	158	27	390	30	0	243	1.29	U	0.05	B	199	0.15		0.007	U	0.04	U	0.35	D,U
MW-1A	25-Jun-96	1.73	6.73	842	12.4																					
MW-1A	25-Jul-96	2.95	7.08	941	13.7																					
MW-1A	28-Aug-96	3.8	6.63	662	14.7																					
MW-1A	26-Sep-96	3.26	6.62	879	10.7																					
MW-1A	28-Oct-96	3.13	6.56	578	9.8	17	70	168	27	439	35	0	240	1.57	U	0.05	B	196	0.16	D	0.007	U	0.03	U	0.31	U
MW-1B	25-Apr-94	2.66	7.15	900	7.5																					
MW-1B	23-May-94	2.01	7.14	840	10.6	12	48	133	23	298	17	0	222	1.16		0.05	B	182	0.19	D	0.005	B	0.05		0.35	D
MW-1B	29-Jun-94	3.63	7.13	835	11.4																					

CLARK FORK GOVERNORS PROJECT FOR CONTROL AND VEGETATED MICROWATERSHEDS

MONITORING WELL SAMPLING RESULTS (Organized by Well Number)

WELL	SAMPLE	FIELD PARAMETERS				LABORATORY ANALYSIS																					
		SWL		EC	T	MAJOR IONS mg/l																DISSOLVED METALS mg/l					
No.	DATE	(bgs)	pH	(uhos/cm)	(C)	K	Na	Ca		Mg	SO4	Cl	CO3	HCO3	F		NO3		Alk	P		As		Cu		Zn	
MW-1B	27-Jul-94	3.98	7.20	1023																							
MW-1B	25-Aug-94	4.09	7.02	836	18.6																						
MW-1B	23-Sep-94		7.08	1198	15.9																						
MW-1B	26-Oct-94	3.61	7.12	1160	8.3	15	54	137		23	324	21	0	253	1.15		0.05	B	207	0.24		0.005	B	0.01	B	0.08	U,D
MW-1B	28-Dec-94	3.61	6.66	1151	9.6																						
MW-1B	05-Mar-95	3.47	6.90	985	10.5																						
MW-1B	26-Apr-95	3.43	7.07	1185	6.6																						
MW-1B	24-May-95	2.30	7.33	989	9.7	14	61	159		26	405	27	0	252	1.20		0.05	B	207	0.17	D	0.005	B	0.01	B	0.01	B,U
MW-1B	28-Jul-95	3.17	7.16	631	11.7																						
MW-1B	25-Aug-95	3.24	7.27	669	14.9																						
MW-1B	12-Oct-95	3.47	7.12	708	9.7																						
MW-1B	08-Nov-95	3.46	6.20	999	9.6	15	58	136		23	321	18	0	250	1.11		0.05		205	0.21	D	0.005	B,U	0.01	B,U	0.02	D,U
MW-1B	13-Feb-96	2.8	7.24	1180	8																						
MW-1B	10-Apr-96	3.45	7.2	1047	5.5																						
MW-1B	21-May-96	1.99	7.27	1039	9.4	14	62	158		27	384	30	0	265	1.18		0.05	B	217	0.15		0.005	B,U	0.01	B,U	0.02	D,U
MW-1B	25-Jun-96	2.44	7.21	807	9.8																						
MW-1B	25-Jul-96	3.02	7.21	834	13.8																						
MW-1B	28-Aug-96	3.59	6.78	584	14.9																						
MW-1B	26-Sep-96	3.92	6.89	632	11																						
MW-1B	28-Oct-96	3.65	6.67	852	9.5	14	57	139	U	23	321	31	0	254	1.19	U	0.05	B	208	0.21	D	0.005	B,U	0.01	B,U	0.02	U
MW-2A	25-Apr-94	1.59	7.12	622	5.8																						
MW-2A	23-May-94	1.39	6.97	541	10.0	4	22	121		18	252	13	0	145	0.76		0.05	B	119	0.26	D	0.006		0.42		1.11	D
MW-2A	29-Jun-94	2.48	6.90	538	11.0																						
MW-2A	27-Jul-94	2.87	7.10	595																							
MW-2A	25-Aug-94	3.10	7.10	562	16.8																						
MW-2A	23-Sep-94		6.84	680	15.8																						

Governor's Demonstration Project			
Treated Site Groundwater Chemistry			
Monitor Well MW-1A			
Metal	5/17/97	7/31/97	8/21/97
Arsenic	-	0.006	0.008
Cadmium	-	0.0013	0.001
Copper	-	0.034	0.05
Lead	-	0.002 B	0.01 B
Zinc	-	0.272	0.29
pH		7.00	6.37
EC		688	728
Monitor Well MW-1B			
Metal	5/17/97	7/31/97	8/21/97
Arsenic	-	0.003	0.005 B
Cadmium	-	0.0001 B	0.001 B
Copper	-	0.001 B	0.01 B
Lead	-	0.002 B	0.01 B
Zinc	-	0.023	0.01 B
pH		7.16	6.29
EC		542	590
Drive Point DP-1A			
Metal	5/17/97	7/31/97	8/21/97
Arsenic	-	0.007	0.018
Cadmium	-	0.0019	0.001
Copper	-	0.035	0.01
Lead	-	0.002 B	0.01 B
Zinc	-	0.532	0.24
pH		6.47	6.07
EC		410	602
Drive Point DP-1B			
Metal	5/17/97	7/31/97	8/21/97
Arsenic	-	0.001	0.005 B
Cadmium	-	0.0032	0.004
Copper	-	0.121	0.02
Lead	-	0.002	0.01 B
Zinc	-	0.71	0.4
pH		6.55	6.47
EC		525	389
Drive Point DP-1C			
Metal	5/17/97	7/31/97	8/21/97
Arsenic	-	0.089	0.055
Cadmium	-	0.0209	0.009
Copper	-	0.307	0.1
Lead	-	0.004	0.01 B
Zinc	-	3.33	1.51
pH		5.87	5.85
EC		588	510

Notes:

All results in mg/l

B - Element concentration below detection

Bank Full Storage - Governor's Demonstration Project		
Major Ions Chemistry		
	Treated Microwatershed	
	MW1B	**MW1A**
Constituent	7/31/97	8/21/97
Potassium	10	14
Sodium	37	42
Calcium	93	120
Magnesium	16	21
Sulfate	155	248
Chloride	11	15
Carbonate as CO3	0	0
Bicarbonate as HCO3	231	220
Alkalintiy	190	180
Fluoride	1.1	1.15
Nitrate plus Nitrite as N	0.05 B	0.05 B
Phosphorus	0.01	0.01 B
Barium, dissolved	0.041	0.1 B
Iron, dissolved	0.37	0.07

Notes:

All results in mg/l
B - Element concentration below detection

Appendix B-2

Treated Chemical Data

CLARK FORK GOVERNORS PROJECT FOR CONTROL AND VEGETATED MICROWATERSHEDS

MONITORING WELL SAMPLING RESULTS (Organized by Well Number)

		FIELD PARAMETERS				LABORATORY ANALYSIS																				
						MAJOR IONS mg/l															DISSOLVED METALS mg/l					
WELL No.	SAMPLE DATE	SWL (bgs)	pH	EC (uhos/cm)	T (C)	K	Na	Ca	Mg	SO4	Cl	CO3	HCO3	F		NO3		Alk	P		As		Cu		Zn	
MW-2A	26-Oct-94	2.46	6.98	630	6.9	4	15	85	13	145	7	0	157	0.89		0.08		128	0.33		0.006		0.02		0.85	U,D
MW-2A	28-Dec-94	2.72	6.53	544	6.5																					
MW-2A	05-Mar-95	2.58	6.44	767	10.0																					
MW-2A	26-Apr-95	2.51	6.56	526	5.7																					
MW-2A	24-May-95	2.42	7.04	528	5.6	4	15	93	15	164	8	0	160	0.76		0.05	B	131	0.15	D	0.005	B	0.26		0.37	U
MW-2A	28-Jul-95	1.93	6.47	576	14.0																					
MW-2A	25-Aug-95	2.13	6.16	628	15.1																					
MW-2A	12-Oct-95	2.39	6.23	634	10.1																					
MW-2A	08-Nov-95	2.25	7.17	542	10.1	4	16	94	15	148	6	0	168	0.87		0.14		137	0.16	D	0.005	U	0.28	U	0.36	U,D
MW-2A	13-Feb-96	1.9	7	550	5.5																					
MW-2A	10-Apr-96	2.15	6.89	437	4																					
MW-2A	21-May-96	0.58	7.13	551	11.8	3	16	96	15	165	8	0	165	0.86		0.05	B	136	0.11		0.005	U	0.25	U	0.34	D,U
MW-2A	25-Jun-96	0.79	6.7	563	11.2																					
MW-2A	25-Jul-96	2.05	6.53	610	13.2																					
MW-2A	28-Aug-96	2.56	6.58	544	13.2																					
MW-2A	26-Sep-96	3.46	6.30	504	11.7																					
MW-2A	28-Oct-96	2.32	6.43	454	8.7	4	17	81	13	146	8	0	172	0.87	U	0.16		141	0.14	D	0.005	B,U	0.32	U	0.37	U
MW-2B	25-Apr-94	1.74	7.02	498	5.6																					
MW-2B	23-May-94	1.31	6.87	525	12.4	4	16	108	16	193	11	0	160	0.76		0.05	B	131	0.24	D	0.005	B	0.12		0.19	D
MW-2B	29-Jun-94	2.14	6.80	519	11.6																					
MW-2B	27-Jul-94	2.42	7.12	515																						
MW-2B	25-Aug-94	3.95	7.08	534	17.3																					
MW-2B	23-Sep-94		6.78	627	15.8																					
MW-2B	26-Oct-94	2.29	7.16	680	6.8	4	15	86	13	150	7	0	157	0.86		0.20		128	0.38		0.005	B	0.05		0.22	U,D
MW-2B	28-Dec-94	2.66	6.24	577	6.5																					
MW-2B	05-Mar-95	2.50	6.54	743	10.1																					

CLARK FORK GOVERNORS PROJECT FOR CONTROL AND VEGETATED MICROWATERSHEDS

MONITORING WELL SAMPLING RESULTS (Organized by Well Number)

WELL	SAMPLE	FIELD PARAMETERS				LABORATORY ANALYSIS																				
		SWL		EC	T	MAJOR IONS mg/l															DISSOLVED METALS mg/l					
No.	DATE	(bgs)	pH	(uhos/cm)	(C)	K	Na	Ca	Mg	SO4	Cl	CO3	HCO3	F		NO3		Alk	P		As		Cu		Zn	
MW-2B	26-Apr-95	2.42	7.04	528	5.6																					
MW-2B	24-May-95	1.51	7.32	467	4.9	4	16	92	14	159	7	0	160	0.74		0.05	B	131	0.42	D	0.005	B	0.07		0.06	U
MW-2B	28-Jul-95	2.03	7.34	549	11.4																					
MW-2B	25-Aug-95	2.17	6.69	568	15.1																					
MW-2B	12-Oct-95	2.50	6.67	578	10.2																					
MW-2B	08-Nov-95	2.33	5.93	530	10.1	4	15	88	14	144	6	0	168	0.84		0.36	U	138	0.19	D	0.005	B,U	0.06	U	0.08	U,D
MW-2B	13-Feb-96	2.4	7.14	528	5																					
MW-2B	10-Apr-96	2.5	7.21	440	4.5																					
MW-2B	21-May-96	0.92	7.04	512	11.4	4	16	95	15	154	8	0	173	0.84		0.05	B	142	0.05		0.005	B,U	0.08	U	0.07	D,U
MW-2B	25-Jun-96	0.93	6.78	558	11.6																					
MW-2B	25-Jul-96	2.17	6.69	553	13.5																					
MW-2B	28-Aug-96	4.59	6.85	594	10.9																					
MW-2B	26-Sep-96	2.57	6.34	491	10.5																					
MW-2B	28-Oct-96	2.53	6.67	421	7.3	4	17	78	13	131	7	0	172	0.87	U	0.44		141	0.48	D	0.005	B,U	0.07	U	0.06	U

B - Element concentration below detection.

U - Element concentration undefendable, spike standard analysis out of range.

D - Relative Percent Difference >25% for duplicate sample analysis.

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Governor's Demonstration Project

Control Site Groundwater Chemistry

Monitor Well MW-2A

Metal	5/17/97	7/31/97	8/21/97
Arsenic	-	0.004	0.005 B
Cadmium	-	0.0024	0.003
Copper	-	0.318	0.37
Lead	-	0.002 B	0.01 B
Zinc	-	0.351	0.44
pH	-	6.96	5.80
EC	-	468	578

Monitor Well MW-2B

Metal	5/17/97		7/31/97	8/21/97
Arsenic	0.0026	B	0.002	0.005 B
Cadmium	0.003	B	0.0003	0.001 B
Copper	0.072		0.069	0.06
Lead	0.001	U	0.002 B	0.01 B
Zinc	0.0597		0.058	0.05
pH	7.22		7.49	6.04
EC	200		415	443

Observation Well OBS-1B

Metal	9/24/96	5/17/97	7/31/97	8/21/97
Arsenic	0.144	-		0.1
Cadmium	0.001 B	-		0.001 B
Copper	0.01 B	-		0.01 B
Lead	0.01 B	-		0.01 B
Zinc	0.44	-		0.27
pH	6.95	-		5.87
EC	776	-		583

Observation Well OBS-1C

Metal	9/24/96	5/17/97	7/31/97	8/21/97
Arsenic	0.013	-	0.013	
Cadmium	0.001 B	-	0.0006	
Copper	0.01 B	-	0.01	
Lead	0.01 B	-	0.002 B	
Zinc	0.17	-	0.11	
pH	7.08	-	7.13	
EC	675	-	462	

Governor's Demonstration Project

Control Site Groundwater Chemistry

Observation Well OBS-2B

Metal	9/24/96	5/17/97	7/31/97	8/21/97
Arsenic	0.007	0.0046 B		0.014
Cadmium	0.003	0.0065		0.006
Copper	0.19	0.402		0.18
Lead	0.01 B	0.001 U		0.01 B
Zinc	0.45	1.37		1.23
pH	6.91	6.7		5.58
EC	545	656		484

Observation Well OBS-2C

Metal	9/24/96	5/17/97	7/31/97	8/21/97
Arsenic	0.019		0.024	
Cadmium	0.001		0.0008	
Copper	0.08		0.024	
Lead	0.01 B		0.002 B	
Zinc	0.25		0.058	
pH	7.01		7.45	
EC	565		445	

Observation Well OBS-3B

Metal	9/24/96	5/17/97	7/31/97	8/21/97
Arsenic	0.006	0.0083 B	-	-
Cadmium	0.001 B	0.0044 B	-	-
Copper	0.18	0.193	-	-
Lead	0.01 B	0.001 U	-	-
Zinc	0.31	0.341	-	-
pH	6.93	6.82	-	-
EC	556	400	-	-

Observation Well OBS-3C

Metal	9/24/96	5/17/97	7/31/97	8/21/97
Arsenic	0.006	0.0034 B	-	-
Cadmium	0.001 B	0.0019 B	-	-
Copper	0.03	0.0452	-	-
Lead	0.01 B	0.001 U	-	-
Zinc	0.11	0.0901	-	-
pH	7.01	6.92		
EC	526	550		