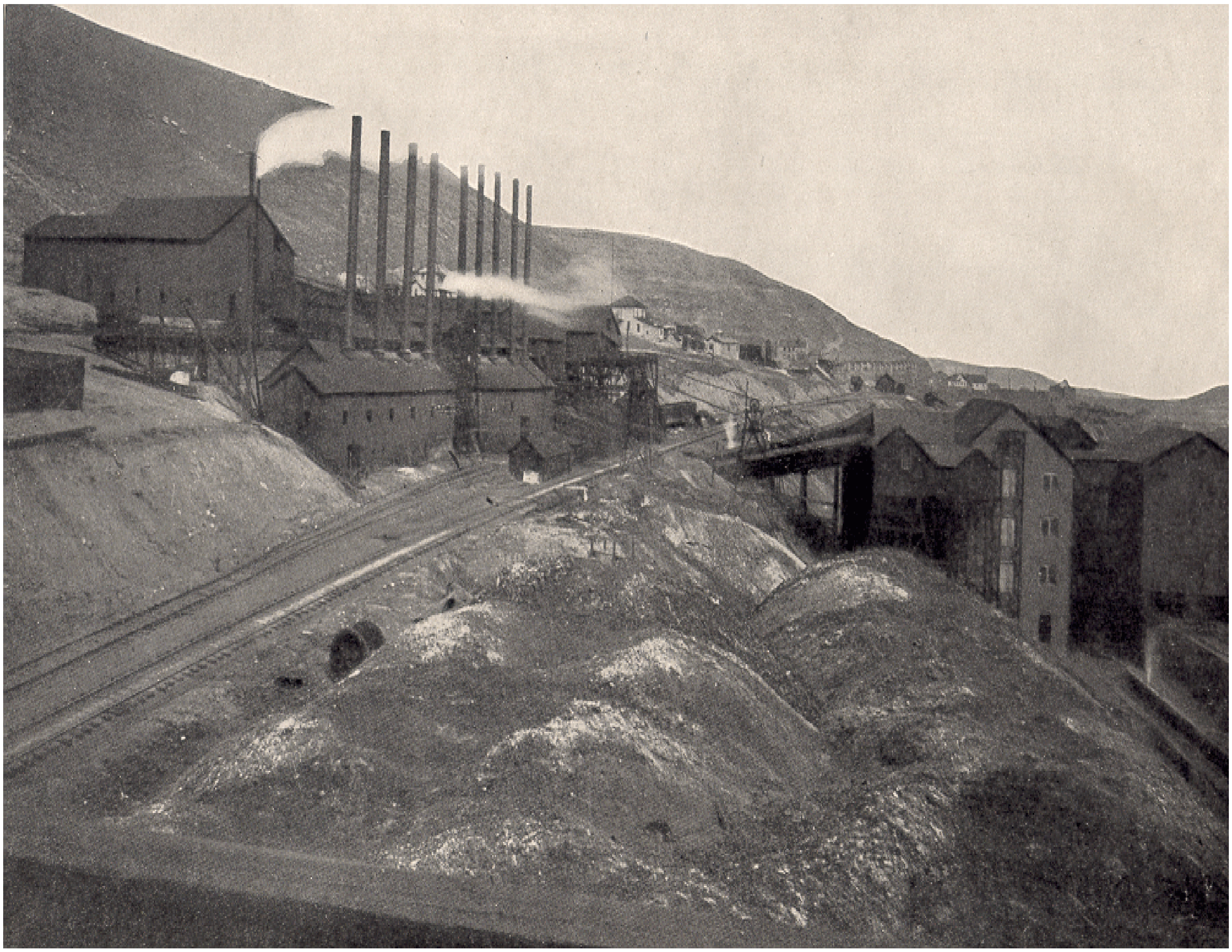
REEVALUATION of the HYDROLOGICAL SYSTEM in the VICINITY of the ANACONDA MINE at BELT, CASCADE COUNTY, MONTANA



Anaconda Copper Mining Company's Coal Plant at Belt, Montana (Photo from Fisher, 1909, Plate IX)

by

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1.0 INTRODUCTION

There have been many reports written about the geology and coal resources found in the Belt, Montana area, which is part of what Fisher (1909) describes as the Great Falls Coal Field (figure 1.1). Therefore, the reader is referred to the work of Weed (1899), Fisher, (1907 and 1909), Silverman and Harris (1967), Montana Bureau of Mines and Geology (MBMG) (1966), and the numerous other reports referenced here for a more detailed description of the area than that presented here.

Fisher (1909) described the Great Falls Coal Field as consisting of 1,500 square miles, lying mainly in Cascade County, but including small portions of Fergus and Chouteau Counties. Shurick (1909) described the area of workable coal within the area to be approximately 230 square miles, in an area generally 30 miles long by 8 miles wide.

1.1 Description of Current Project

In order to control the flow of water entering the Anaconda Mine, an understanding of the local geology and hydrogeology is necessary. Compiling existing information in a form to help with the understanding of the controls on recharge was a key goal of this study. The main components of the current project consisted of: 1) geologic framework and description; 2) hydrologic monitoring and water-quality sampling of key sites adjacent to the historic Anaconda Mine workings; 3) multi-spectral analysis; and 4) development of a three-dimensional (3-D) computer model. In addition the MBMG had another on-going project in the area that was collecting hydrologic information on a more regional basis. Information from that work was used to prepare portions of this report.

Recent geologic mapping by the MBMG was used to develop cross sections and the relationship of various formations to the underground mine workings. Besides the cross sections, the geologic data were converted into an electronic format that was used as a portion of the 3-D model. Existing wells were identified by geologic formation to assist with the identification of potential recharge areas.

The hydrologic portion of the project consisted of flow monitoring from selected mine discharges and Box Elder Creek. It also included water-quality sampling for inorganic metals analysis, and limited isotope analysis from selected mine discharges, selected surface water and ground-water sites, and water-level monitoring from existing wells.

Limited Multi-Spectral analysis was performed using available satellite images to augment the 3-D model development. Various remote sensing techniques were applied to identify areas of potential recharge to the mine or discharge points from the mine.

The 3-D model development included compiling all available data on the extent of underground mine workings, locations of exploration drill holes, and local geologic information into an ArcView project. The model will be used to present the relationships between the local geologic formations, ground-water sources, surface-water sources, and land-use practices that might influence the amount and location of water entering the mine workings. The completed model will be used to identify areas where additional information is necessary to better determine options for reducing the flow of water into the underground mine workings.

1.2 Mine Development and Ownership

The first coal mine developed in the Belt area was started by John K. Castner in 1877 (Western Mining World, 1896), and was known as the Castner Coal Mine. Coal from this mine was originally shipped by wagon to Fort Benton, a distance of 38 miles.

P.J. Shields leased the Castner Coal Mine in 1892, and shortly thereafter, he formed a partnership with Marcus Daly (Stober, 1979) to purchase the mine. The new company was incorporated as the Castner Coal and Coke Company. In 1895, the company merged with the reorganized Anaconda Mining Company, as the Anaconda Copper Mining Company, with the mine becoming the Anaconda Copper Mining Company Mine, or simply the ACM Mine. The ACM Mine operated almost continuously from 1895 until 1912, when The Anaconda Copper Mining Company shut the mine down, with portions of the mining operation being dismantled and equipment shipped to Butte (Stober, 1979). During its peak, the mine employed more than 1,000 men and produced an average of 300,000 tons per year (Silverman and Harris, 1967). Silverman and Harris (1967) estimated that this mine produced 7.5 million tons of coal during its 25-year-period of operation. One problem with the coal mined at this site was its high ash and sulfur content (Shurick, 1909). Iron-pyrite nodules that were found in the coal were the source of the sulfur. However, the iron-pyrite nodules were recovered from the washing process and shipped to ACM's Great Falls smelter and used as flux and additional fuel in the blast-furnace charge (Fisher, 1909).

The mine reopened in 1913 when G.W. Merkle leased the property from ACM and operated until 1922 (GCM Services Inc., 1983). During this time, mining consisted of the removal of the pillars left in place during the original mine development. The pillars were removed starting at the back of the mine, allowing the roof to collapse (Stober, 1979). Stober (1979) stated that the removal fo the pillars and subsequent roof collapse did not result in land depressions above the mine.

The mine had two primary openings. The original adit developed by Castner was in Castner Coulee (GCM Services Inc., 1983), which is the location of the U.S. Highway 87 access road into Belt. This opening became known as the No. 1 Mine (Western Mining World, 1896). Sometime between ACM's purchase and 1896, the No. 2 Mine adit was developed in the next coulee, one-quarter mile to the south (figure 1.2). The entire area mined through the No. 1 and No. 2 mines has been referred to generically as the Anaconda Mine over the years. The adit discharging acidic water is the location of the No. 2 Mine.

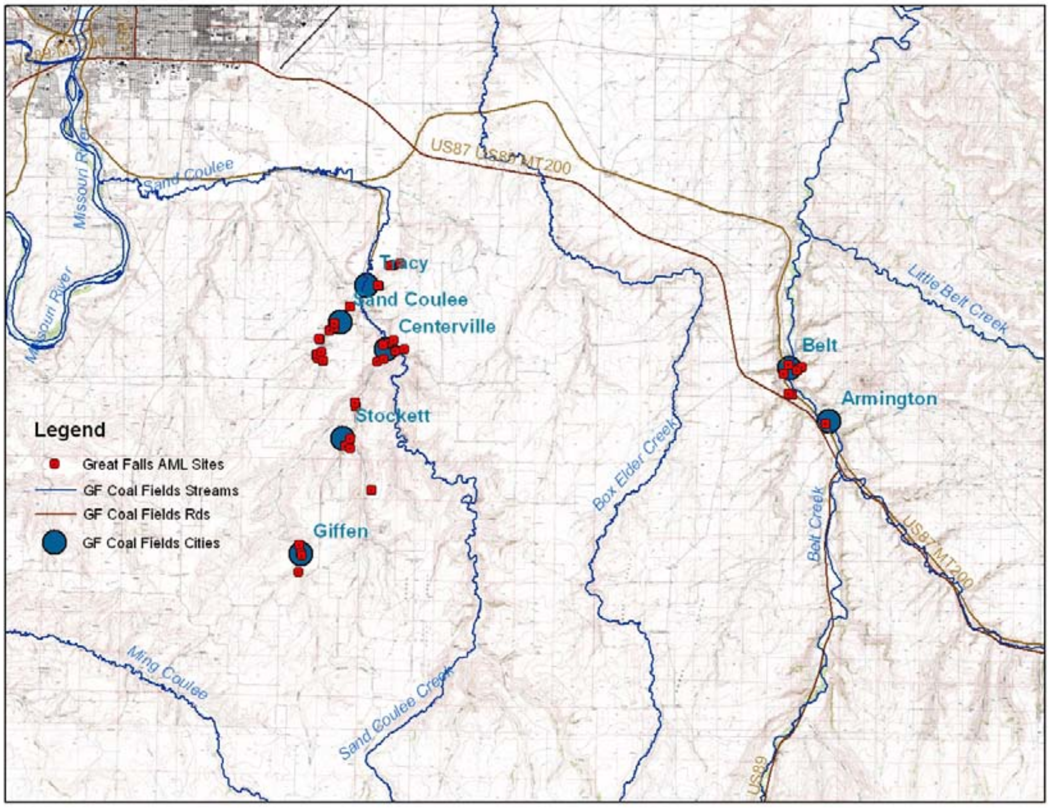


Figure 1.1. Location of study area and abandoned coal mine sites in the region.

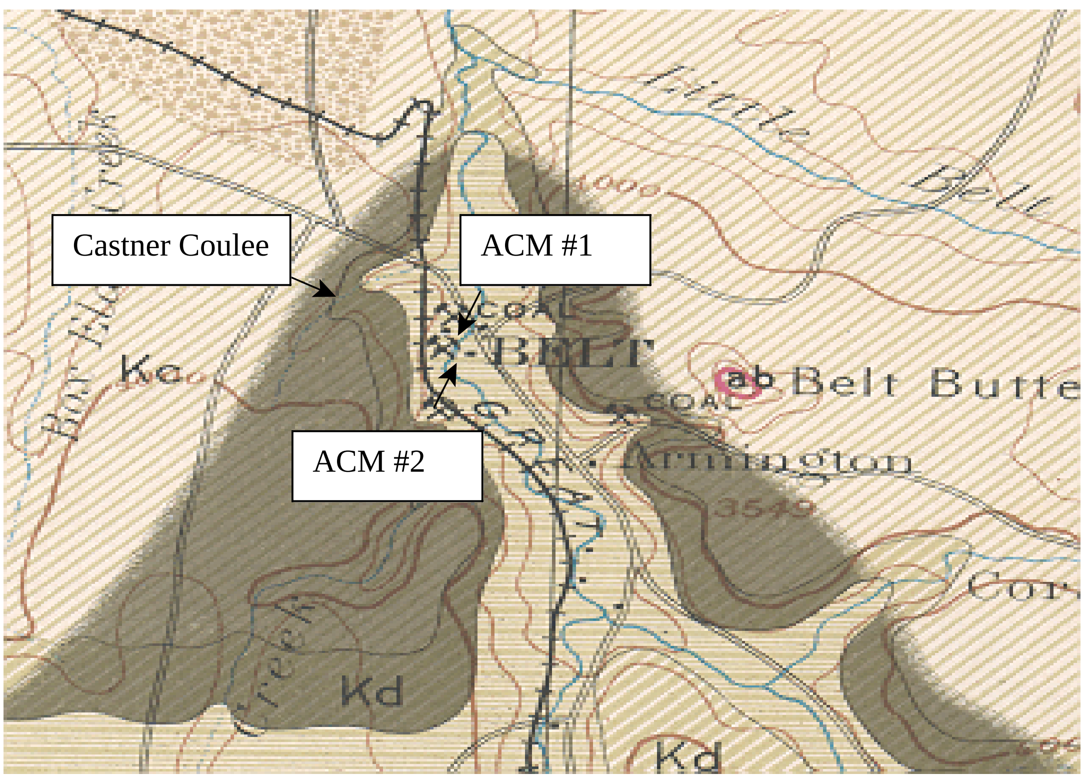


Figure 1.2. Location of ACM Mines # 1 and #2, and Castner Coulee. (Map modified from Weed 1898.)

The underground mine workings were very extensive, extending almost 2 miles west-southwest of Belt. Figure 1.3 shows the approximate area and major haulage routes in the mine.

1.3 Previous Site Work

The Montana Department of Environmental Quality (DEQ) - Mine Waste Cleanup Bureau in the 1980's identified a number of environmental problems associated with the historic coal mines and their ancillary facilities in the Belt area. As part of DEQ's activities, the mine adit for the Anaconda Mine (ACM No. 2 Mine) was closed and a pipe installed to carry the acidic water discharging from the mine downhill where it discharges into a channel carrying acid water from another discharge. Water flows in this channel adjacent to a reclaimed waste pile before discharging to Belt Creek.

DEQ, along with the U.S. Bureau of Mines (USBOM) in 1990, installed a series of wetlands for passive treatment of acid-mine water originating in the next coulee (unnamed)south of the ACM No. 2 Mine adit. This water is very acidic also, but the flow is considerably less than that from the Anaconda Mine. A portion of this water was diverted into the wetlands for treatment and then discharged to Belt Creek. However, due to the high iron concentrations and harsh winter weather in the area, the wetlands were not able to achieve an acceptable level of treatment and were abandoned. Water from this location flows under the existing railroad beds, flows down a steep hill, and then discharges into the same channel that receives the Anaconda Mine drain water. This site was called the French Coulee mine drain during this study.

The United States Geologic Survey (USGS) conducted an intensive water quality study of a number of sites in the Belt area as part of a study of acid mine drainage problems in the Stockett-Sand Coulee and Belt areas. They installed a flume and stilling well for continuous monitoring of the discharge from the Anaconda Mine and collected periodic water quality samples from various sites.

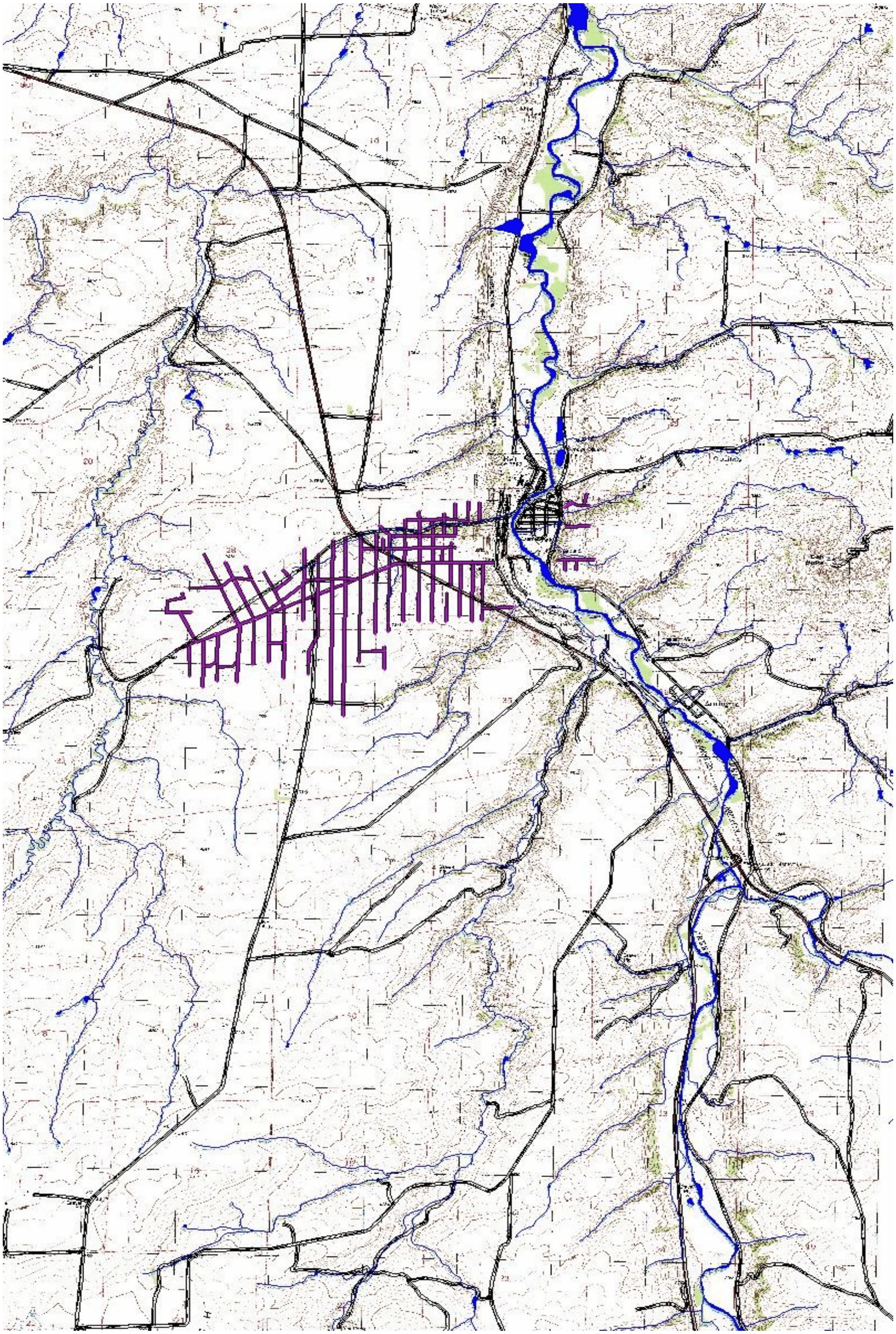


Figure 1.3. Approximate extent of major haulage routes for the Anaconda Mine.

When the coal-waste area below the Anaconda Mine, and adjacent to the channel receiving acid mine water discharge, was reclaimed, a series of six shallow monitoring wells were installed by DEQ for ground-water monitoring. These wells were installed for monitoring of a proposed grouting project aimed at mitigating the discharge of contaminated ground-water into Belt Creek. However, this project was postponed and no additional data were collected from these wells.

2.0 GEOLOGY

2.1 Stratigraphy and Water-Bearing Units

Coal was mined from the upper part of the Morrison Formation which is overlain by the lower Kootenai Formation, table 2.1. A few miles north of Belt, the upper Kootenai and overlying Blackleaf Formation are also exposed. Tertiary alluvial terrace gravel caps part of the bench overlying the mine and glacial deposits overlie the Kootenai or Blackleaf Formations north of the mine.

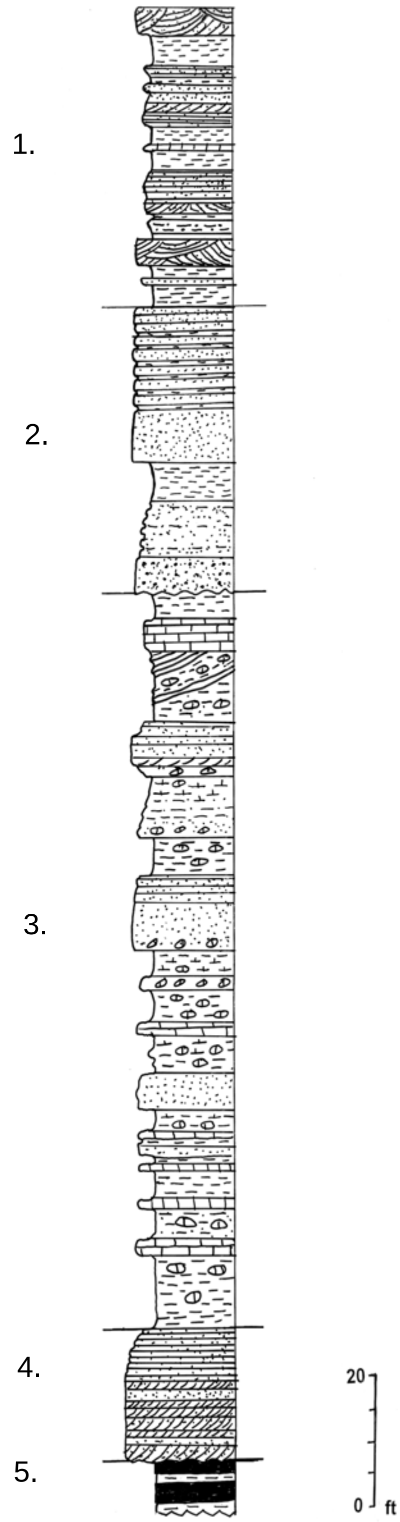
In the mine area, the Morrison Formation is underlain by the Swift Formation and the Madison Group. However, within a few miles south of Belt, other units appear between the Swift and the Madison: the Sawtooth, Otter, and Kibbey Formations. Age, lithology, thickness, and depositional environments of these stratigraphic units are summarized in table 2.1.

Possible bedrock sources of ground-water recharge to the mine are the Sunburst Member of the Kootenai Formation (quartzose sandstone unit of Walker, 1976), the Cutbank Member of the Kootenai Formation (basal sandstone of Walker, 1976) (figure 2.1), the Swift Sandstone, and the Madison Group limestone. Some water could also enter the mine from coal and thin sandstone units in the Morrison Formation. Surficial deposits that may serve as local sources are Quaternary channel alluvium, and Tertiary alluvial terrace gravel on the benches above Belt Creek.

Stratigraphic Unit	Period	Lithology	Thickness	Depositional Environment
Blackleaf Formation	Cretaceous	Black shale and sandstone beds	Not present at mine; 600' thick to north	Mostly marine
Kootenai Formation	Cretaceous			
Fifth member		Red mudstone and sandstone	Not present at mine; 120' thick to north	Alluvial plain
Fourth member		Fine-grained, thin-bedded red or brown sandstone	45' thick at mine	Deltaic and fluvial
Sunburst Sandstone		Clean, porous quartz sandstone	45' thick at mine	Marginal marine
Second member		Red mudstone with limestone lenses	115' thick at mine	Alluvial plain
Cutbank Sandstone		"Salt and pepper" sandstone, may be conglomeratic	20' thick at mine	Fluvial
Morrison Formation	Cretaceous and Jurassic	Upper coal and black shale, lower green mudstone with sandstone and limestone	165' at Armington	Alluvial plain
ELLIS GROUP	Jurassic			Marine
Swift Formation		Orange-brown sandstone, conglomeratic, fossiliferous	50' thick at mine	
Sawtooth (Piper) Formation		Oolitic limestone, shale and siltstone	Not present at mine; 30' thick to south	
BIG SNOWY GROUP	Mississippian			Marine
Otter Formation		Green shale, limestone and gypsum	Not present at mine; 300' thick to south	
Kibbey Formation		Red mudstone, siltstone, and fine-grained sandstone	Not present at mine; 100' thick to south	
MADISON GROUP	Mississippian			Marine
Mission Canyon Formation		Gray, thick-bedded limestone	800' thick to south of mine	
Lodgepole Formation		Gray, thin-bedded limestone and shale	700' thick to south of mine	

Table 2.1 Stratigraphic units in the mine area.

The Kootenai sandstones and the alluvial terrace gravel overlie the Morrison coal horizon of the mine and are therefore likely sources of recharge to the mine. One of the questions of this study is whether the deeper Jurassic Swift and Mississippian Madison aquifers could also be sources of water in the mine. Several



.1. **<u>Fourth member of Kootenai Formation (informal)</u> (Kk$_4$).**
(Red sandstone unit of Walker, 1974)

Red or tan interbedded platy sandstone and shale.

2. **<u>Sunburst Sandstone member of Kootenai Formation</u> (Kk$_5$)**
(Quartzose sandstone unit of Walker, 1974)

Clean, well-sorted limonite-speckled quartzose sandstone with little or no black chert interbedded with subordinate shale.

3. **<u>Second member of Kootenai Formation (informal)</u> (Kk$_2$).**
(Limestone concretion unit of Walker, 1974)

Red mudstone with lenticular bodies of sandstone and limestone, and conspicuous limestone concretions.

4. **<u>Cutbank Sandstone of Kootenai Formation</u> (Kk$_c$)**.
(Basal sandstone of Walker, 1974)

Coarse- to medium-grained chert-rich sandstone. Note that at Belt, the Cutbank Sandstone thickens from 20 to 80 ft in less than a mile (Walker, 1974, p. 50).

5. **<u>Upper Morrison Formation coal.</u>**

Figure 2.1 Lower Kootenai Formation and underlying Morrison coal at Belt (modified from Walker, 1974).

geologic features in this area might allow this possibility. These include: 1) pre-Jurassic erosional beveling of a regional pre-Jurassic structure; 2) paleotopography of the pre-Jurassic Madison surface, and Jurassic erosion into that surface; 3) Structures of the Great Falls Tectonic Zone; and 4) influence of the Sweetgrass Arch.

2.1.1 Pre-Jurassic Regional Structure

Prior to deposition of the Jurassic Ellis Group (Sawtooth, Rierdon, and Swift formations), a regional uplift tilted the sedimentary units to the south. This was followed by erosional beveling preceding deposition of the marine Ellis Group, and resulted in a pre-Jurassic surface of progressively younger units to the south (figure 2.2). On the northwest flank of the Little Belts, the units between the Swift and Madison include the Big Snowy Group (Kibbey, Otter, and Heath Formations), Tyler, Amsden, and Quadrant Formations. Along the Smith River, the Jurassic Sawtooth and Rierdon Formations are also present. By contrast, at Belt, the Swift rests directly on Madison Group limestone (figure 2.3). Swift overlying Madison is exposed near Stockett and in Sand Coulee about 5 miles southwest of the mine (figure 2.4). At some exposures, folds in the upper Madison do not carry through to the overlying units, and at others, the dip of the Madison opposes that of the overlying Swift, with Swift dipping roughly to the north, and Madison dipping roughly to the south.

Several factors relative to this structure may have implications for ground water:

1. The Madison limestone is much closer to the surface at Belt than to the south where a wedge of Big Snowy Group thickens significantly between the Madison and Swift. Big Snowy Group is not present north of Belt. (Plate 1, cross section D-D')
2. The Madison Limestone was exposed prior to the Jurassic from Belt northward. It may therefore thin to the north because of pre-Jurassic erosion. If the Madison Limestone thins north of Belt, this may promote a northward rise in the water table of the Madison.

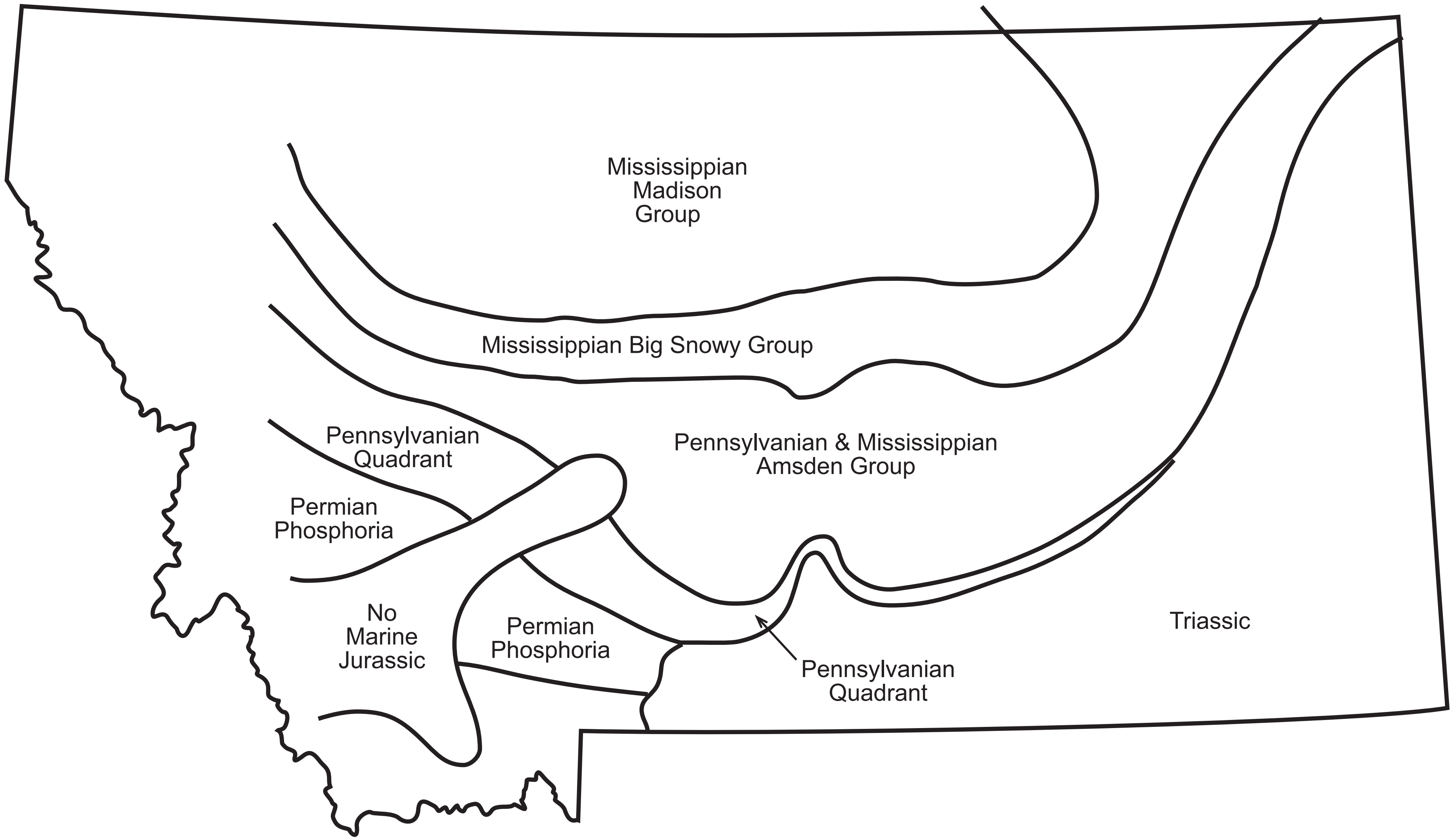


Figure 2.2. Stratigraphic units that underlie the marie Jurassic Ellis Group, indicatin southward tilting and erosional beveling prior to the deposition of the Ellis Group (modified from Schmitt, 1953).

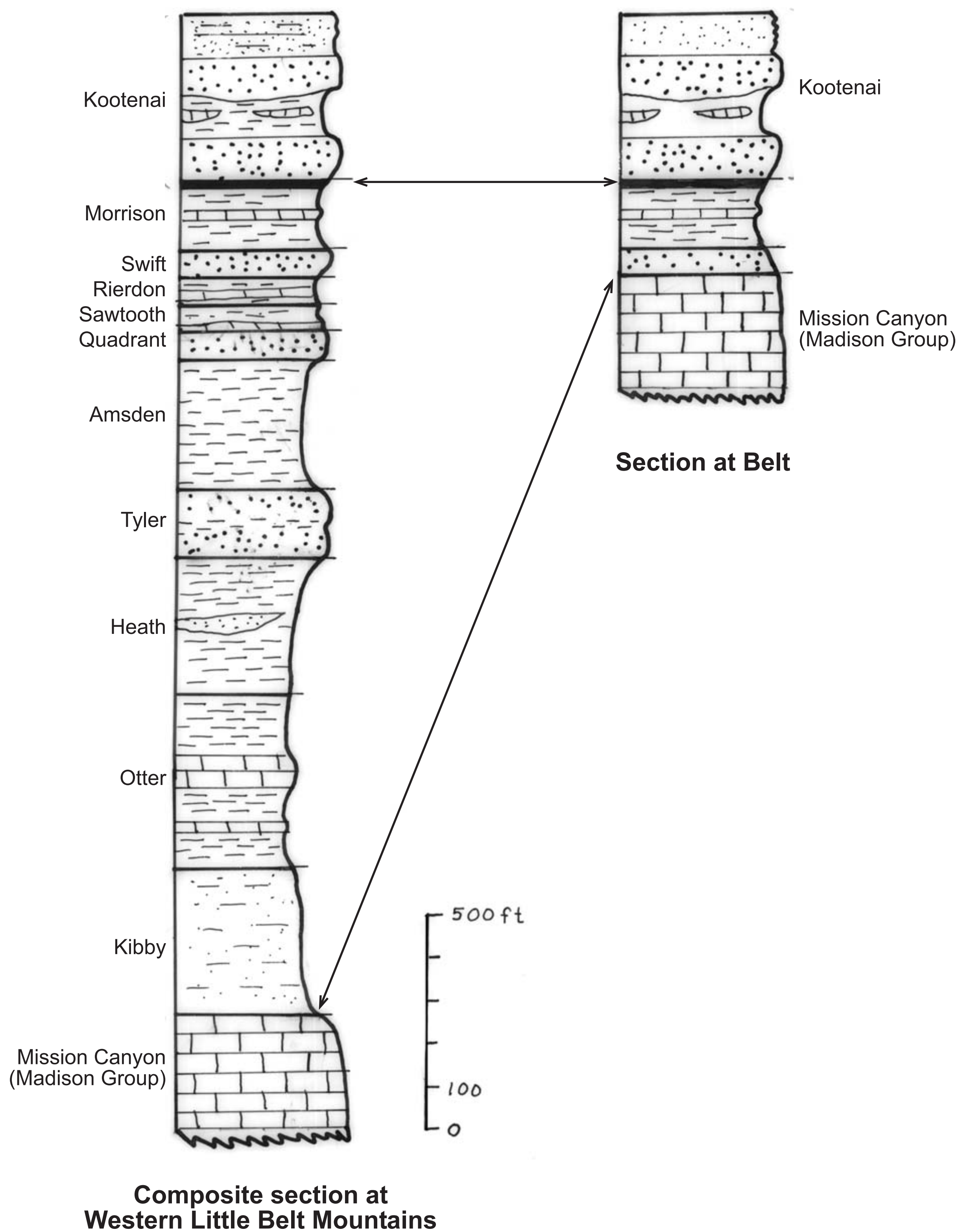


Figure 2.3 Comparison of interval between Morrison Formation coal and Madison Group limestone in western Little Belt Mountains and in the Belt mine area.

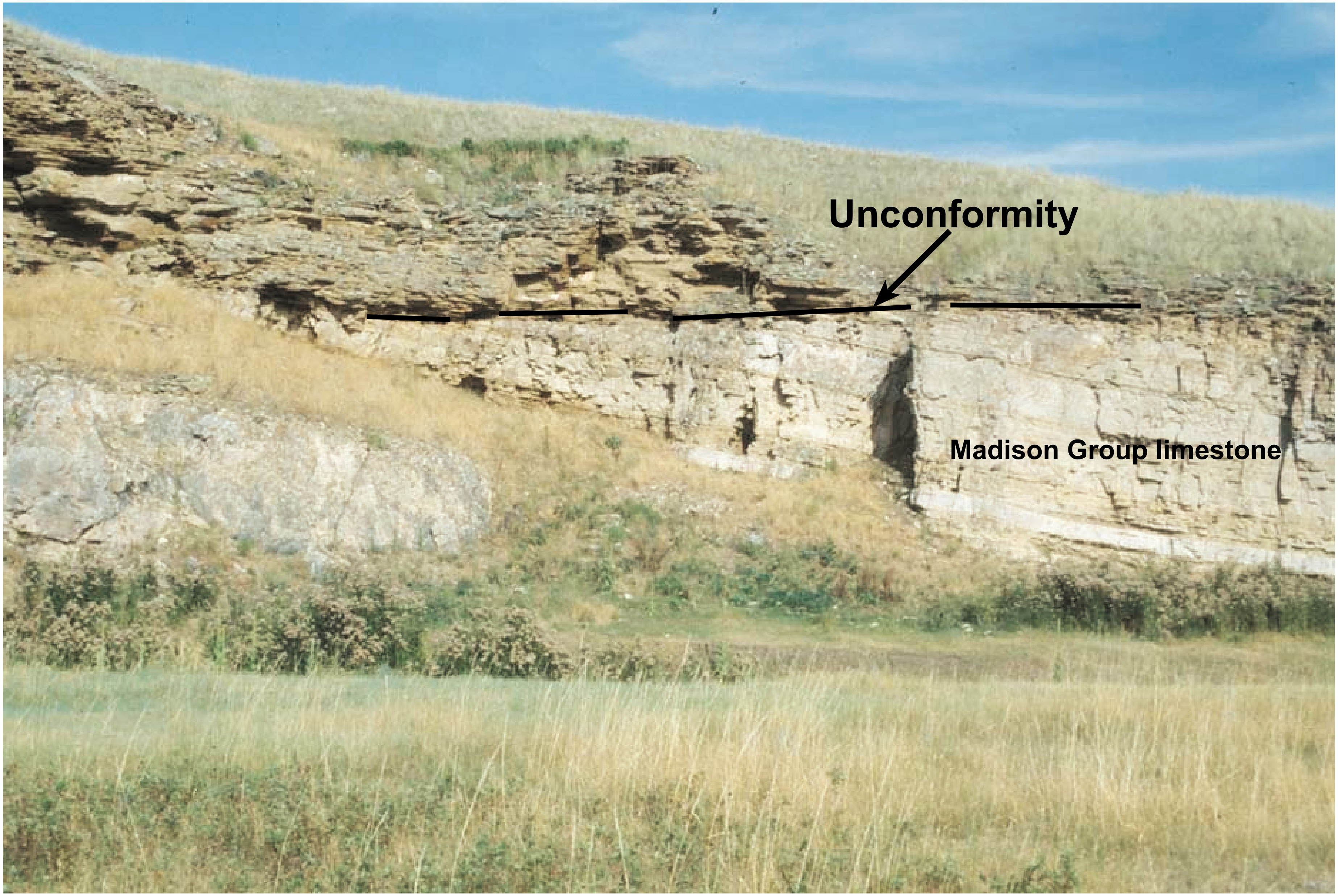


Figure 2.4 Contact between Swift Sandstone and Madison Group limestone in Sand Coulee (photo by R.K. Schwartz).

There may be a syncline in the Madison Limestone not present in the units overlying the angular unconformity at the top of the Madison. Across the axis of the syncline, the pre-Jurassic southward dip may surpass the north to northeastward dip off of the Little Belts. Ground water may move up-dip in this area through more permeable zones that follow bedding, such as bedding plane karst, possibly contributing to artesian flow. A hingeline between a regional area of recharge to the Madison Group aquifer on the flanks of the Little Belts to a regional area of discharge, with areas of artesian flow, has been recognized (M. Miller, oral communication). This hingeline may be related in part to the possible syncline in the Madison Group.

2.1.2 Paleotopography of Jurassic Depositional Surface and Jurassic Erosion

The pre-Jurassic erosional surface had significant topography (Meyers and Schwartz, 1993). One of the major paleohighs, Belt Island, has been defined by thickness isopach lines for the Sawtooth, Rierdon, and Swift Formations, including the zero isopach lines (figure 2.5) (Peterson, 1957). The Sawtooth and Rierdon Formations are not present in the Belt area because of this paleohigh, but the Sawtooth is present a few miles south of Armington. An interpretive cross section (figure 2.6) (Walker, 1976), shows Belt Island as a Madison Group anticline or dome exposed during the Jurassic. This interpretation suggests that the Madison was folded sometime after the regional southward tilting, but prior to the Jurassic.

In the area of the mine, the Swift rests directly on the Madison Limestone. Other paleohighs have been recognized based on depositional environments of the overlying Jurassic units (Meyers and Schwartz, 1993; Porter, 1989) and sequence stratigraphy (Porter, 1989). In addition, channels were eroded into the Madison during the Jurassic (Meyers and Schwartz, 1993) (figure 2.7), also contributing to the irregularity of the Madison surface. Some of the irregularities are apparent in a series of seven cross sections in the mine area based on MBMG Ground Water Information Center (GWIC) data and outcrop data. (Plate 1), and in a 3-D model of the surface of the Madison prepared for this report. A pre-Jurassic Madison paleohigh is

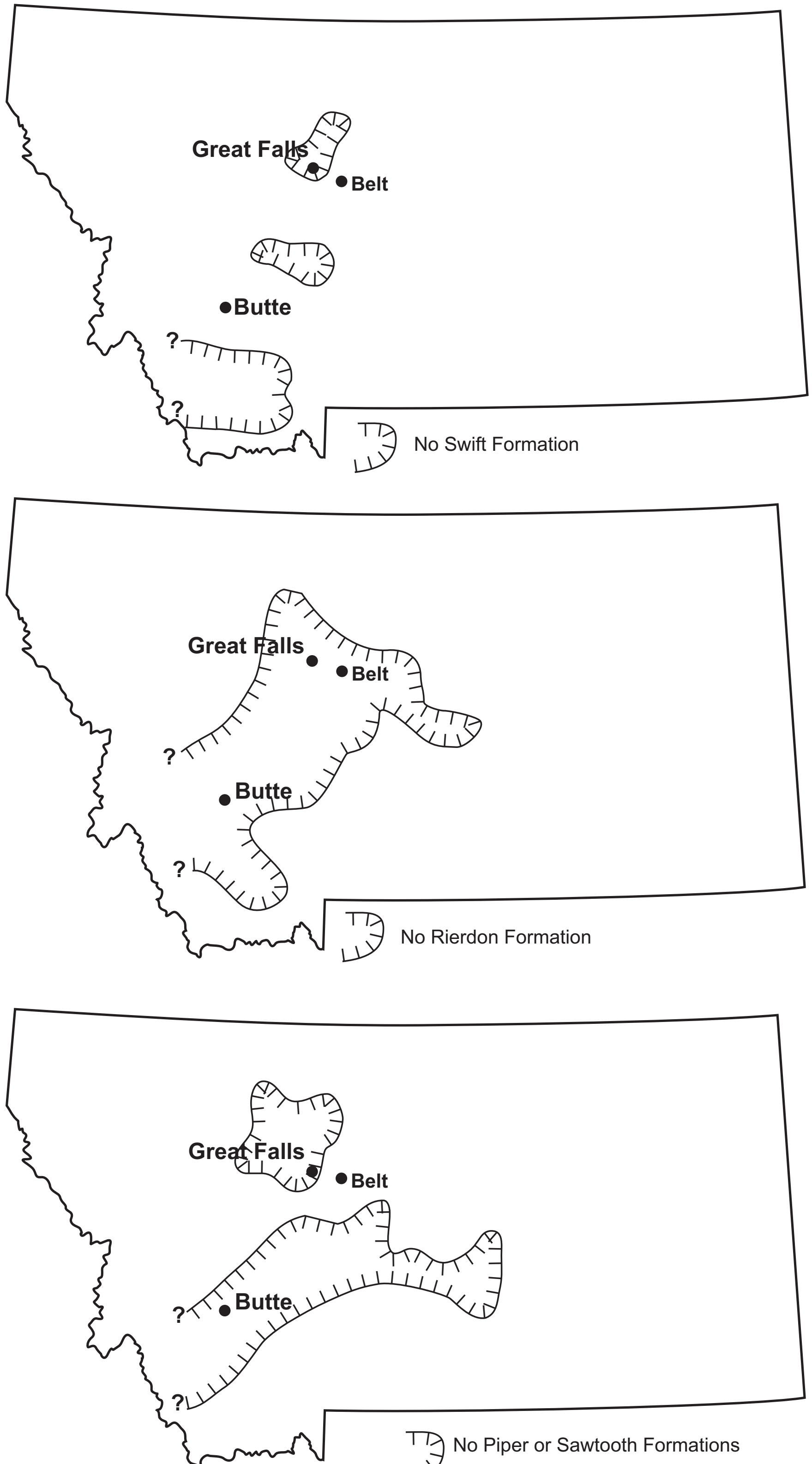
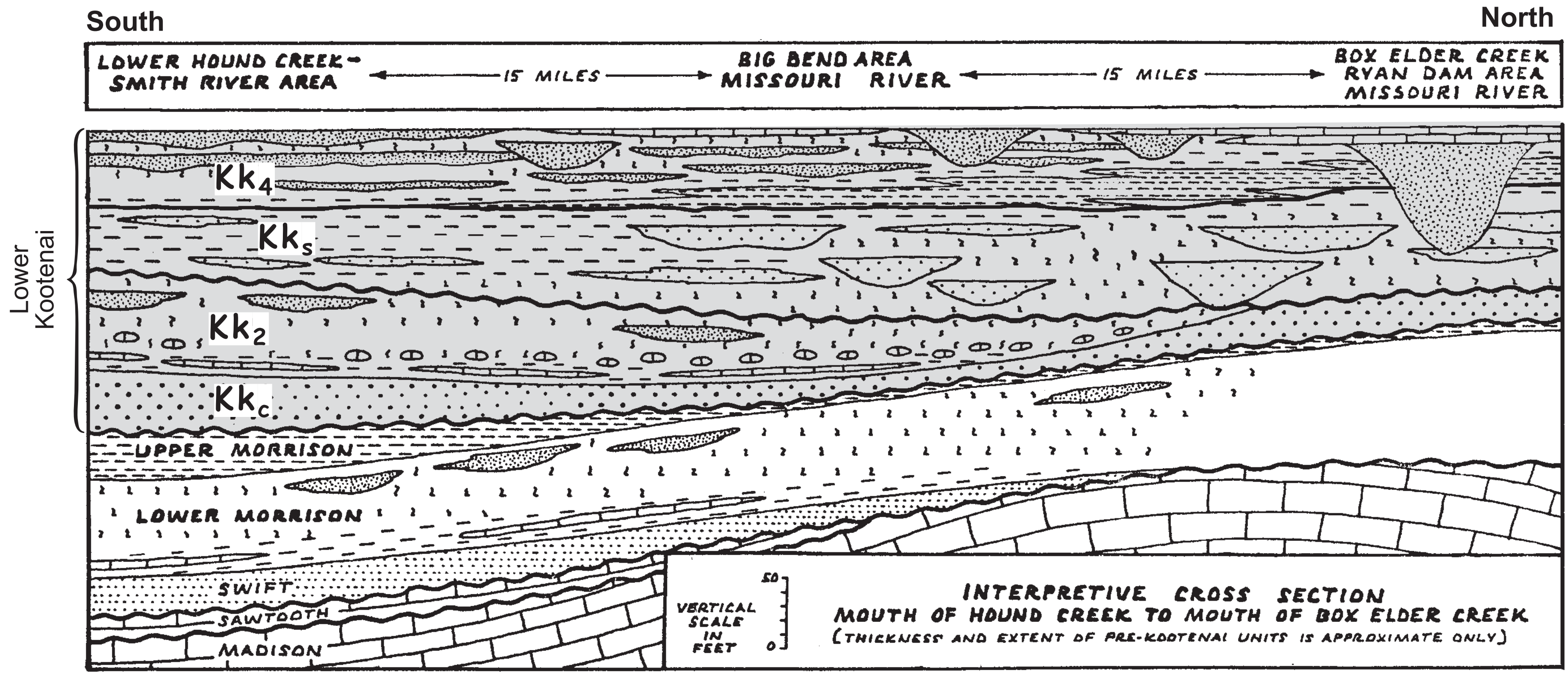


Figure 2.5. Zero isopach lines for the Sawtooth/Piper, Rierdon, and Swift Formations (Ellis Group) indicating the presence of a paleohigh, Belt Island (modified from Peterson 1957).



from Walker 1974

Figure 2.6 Interpretive cross section showing onlap of Sawtooth and Swift Formations over a paleohigh that exposed Madison Group limestone during the Jurassic. Note the interpretation that, to the south, the Madison is higher than younger units to the north.

Figure 2.7 Unconformity between Swift Sandstone and Madison Group limestone showing channeling into the Madison (photoby R. K. Schwartzx).

present just north of Belt in cross section D-D’ (Plate 1). It is not known if this structure resulted from folding of the Madison Limestone as represented in figure 2.6, or if it is an erosional feature.

2.1.3 Great Falls Tectonic Zone Structures

Belt lies within a regional northeast-striking structural zone, the Great Falls Tectonic Zone (O’Neill and Lopez, 1985) that extends from Idaho into Canada (figure 2.8). The Great Falls Tectonic Zone is thought to be a basement suture zone (O’Neill, 1997; O’Neill and Lopez, 1985), and to have had recurrent movement throughout geologic time. A northeast-striking structural grain is apparent in the Belt area from northeast-striking folds and faults mapped in the general mine area (figure 2.9). Pre-1915 unpublished Castner Coal Company (Anaconda Mine) mine maps and correspondence retrieved from the Montana Historical Society show a northeast-striking fault that extends through the northern border of the mine that is on strike with one of the mapped folds (Vuke and others, 2002). This fault may restrict the movement of ground water in certain aquifers in the mine area. Associated fractures may serve as planes for ground water movement. Preliminary flume measurements on either side of this fold-fault trend on Box Elder Creek indicate loss of water to the north. This may suggest that water in the creek is diverted by fractures into downward flow that may contribute water to the mine.

Three depressions occur in this area, and are thought to be caused by collapse over karst voids in the Madison Group limestone (Vuke, 2000; Vuke and others, 2002). Two of the depressions (figure 2.9) with the mine fault and associated folds and also with geologic structures southwest of the mine (figure 2.9), further suggesting that a northeast-striking regional structure passes through the mine area. Structurally controlled development of karst in the Madison may allow local groundwater flow from the southwest toward the mine.

Recurrent movement on the faults of the Great Falls Tectonic Zone may have further ground-water implications because faults may control abrupt thickness changes in units. The cross sections (Plate 1) show

Figure 2.8 . Location of the Great Falls Tectonic Zone (modified from O'Neill and Lopez, 1985).

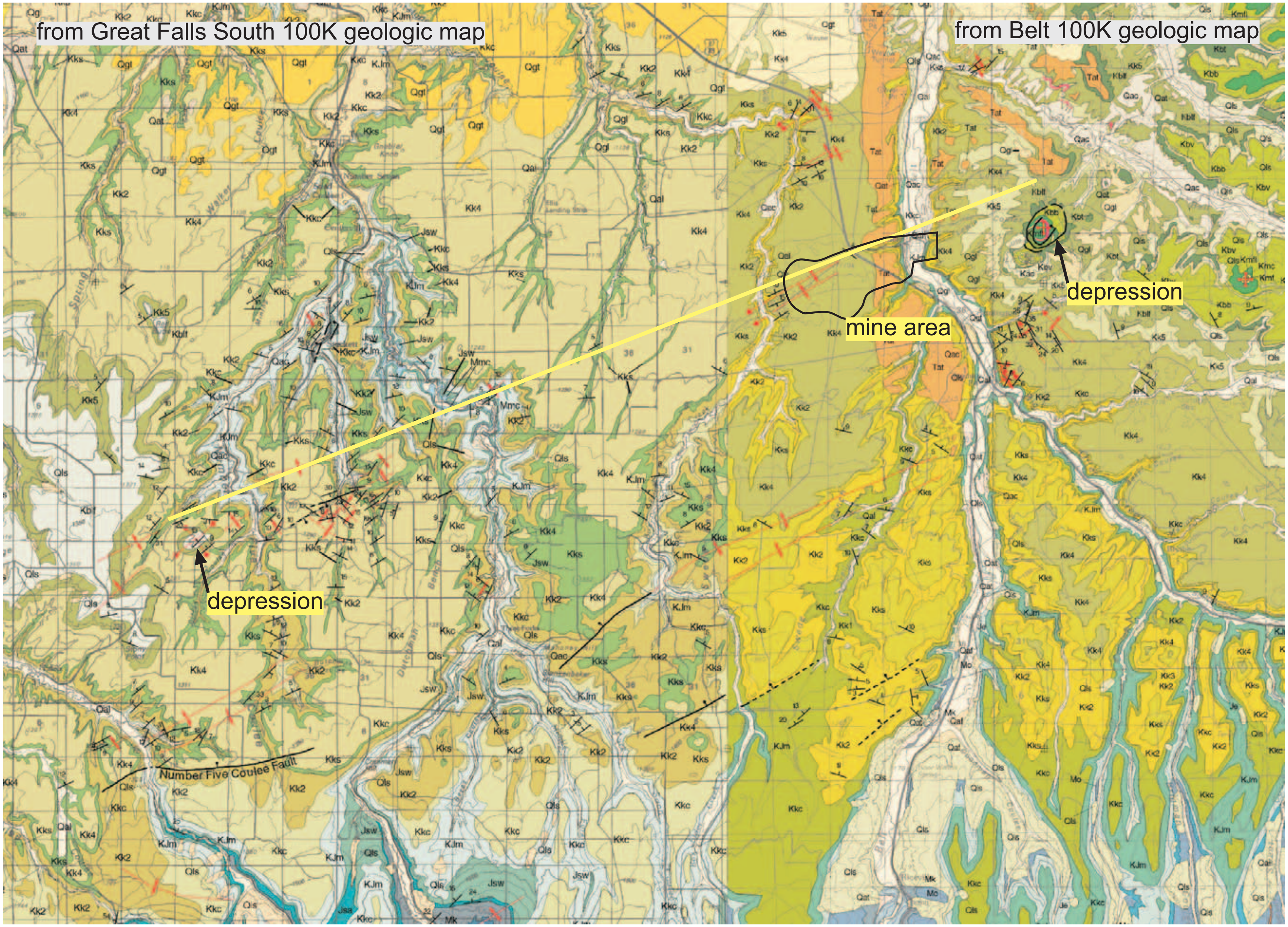


Figure 2.9. Location of mine between two depressions and on strike with surface faults and folds. The depressions may have resulted from karst development in the Madison Group limestone that may have followed a structural trend. Note the other northeast-striking structures in this area.

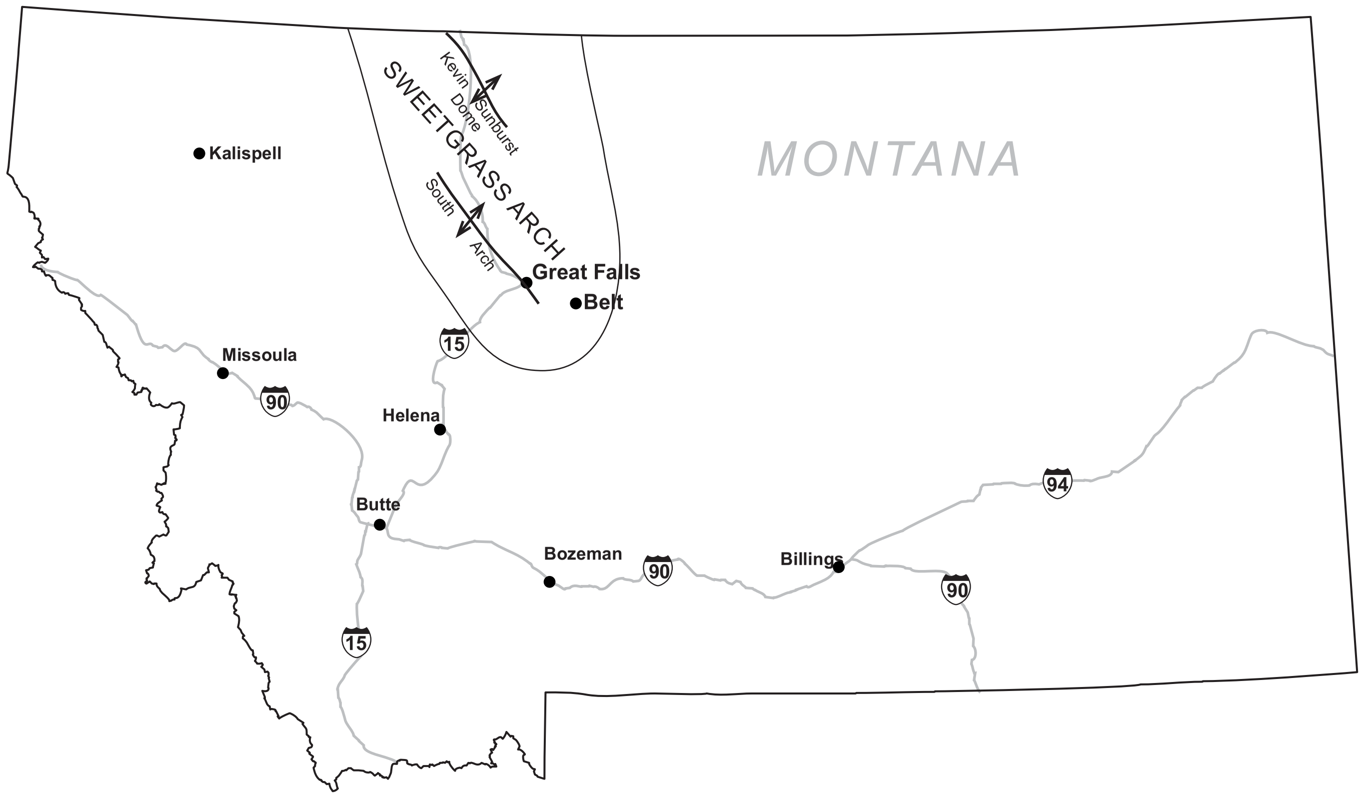


Figure 2.10 Distribution of Kootenai Sunburst Sandstone and location of Sweetgrass Arch (modified from Walker, 1974)

a gradual thinning of the Big Snowy Group, for example, but it is also possible that the Big Snowy Group terminates abruptly against a down-to-the-south paleofault.

2.2 Influence of Sweetgrass Arch

The Anaconda Mine lies on the southeast flank of the Sweetgrass Arch , another basement structure that has had recurrent movement throughout geologic time. The northward dip off the Little Belt Mountains south of the mine is deflected to a gentle northeast dip in the mine area because of the influence of the Sweetgrass Arch . A surface dip of 4° northeast was measured over the mine area (Vuke and others, 2002) although measurements on folds immediately east of the mine suggest that they plunge slightly to the southwest. The direction of dip on the mined coal is significant for ground-water movement within the mine. Discharge into Belt Creek suggests that the dip is to the northeast as measured above the mine.

The Sweetgrass Arch also apparently influenced the distribution of the Sunburst Sandstone (quartzose sandstone of Walker, 1976), one of the aquifers that overlies the mine. The Sunburst Sandstone was deposited in marginal marine environments of a shallow boreal sea. Its distribution coincides with the position of the Sweetgrass Arch suggesting that there was reversal of movement on the structure from a paleolow during the deposition of the Sunburst Sandstone with the influx of the sea, to a paleohigh later as the arch developed (Figure 2.10).

3.0 REGIONAL HYDROGEOLOGY

As mentioned previously, the MBMG had a companion study underway in the Belt area looking at the regional hydrogeology. That study consisted of identifying wells from the area just south and east of Armington Junction to the west of Belt based upon the geologic formations the wells are completed in. The study involved measurement of water levels in selected wells monthly or quarterly to establish trends, activation of the flume on the Anaconda Mine drain channel for flow monitoring, and collection of water quality samples from key locations. That work is on-going.

3.1 Well Inventory

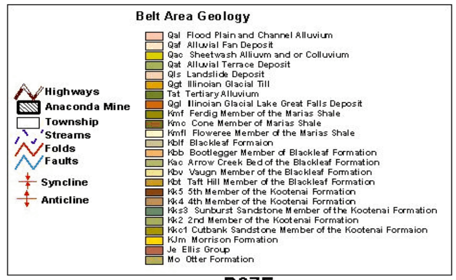
A search of the MBMG GWIC database for water wells in the study area was conducted. Wells were then selected based upon access, geologic information, and distribution throughout the study area. Field visits were conducted to verify locations, accessibility, and measure water-levels. Selected wells were then monitored either monthly or quarterly as part of the companion study. Information from the well inventory and water-level monitoring was used to prepare the ground-water flow maps.

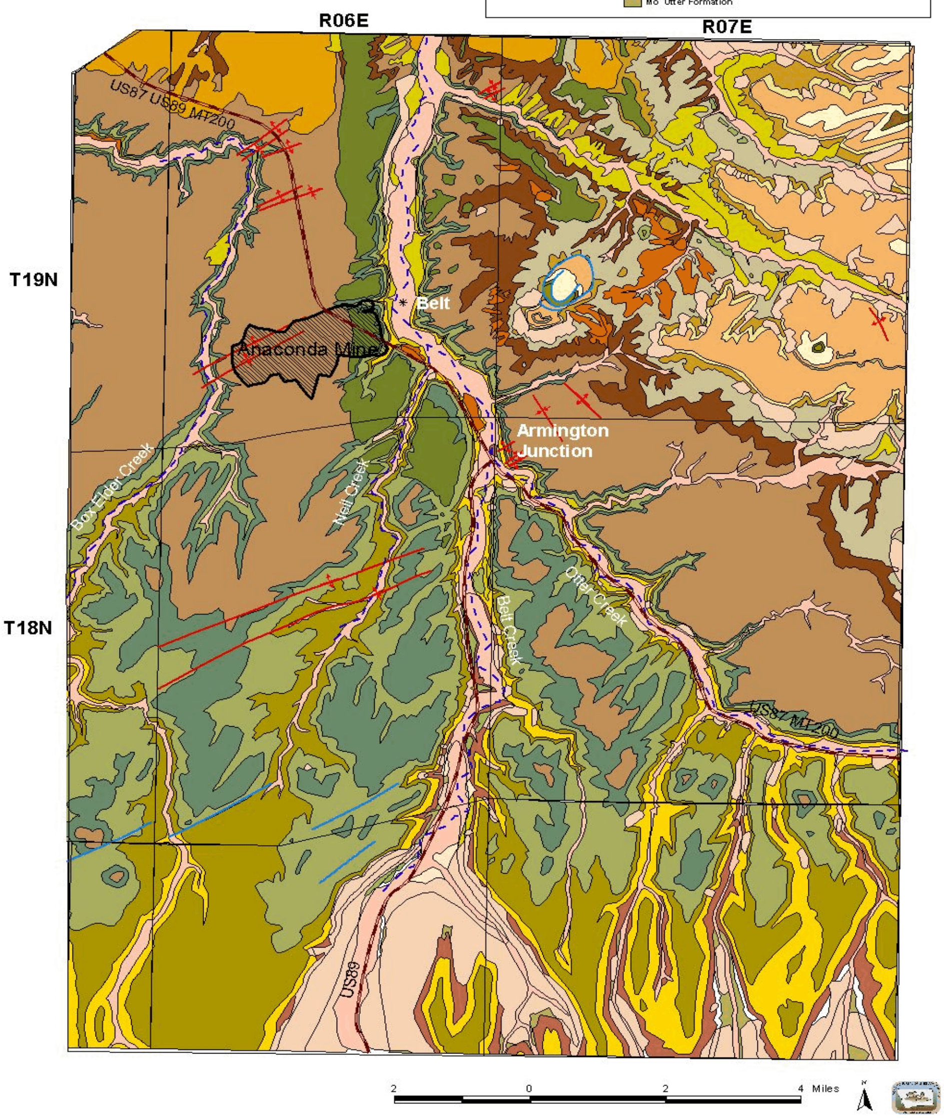
3.2 Recharge to the Anaconda Mine

Based on very preliminary interpretations a significant source of water to the Anaconda Mine appears to be from the overlying Kootenai Formation. Figure 3.1 is a surficial geologic map of the area above and adjacent to the Anaconda Mine. The Kootenai Formation is as much as 200 feet thick in the Belt area. The lower sandstone unit (Cutbank Sandstone Member, figure 2.1) forms an aquifer directly overlying the targeted coal bed. The Cutbank Sandstone Member is overlain by an unnamed fine-grained unit (Second member, figure 2.1) that forms an aquitard. The Sunburst Sandstone Member forms another aquifer overlying this aquitard. The upper unit of the Kootenai Formation is another unnamed fine-grained aquitard (Fourth member, figure 2.1). The Kootenai Formation is highly fractured causing some degree of vertical hydraulic connection from the surface down to the underlying coal bed.

Wells and springs in the Kootenai Formation have been inventoried at 37 locations in the Belt area. Water levels have been monitored in 9 wells completed in the Kootenai Formation near the Anaconda Mine. Two general trends are apparent from existing water-level fluctuation data (figure 3.2). Wells completed in the uplands up-gradient of the mine have very minor water-level fluctuations trending flat to a slight decline. Wells completed near streams or small tributaries generally indicate a declining water level in response to the recent drought. Figure 3.3 is a potentiometric surface map of the Kootenai Formation based on measurements collected during the well inventory conducted in 2002 and 2003. This map was contoured using measurements from 37 wells and springs near the mine. This map shows only general water-level

Figure 3.1: Geologic Map of the Anaconda Mine Area, Belt Montana





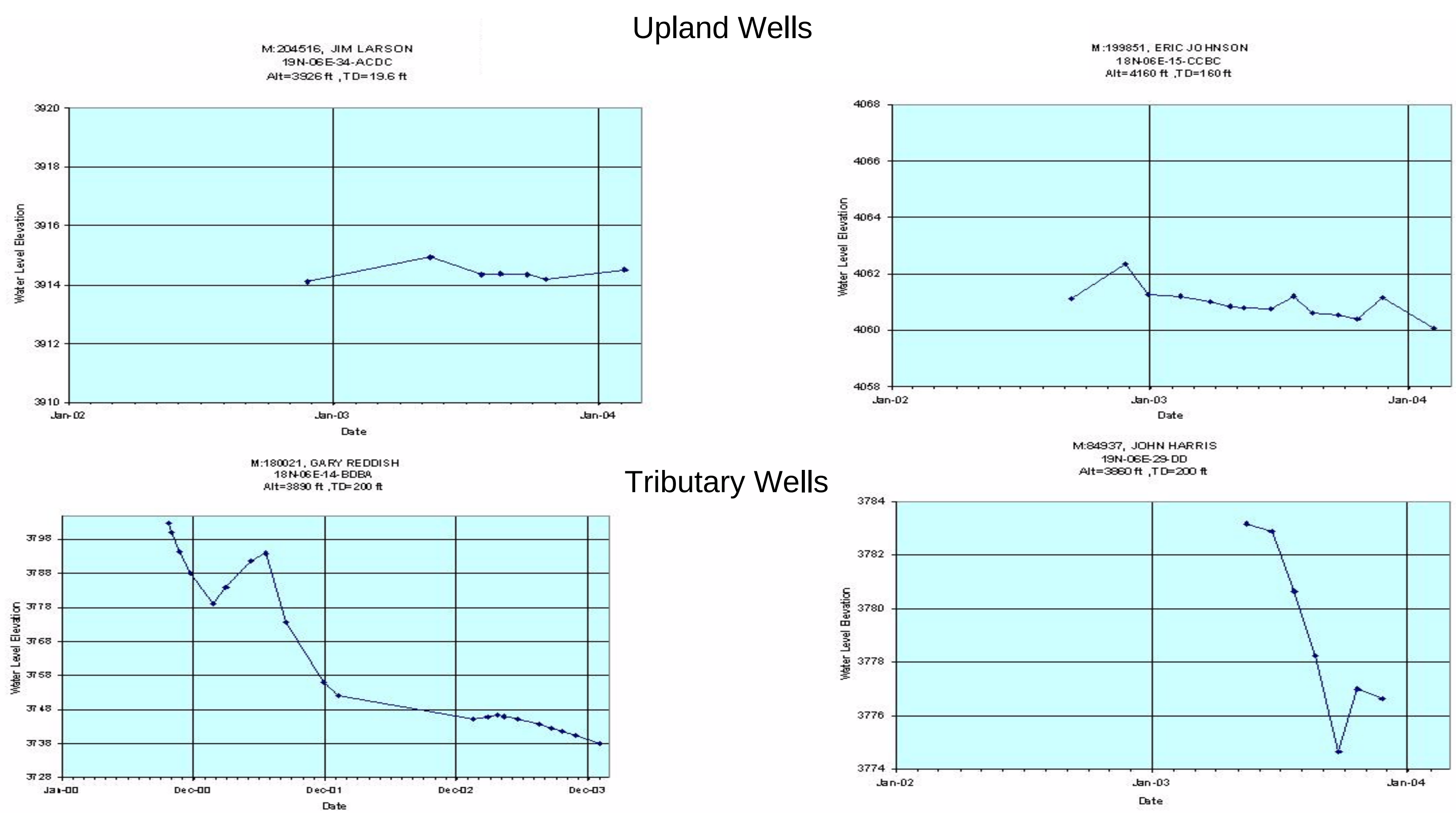


Figure 3.2. Hydrographs showing water-level fluctuations in the Kootenai aquifer. Hydrographs are from two upland wells (Larson and Johnson) and two wells in tributaries. Locations of these wells are shown on figures 3.3 and 3.4.

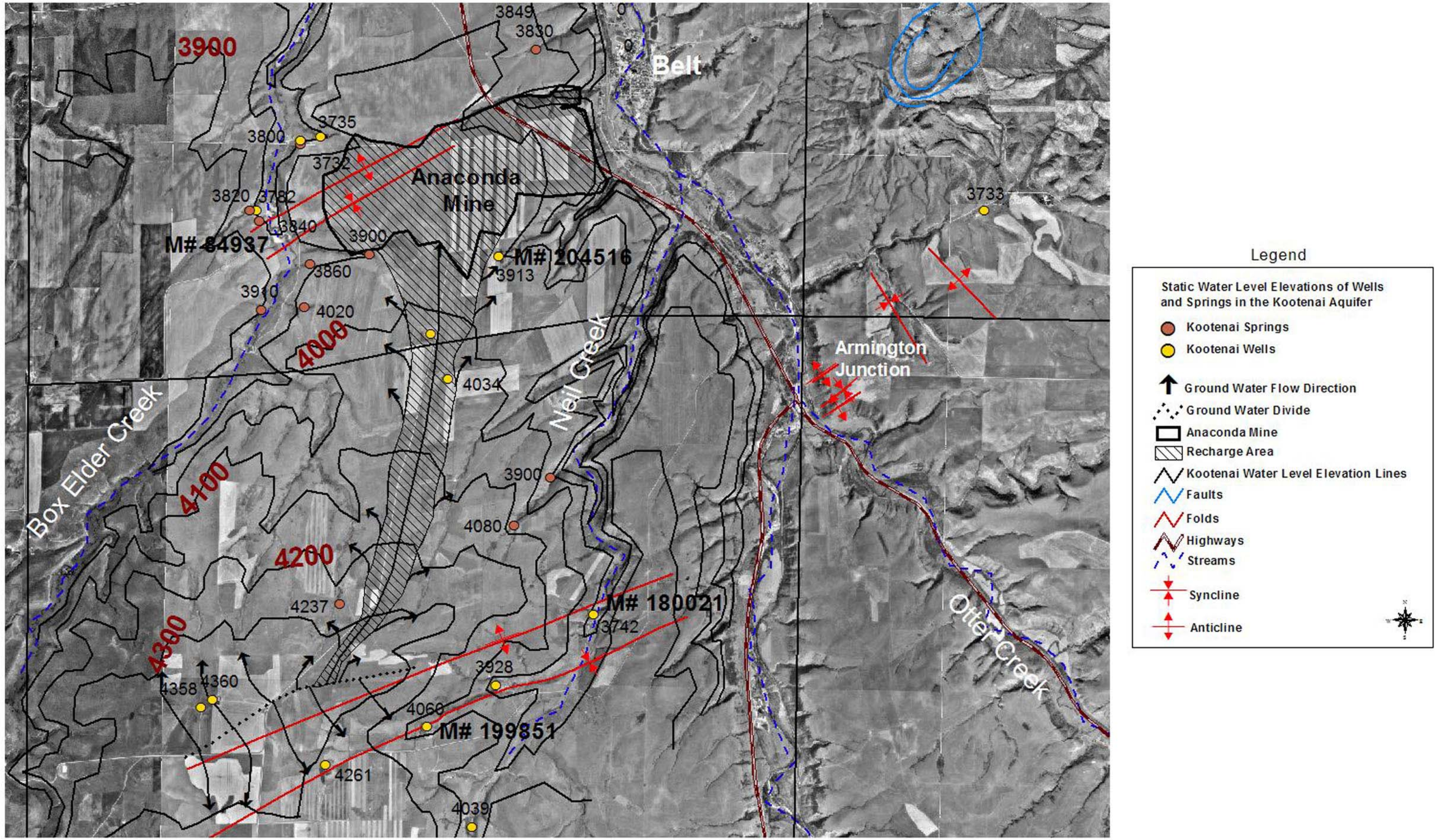


Figure 3. Potentiometric surface and ground water divide of the Kootenai Formation

conditions in the mapped area. Additional wells at critical locations will be needed to accurately depict ground-water flow. In addition, a more accurate contour map requires monitoring of water levels at approximately the same time. The mapping depicts a ground-water divide located about 3.5 miles south of the Anaconda Mine. Only precipitation falling north of this divide has the potential to move towards the mine. Ground-water flow is perpendicular to the water-level contours. The upland between Belt Creek and Box Elder Creek is highly dissected by tributaries to the two streams. These tributaries plus the main stems of the two streams are discharge areas for ground water moving out of the Kootenai Formation. The potential recharge area to the Anaconda Mine starts at the ground-water divide 3.5 miles south of the mine and extends to the region directly overlying the abandoned mine workings. This forms a relatively narrow band following the axis of the surface water divide between Belt Creek and Box Elder Creek. The potential recharge area covers about 2,100 acres overlying and up gradient of the mine. The highly dissected nature of the upland appears to cause some of the precipitation falling on the upland to bleed out and discharge to the surface water drainages and springs in the valley walls. A portion of this water is consumed by vegetation in the drainages as shown by the areas of dense plant cover depicted on figure 3.4. Several of the springs appear to be related to the contact of the Sunburst Sandstone Member (aquifer) and the underlying unnamed fine grained unit (aquitard) (Second member).

The ground-water divide south of the mine appears to be both topographically and structurally controlled. The topographic high area forming the ground-water divide is located just north of a paired anticline-syncline structure that trends N 45° E.

4.0 HYDROLOGIC MONITORING ACTIVITIES

Monitoring consisted of continuous-flow monitoring of the discharge from the Anaconda Mine drain and two locations on Box Elder Creek, and continuous physical-parameter monitoring at the Anaconda Mine drain, French Coulee Mine drain, and the upper flume on Box Elder Creek.

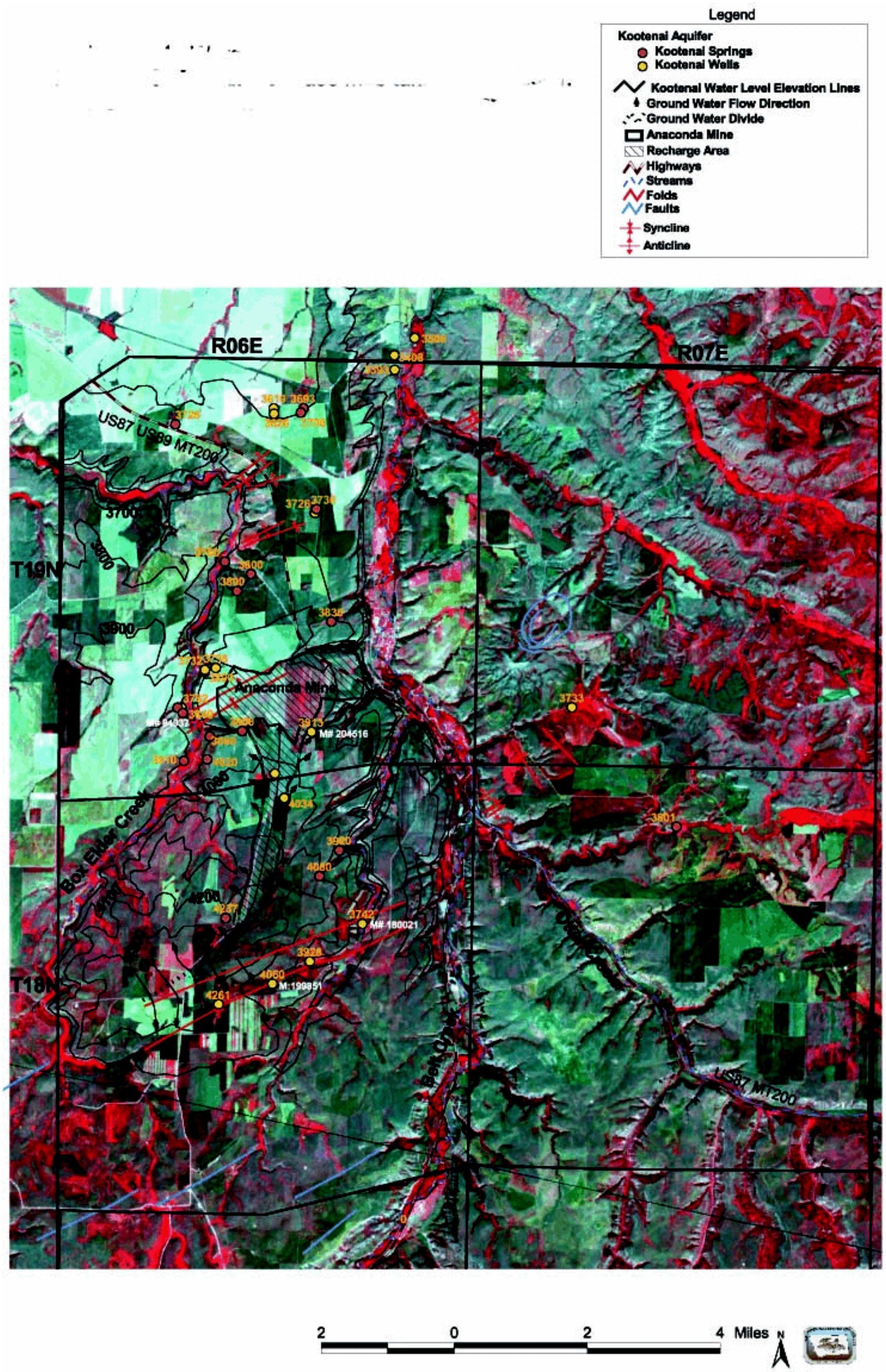


Figure 3.4 Water-level contours are plotted on an infrared ASTER satellite base map taken in July 2001. Red-colored areas have relatively dense plant cover.

4.1 Flow Monitoring

Flows from the Anaconda Mine drain were recorded at the H-Flume located in the discharge channel downstream of the Anaconda Mine discharge. This flume was installed during previous investigations.

Two new 6-inch Parshall flumes were installed on Box Elder Creek. The upper location was chosen for its location above (up-gradient) the Anaconda Mine workings, while the lower location was located approximately 1½ miles downstream. These flumes were installed in late-May, 2003 and were equipped with pressure transducers for monitoring flow rates.

4.1.1 Anaconda Mine Drain

Very little information is available on the amount of water encountered during operation of this mine. However, there are several references in the literature (Shurick, 1909 and GCM Services Inc, 1983) that described the mine as being fairly to very wet and that it was built to be self draining. GCM Services Inc states that there were a number of pumps employed to keep the mine dry. Shurick (1909) described the use of the `Finlander Pump' to drain water short distances and described as "a tub set up near the roof with a trough leading to the room mouth". Shurick stated that it gave satisfactory results. Understanding the source and quantity of water entering and leaving the mine is very important to determine how best to limit the volume of water entering the mine. A short article by Rowe (1909) stated that the mine was idle almost the entire month of June, 1908, due to floods. Unfortunately, the article doesn't say if the flood was in the mine or a surface water phenomenon. However, Stober, 1979, described a June, 1908, flood along Belt Creek that washed away several houses and a suspension bridge and covered an area known as Coke Oven Flats with water. It is possible that it is this flood that Rowe was referring to in his article.

The U.S. Geological Survey (USGS) installed a 1½ foot H-Flume below the Anaconda Mine drain for flow monitoring for the period October 1, 1994, through September 30, 1996, a 24-month period (Karper, 1998). Summary statistics for this period are contained in Table 4.1. Figure 4.1 is a hydrograph showing flow in gallons per minute (gpm). A portion of the hydrograph is estimated and is shown with a dashed line.

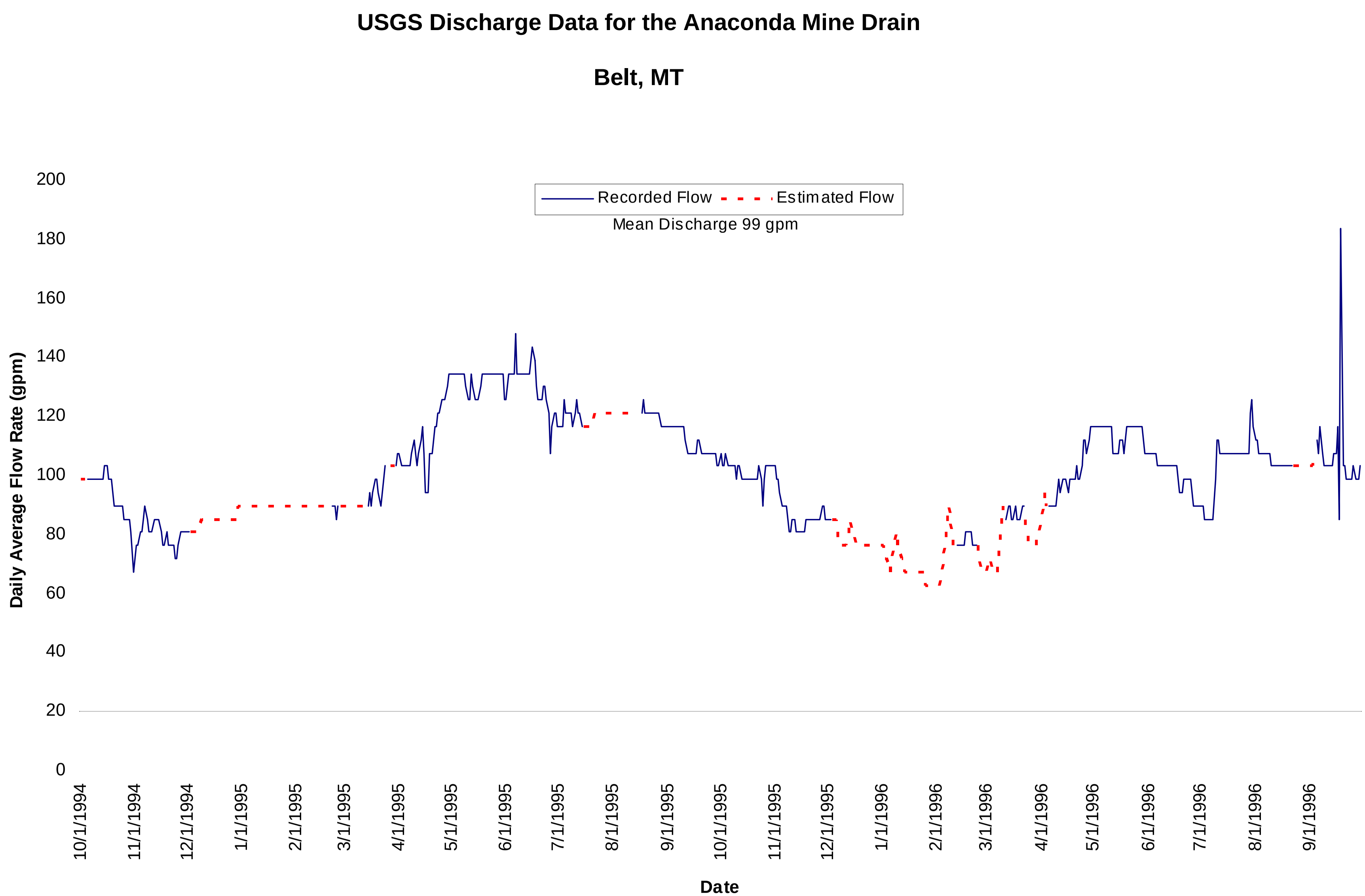


Figure 4.1 Hydrograph of USGS recorded-flow rates for the Anaconda Mine drain (1994 - 1996)

Agency	Monitoring Period	Mean Flow (gpm)	Maximum Flow (gpm)	Minimum Flow (gpm)
USGS	10-01-94 to 09-30-96	99	184	63
MBMG	08-08-02 to 01-08-04	132	158	111

Table 4.1. Anaconda Mine Summary Flow Statistics, Average Daily Flow.

The MBMG reactivated the USGS flume and stilling well as part of its regional study in the Belt area. Originally, a Stevens Type-F recorder was installed in the stilling well. However, the water in the stilling well froze during the winter, limiting data collection from late-December, 2002, through March, 2003. The recorder was replaced by a pressure transducer in August, 2003. This transducer was replaced by another pressure transducer located directly in the flume, to alleviate freezing problems. Table 4.1 contains a summary of flow statistics for the recent monitoring, while figure 4.2 shows the daily average flow rates recorded by the MBMG. These flows are consistently higher than those recorded by the USGS in the mid-1990's (Table 4.1), and do not show the same level of seasonal variation.

Daily precipitation amounts are plotted in figure 4.3 to identify any flow response that might occur from precipitation events. While it appears there may be an occasional response in flow following several precipitation events, these increases may in fact, represent storm run-off entering the drainage channel upstream of the flume. Due to the location of the flume and the distance between the flume and the Anaconda Mine discharge shown in figure 4.4, storm run-off has the potential to influence the flows measured. This influence would indicate an increase in flow, which might not be coming from the Anaconda Mine discharge. It appears that the influence of precipitation is more regional (gradual) than local (quick) in nature.

4.1.2 Box Elder Creek

Figure 4.5 shows the location of the two Box Elder Creek flumes along with a representation of the underground mine workings. Both flumes are 6-inch fiberglass Parshall models.

Montana Bureau of Mines and Geology
Anaconda Mine Drain Discharge
Belt, MT

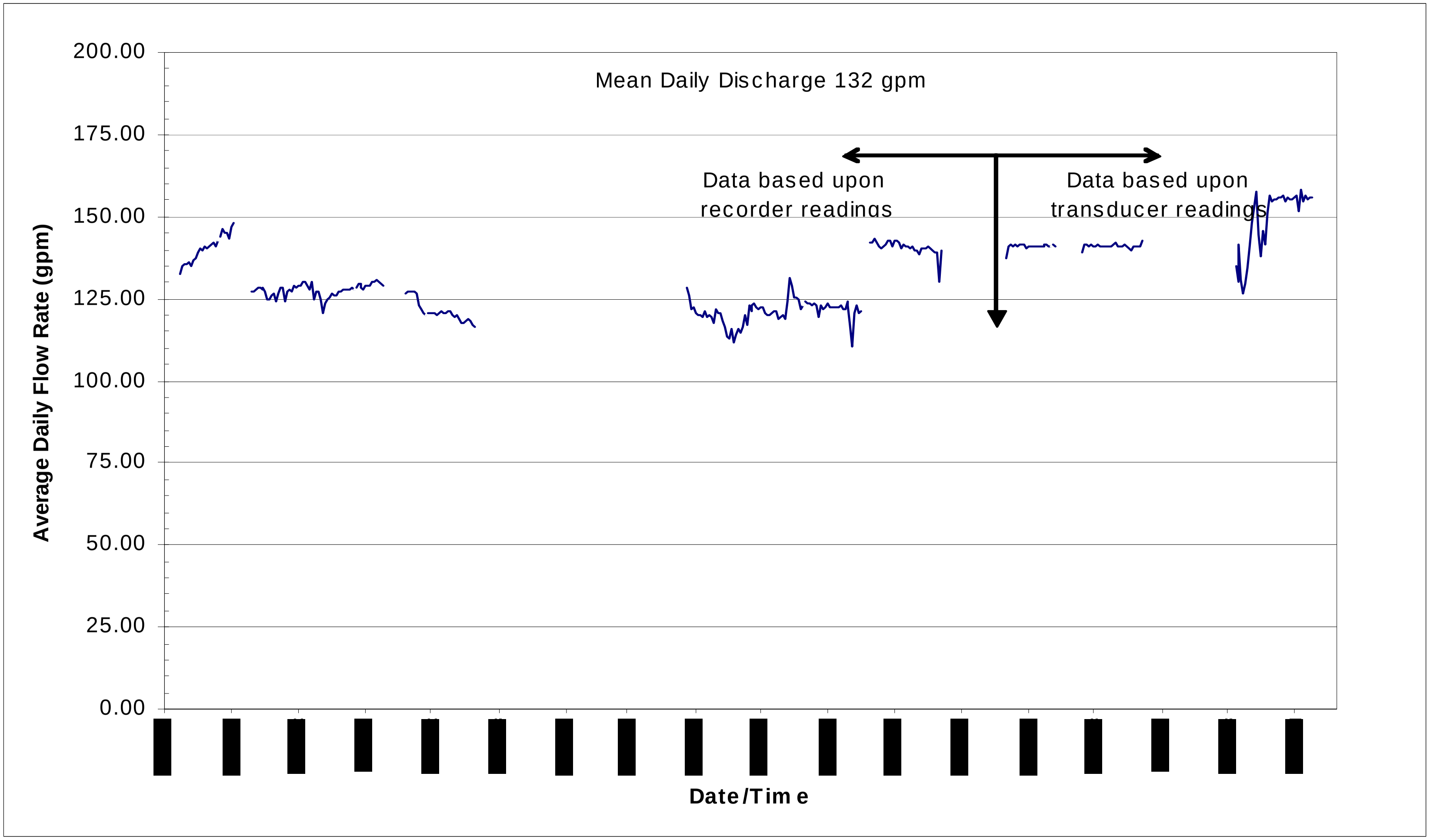


Figure 4.2 Hydrograph of MBMG recorded-flow rates for the Anaconda Mine drain (2002 - 2004).

Montana Bureau of Mines and Geology
Anaconda Mine Drain Discharge
Belt, MT

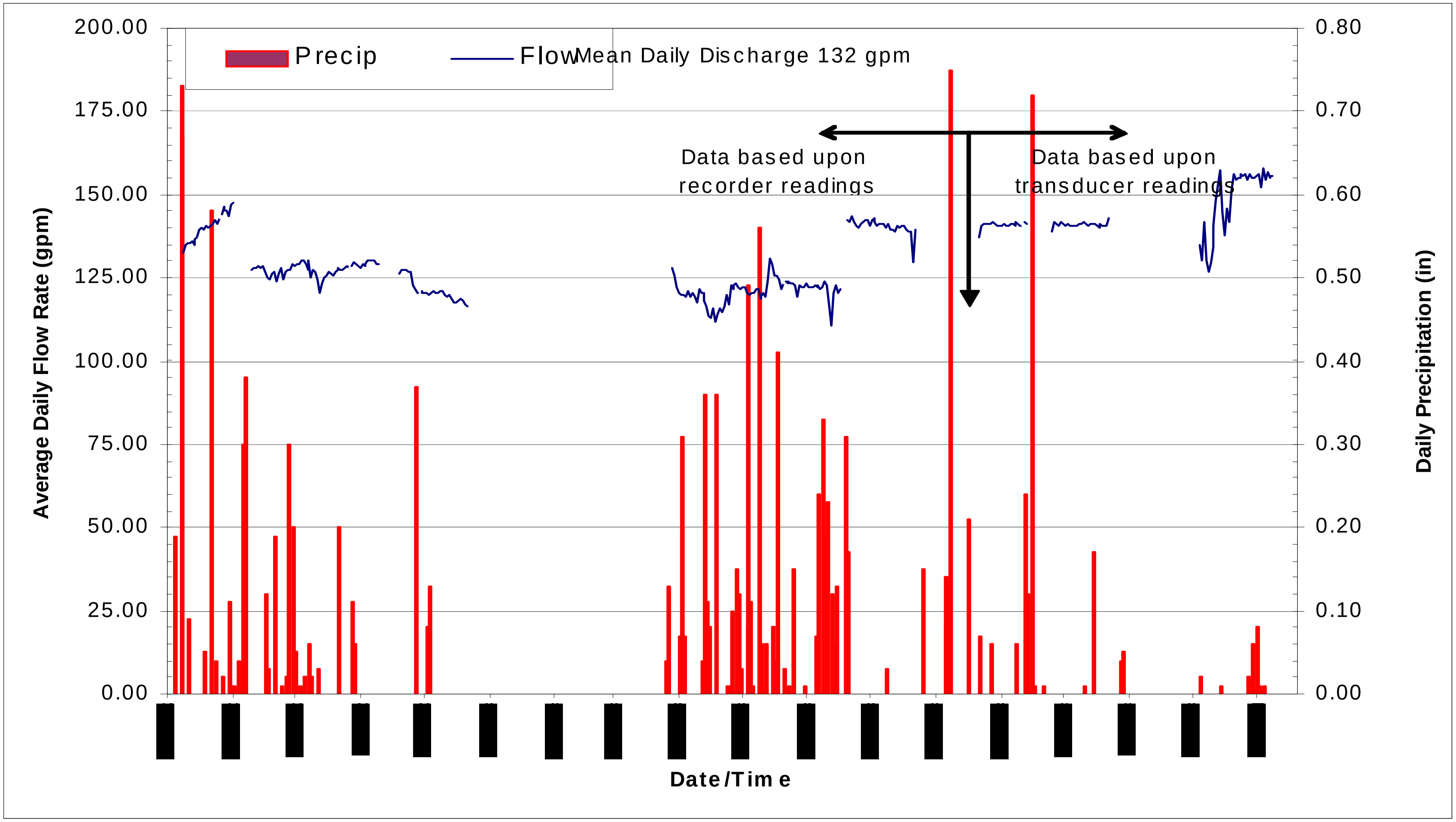


Figure 4.3 Hydrograph of Anaconda Mine drain flow rates with daily precipitation amounts.

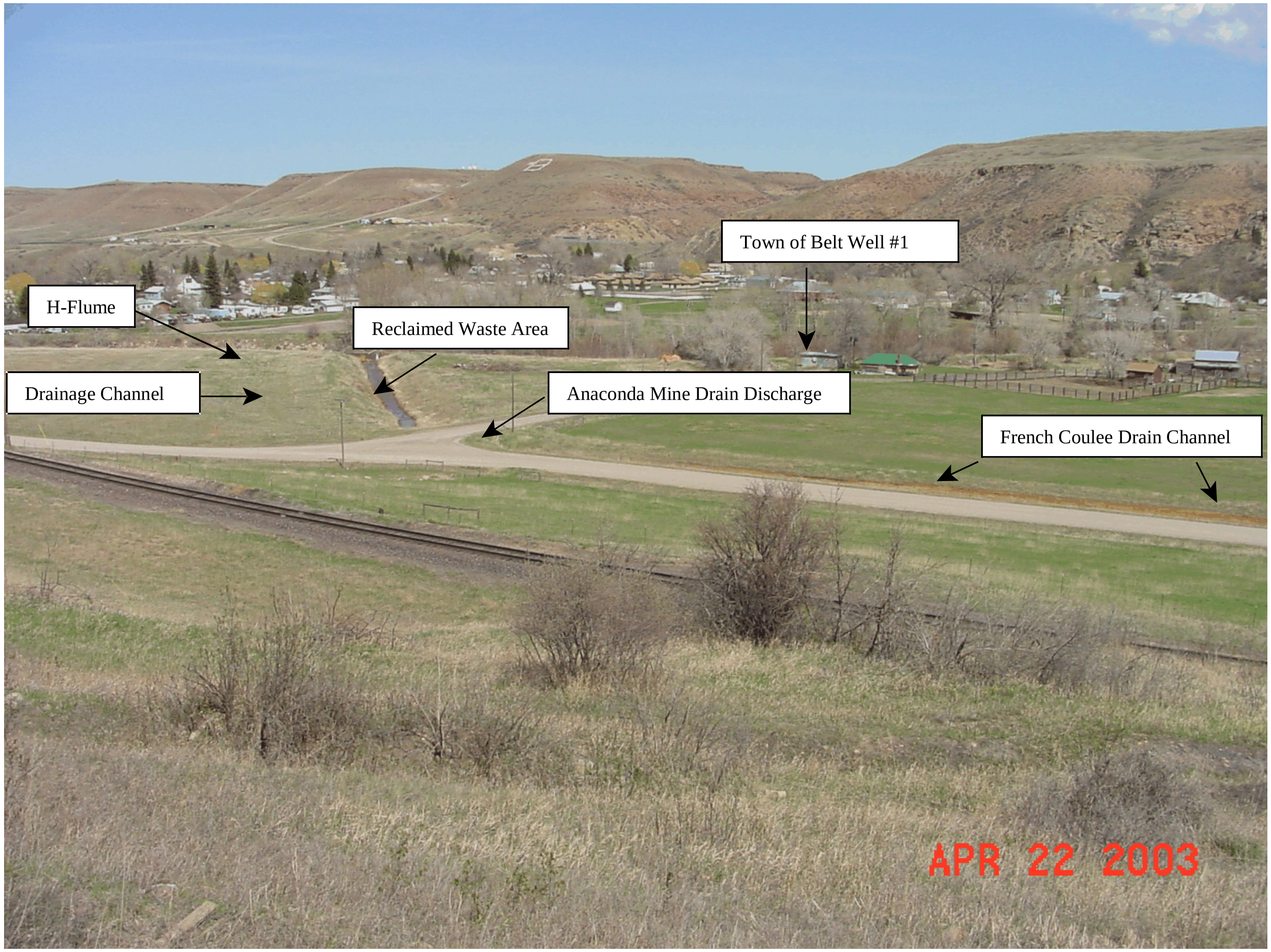


Figure 4.4. Location of Anaconda Mine drain and drainage channel, H-Flume, reclaimed waste pile, and French Coulee drain channel.

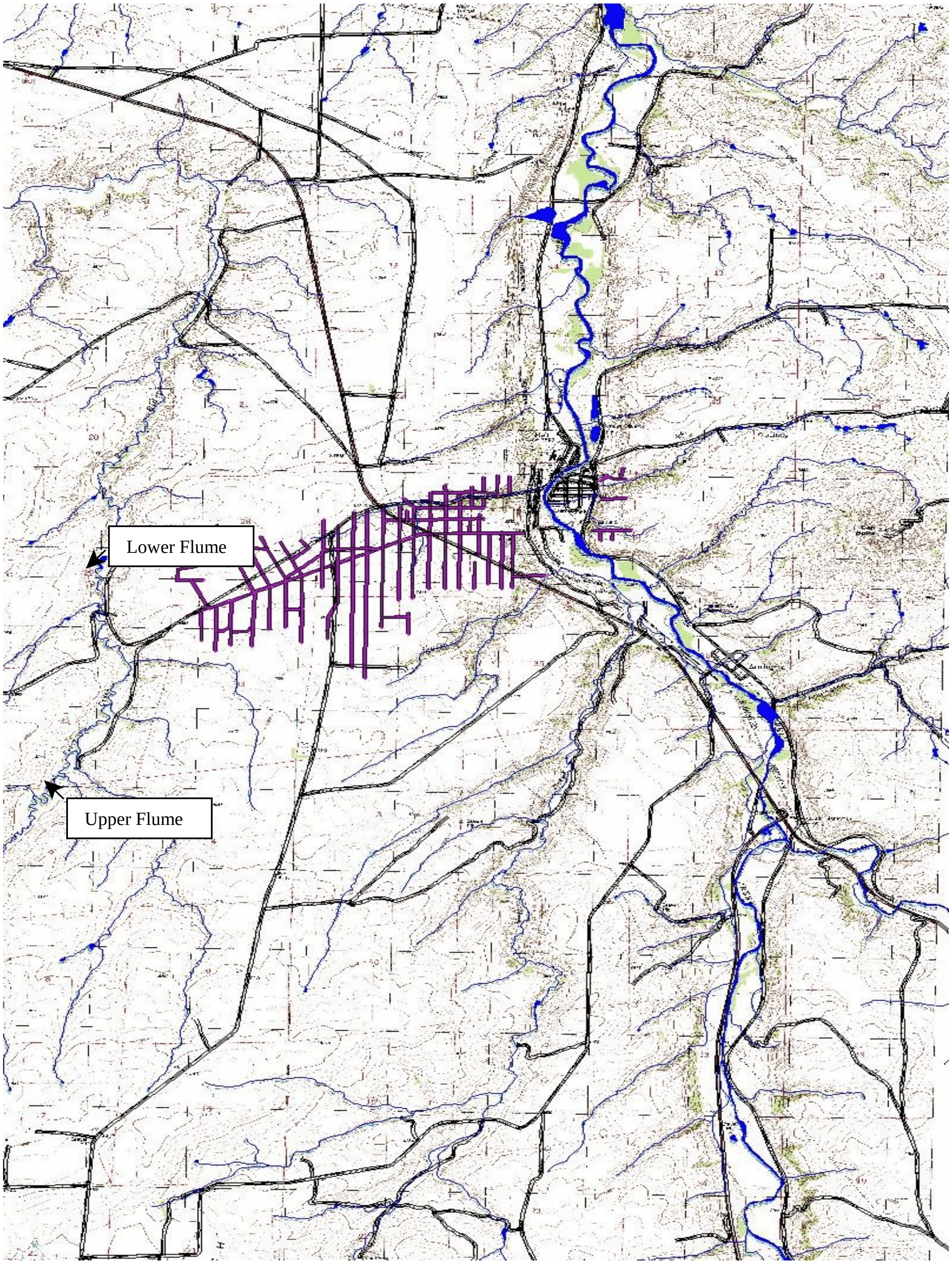


Figure 4.5. Location of Box Elder Creek flumes in relationship to underground mine workings.

4.1.2.1 Upper Box Elder Creek Flume

The upper flume was installed up-gradient of any known workings associated with the Anaconda Mine. The flume was located in a portion of the channel on the Larson Ranch that reportedly has year-round, or nearly year-round flow. Figure 4.6 is a hydrograph showing flows at this site from May 22, 2003 through January 7, 2004. The mean flow was 37 gpm. Table 4.2 contains a summary of flow rates for both Box Elder Creek flumes.

	Upper Box Elder Creek	Lower Box Elder Creek
Mean	37	17
Maximum	184	201
Minimum	0	0

All flows are in gallons per minute (gpm)

Table 4.2. Summary Flow Statistics for the Box Elder Creek Flumes.

Flows declined steadily from May through late July before leveling off, with flows at 10 gpm, or less, for the next month. Flows increased some in September, and rose to levels between 25 to 75 gpm in October and November. Flow rates since late November appear to be affected by ice forming within and adjacent to the flume, and should be used with caution.

The area adjacent to this flume is planted in alfalfa, which is a high-water-use crop, therefore, it is not surprising that flows drop-off during the peak of the growing season.

4.1.2.2 Lower Box Elder Creek Flume

The lower flume was installed approximately 1½ miles downstream of the upper flume, on land owned by the Pleasant Valley Colony. Table 4.2 contains a summary of flow statistics for this site.

Flows declined steadily from the end of May when the flume was installed until early July. Since early July, no flow has been recorded at this site (figure 4.7). The land upgradient and adjacent to this site was

Montana Bureau of Mines and Geology
Upper Box Elder Creek Flume
Belt, MT

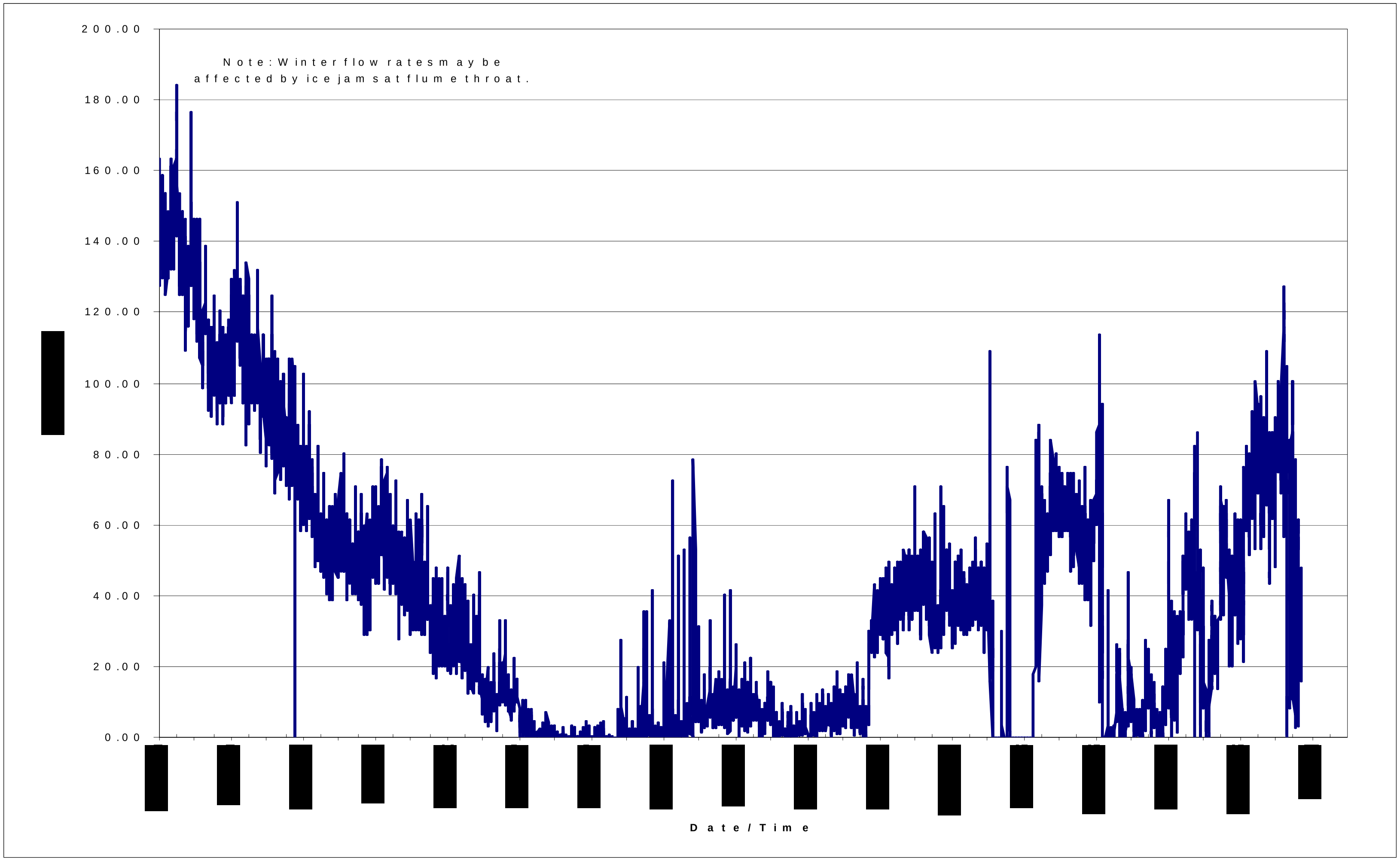


Figure 4.6 Upper Box Elder Creek hydrograph of recorded flow rates, May 22, 2003 through January 7, 2004.

Montana Bureau of Mines and Geology
Lower Box Elder Creek Flume
Belt, MT

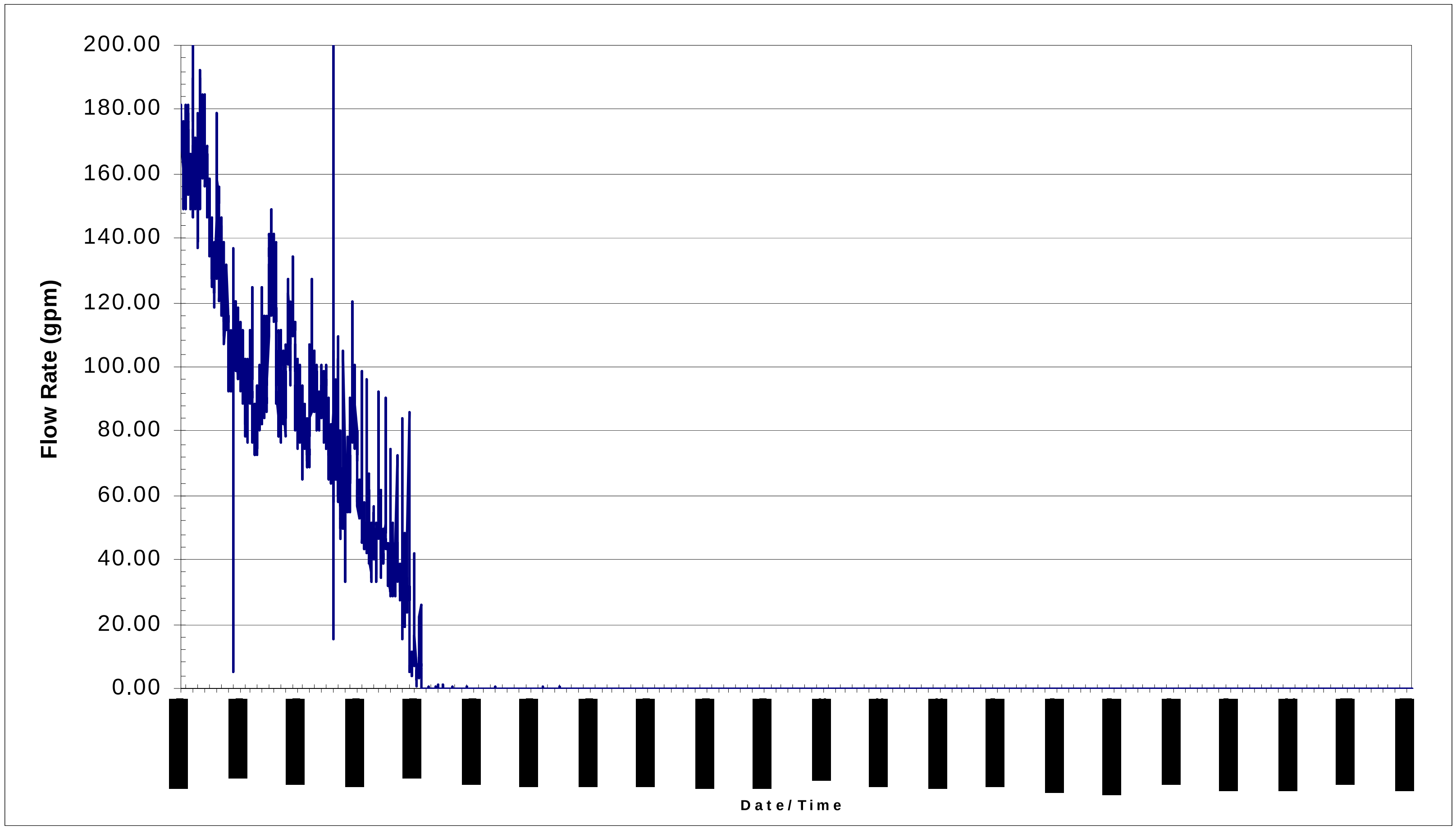


Figure 4.7 Lower Bow Elder Creek hydrograph of recorded flow rates, May 22, 2003 through January 7, 2004.

planted in winter wheat during the past year.

The county road crosses Box Elder Creek about mid-way between the two monitoring sites. The area upstream of the road has alfalfa planted, while the area downstream is planted with winter wheat. During late fall and early winter, the flow of water extended beyond (downstream) the road, however, it infiltrated into the ground before reaching the flume.

4.1.2.3 French Coulee Mine Drain

In addition to the above-mentioned three sites which had continuous flow-rate equipment installed, periodic flow rates were measured from the French Coulee Mine drain. A pipe dam was constructed just below the culvert beneath the train tracks, and flow rates were measured using a bucket and stop watch during most site visits. The mean, maximum, and minimum flows were 8, 11, and 6.5 gpm, respectively. Figure 4.8 is a flow hydrograph for this site. Flows increased gradually between March and mid-May before falling and leveling off for the most part from June through early January, 2004. When precipitation totals between flow measurements are plotted on this graph (figure 4.9) it appears that flows might increase somewhat following precipitation events.

4.2 Physical Parameter Monitoring

Physical parameter monitoring was conducted at the Anaconda Mine drain discharge, French Coulee Mine drain discharge, and the upper Box Elder Creek flume site. Multi-parameter probes (sondes) were used to record the following parameters: pH, specific conductance (SC), temperature, dissolved oxygen (DO), and redox. The sondes were moved from their original locations, to more representative locations during June 2003. Initially, the sondes were set-up to collect data every 20 minutes; however, this increment was changed to every 30 minutes in June. The sondes were calibrated and set-up with a starting and ending date and time in the lab before deployment. The sondes were typically left in-place for 2 weeks and replaced with another sonde for the next 2 week period.

Montana Bureau of Mines and Geology
French Coulee Mine Drain
Belt, MT

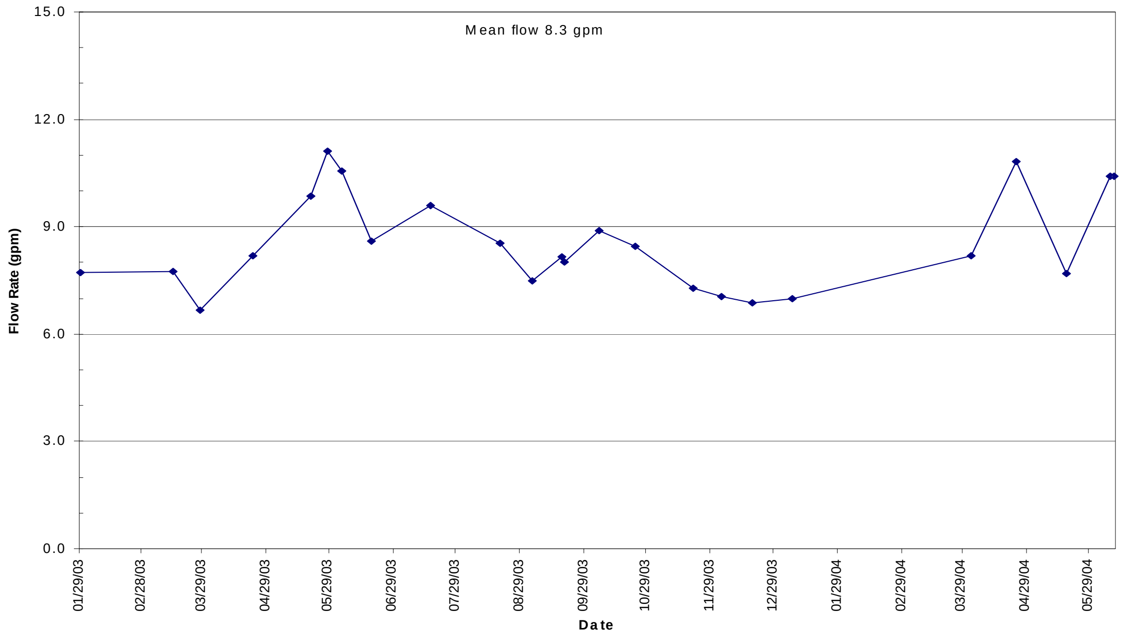


Figure 4.8 French Coulee Mine drain hydrograph of measured flow rates.

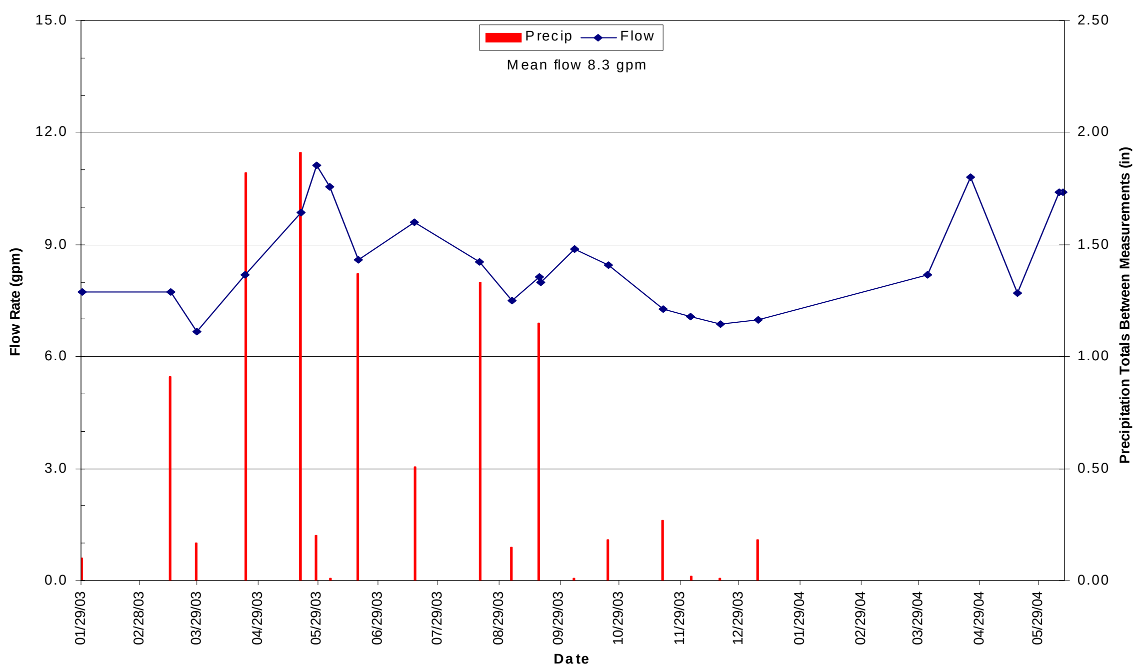


Figure 4.9 French Coulee drain hydrograph of measured flow rates with precipitation totals between measurements.

The sondes were downloaded, cleaned and re-calibrated in the laboratory before being re-installed. Fouling from algae and/or iron precipitates was a continual problem at all three sites (figure 4.10). However, when the locations of the Anaconda Mine and French Coulee drain sondes were completed in June, the severity of the fouling was reduced considerably. Even with the improvement in operation following the sondes relocation, dissolved oxygen measurements were still affected by algae fouling. Figure 4.11 shows the algae growth adjacent to the sonde in the French Coulee site. In an attempt to further reduce probe fouling at this site, a 2.5-foot piece of 30-slot PVC well screen was installed in the discharge water, with the sonde installed inside the well screen. Unfortunately, this did not reduce the fouling problem; instead it appeared to make matters worse for other parameters. Other parameters, i.e. SC, exhibited considerable drift during the August 18-October 23 period when the sonde was placed inside the screen.

4.2.1 Anaconda Mine Drain Monitoring

The multi-parameter sonde was installed on the down-gradient side of the road culvert underneath the county road initially; however to obtain more representative data, the sonde was moved upstream a short distance and installed directly inside the end of the drain pipe that carries water directly from the mine adit. Moving the sonde dramatically reduced the precipitates that formed on the probes and reduced the amount of variability seen in temperature readings in particular. *Figures 4.12a and b, and 4.13a and b* are time trend plots for pH-temperature, SC, dissolved oxygen, and redox for the period of monitoring at this site. Table 4.3 contains a summary of statistics for the monitored parameters.

	pH	SC (umhos/cm)	Temperature (^{0}C)	DO (mg/L)	%DO (%sat)	Redox (mv)
Mean	2.85	2,264	9.86	1.11	11.5	624
Maximum	3.97	3,022	11.19	3.44	33.1	657
Minimum	2.46	1,481	7.37	0.06	1.4	550
Number Readings	14,028	14,028	14,028	14,028	9,060	14,028

Table 4.3 Summary statistics for the Anaconda Mine drain, January 28, 2003 through January 7, 2004.

Figure 4.10 Photo of probe fouling by precipitates.

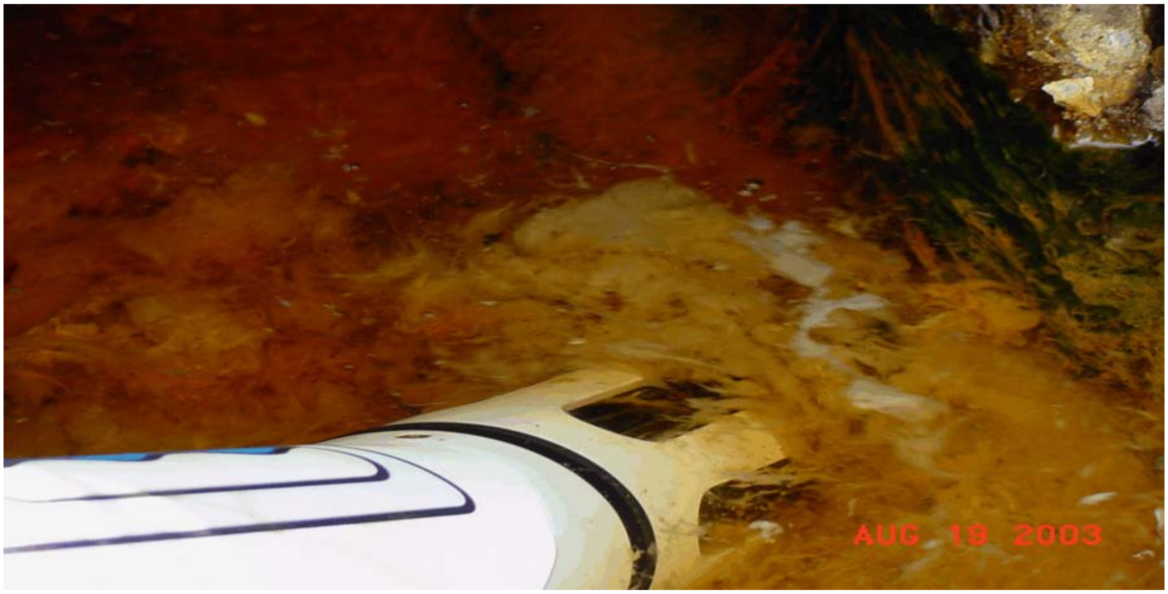
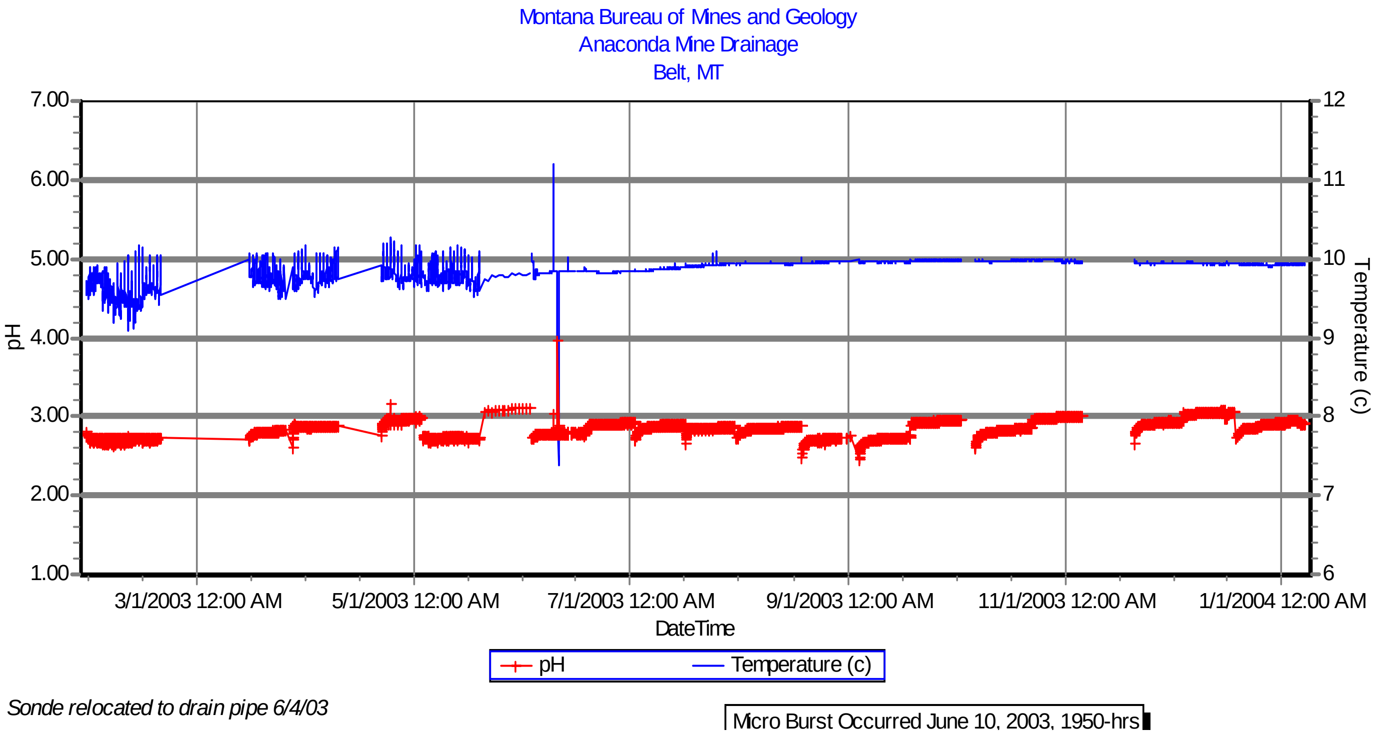


Figure 4.11 Photos of algae growth at French Coulee site.



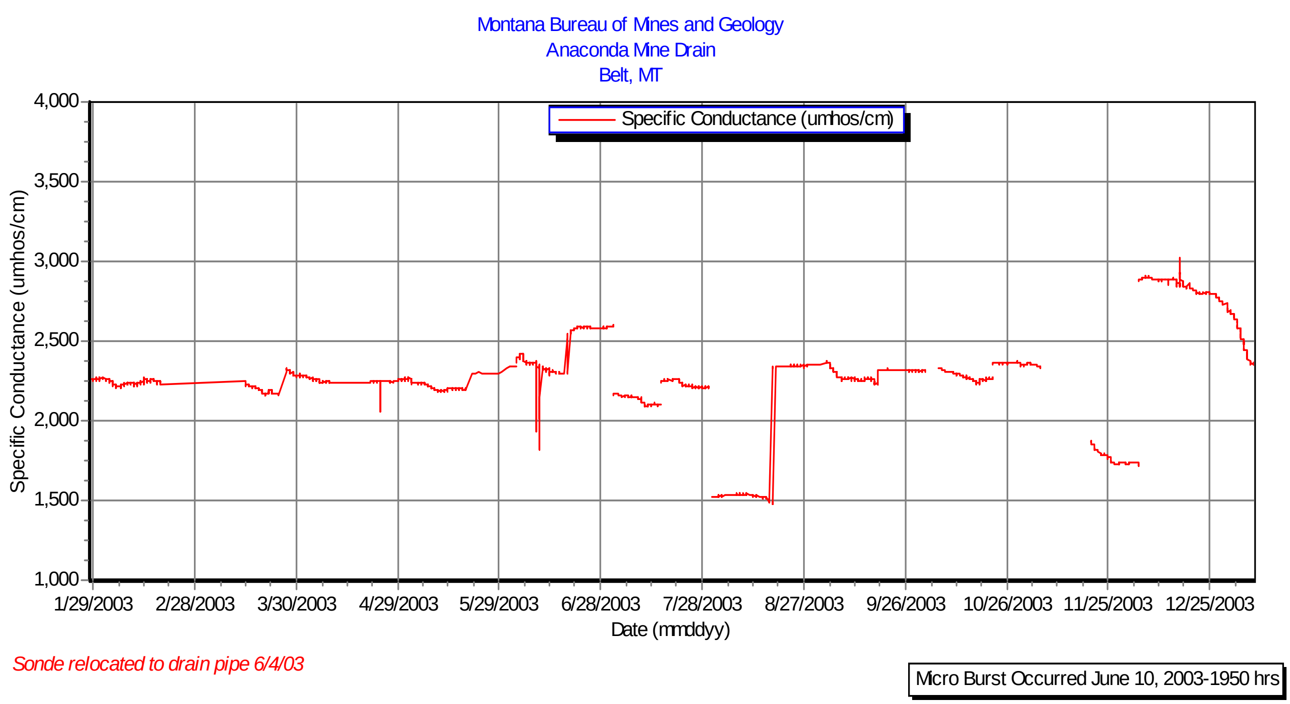


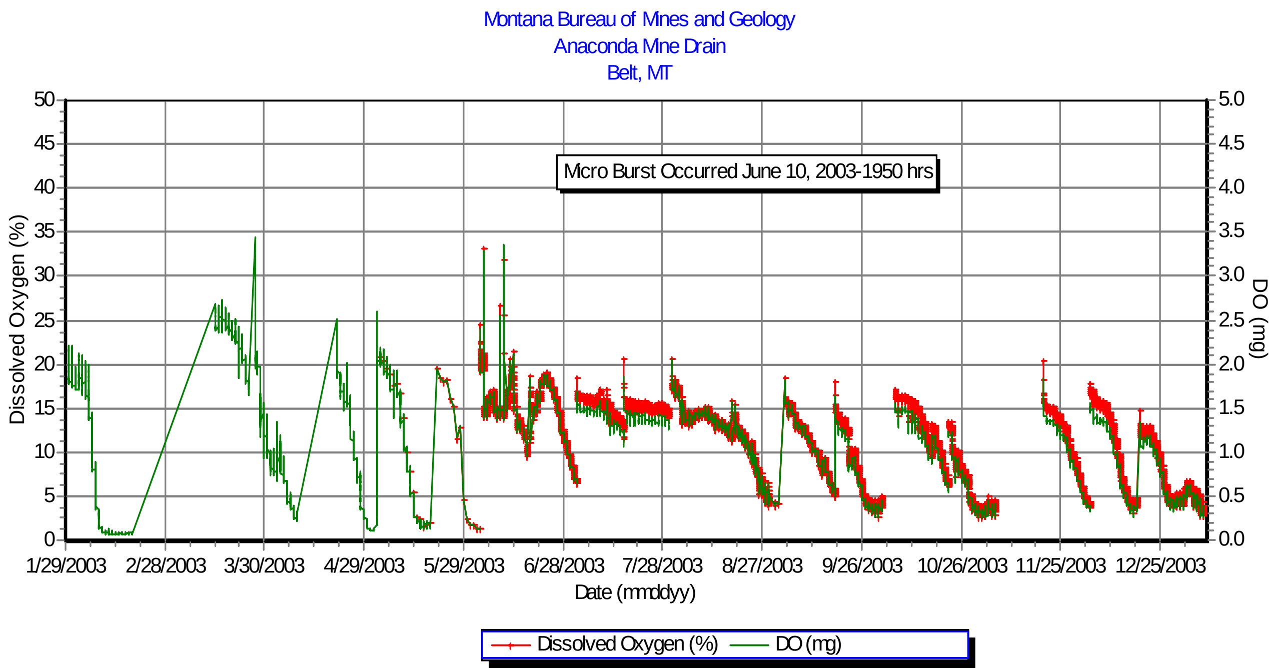
Figure 4.12 Graphs of pH - temperature (top 4.12a) and SC (bottom 4.12b) values from the Anaconda Mine drain.

The pH and temperature of the water coming from the mine are very consistent as shown in figure 4.12a. The most significant change occurred during and immediately after a rainstorm and micro-burst the evening of June 10, 2003. Severe winds and heavy rain hit the town of Belt with winds as strong as 100 miles per hour (National Weather Service, 2004). The pH and water temperature both increased to the maximum recorded levels during the storm, while the rise in temperature was followed by a drop in temperature of almost 3°C, before returning to pre-storm levels. These changes are most likely not representative of actual water draining from the mine, but are likely the result of the storm and storm runoff temporarily backing water up behind the road culvert. When these data points are removed from the graph the graph lines are almost flat. It appears that it takes about one hour for the pH probe to stabilize each time a new sonde was installed; however, the change during this period was usually a tenth of a unit or less. No seasonal trends (changes) are noticeable for either of these parameters.

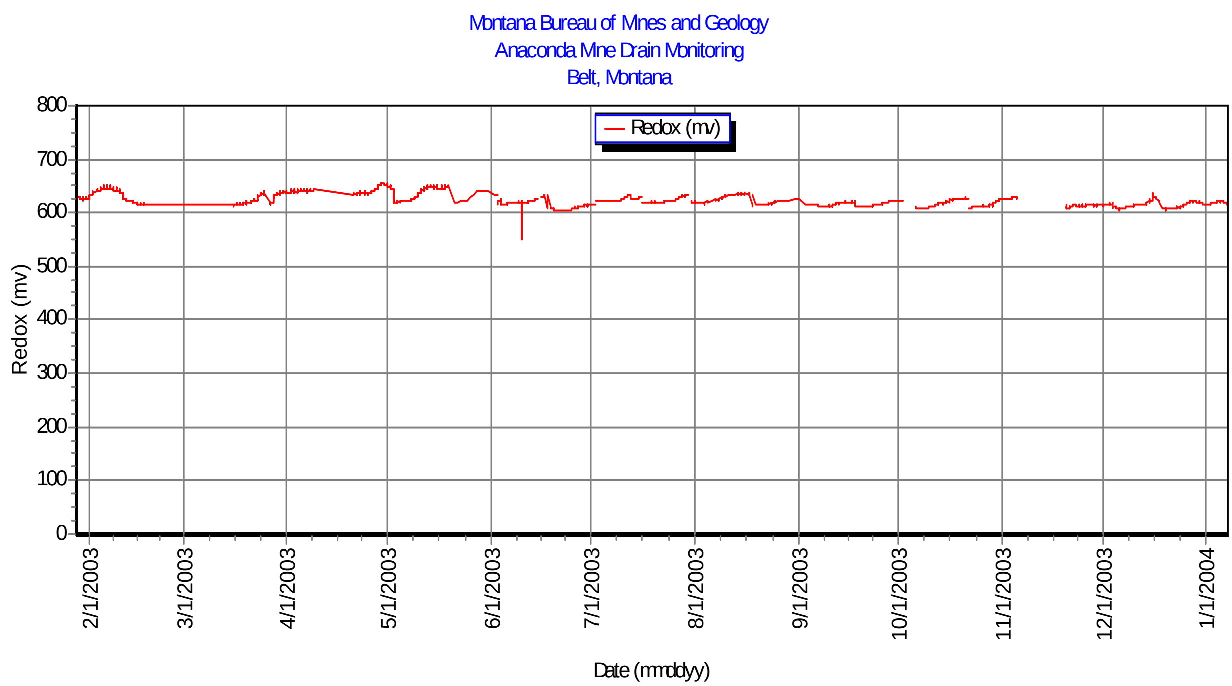
Figure 4.12b is a graph showing SC readings over time. The most significant change is SC took place during the June micro-burst, with SC values dropping 500 or more umhos/cm. It appears that upon two or possibly four occasions a calibration error might have occurred, as SC values while consistent during the two week period, were considerably different than the periods preceding and following. (It should be noted that no problems were encountered during calibration during any of these periods.) No seasonal trends are noticeable on this graph.

Figure 4.13a shows DO and percent DO values over time. As mentioned previously, these probes were the most susceptible to fouling. While relocating the sondes had some initial improvement on the probes fouling, the measured levels still dropped off consistently during each two week monitoring period. Extreme care should be used when using the DO data, however, it is safe to say DO concentrations are probably less than 2.5 mg/L in this water. These values are well below recommended aquatic life standards.

Redox values are very consistent at this site also (figure 4.13b). The greatest redox change occurred during the June micro-burst, and were similar to the changes seen in pH, temperature, and SC. Some fouling may be occurring on this probe also during each period of deployment, as a slight increase in redox occurs



Sonde relocated to drain pipe 6/4/03



Sonde relocated to drain pipe 6/4/03.

Figure 4.13. Graphs of DO - %DO (top 4.13a) and redox (bottom 4.13b) values from the Anaconda Mine drain.

gradually during each two week period. However, this change is so minor and the overall trend of the graph is so flat that the average value of 624 mv is probably very representative of this water. Once again no seasonal water quality trend is noticeable for this parameter.

Based upon the overall consistency of the physical parameters monitored in the Anaconda Mine drain water, the mine water appears to be unaffected by seasonal changes. Either the source and quality of the water entering the mine is very consistent, or chemical changes occur within the mine workings very quickly, so that the water discharging from the mine shows no effects of seasonal changes, or the source of acid production is primarily near the mine floor, not subject to changes in water levels.

4.2.2 French Coulee Mine Drain Monitoring

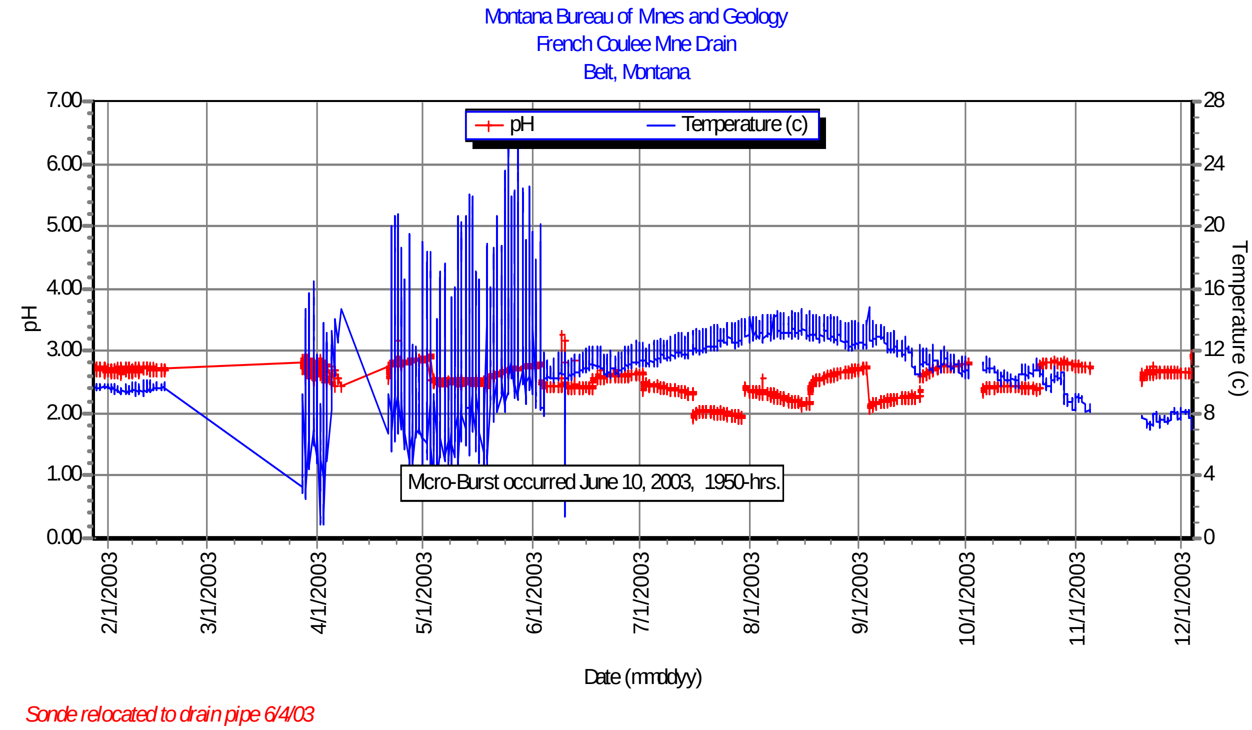
Originally the sondes were installed at the bottom of the hill in a small pool area that allowed complete submergence of the sonde-probes. However, considerable fouling of the probes occurred and ambient temperatures affected the water temperatures. Once the sondes were moved (June 4, 2003) to the inside of the discharge pipe at the top of the hill the extreme temperature changes were reduced and the amount of bio-fouling was also reduced.

Similar changes in pH, temperature, and SC were seen at this site as those noted at the Anaconda Mine drain during the June Micro-burst. Figures 4.14 and 4.15 are graphs of the various physical parameters monitored at this site over time, while Table 4.4 contains a statistical summary of the data.

	pH	SC (umhos/cm)	Temperature (^{0}C)	DO (mg/L)	%DO (%sat)	Redox (mv)
Mean	2.55	4,503	10.59	1.77	9.9	606
Maximum	3.25	7,298	25.19	13.39	96.8	680
Minimum	1.93	2,204	0.83	0.00	0.0	430
Number Readings	14,022	14,022	14,035	14,022	9,283	14,035

Table 4.4. Summary statistics for the French Coulee Mine drain, January 28,2003 through January 7, 2004.

In an attempt to further reduce probe fouling at this site, a piece of 4-inch PVC well screen was



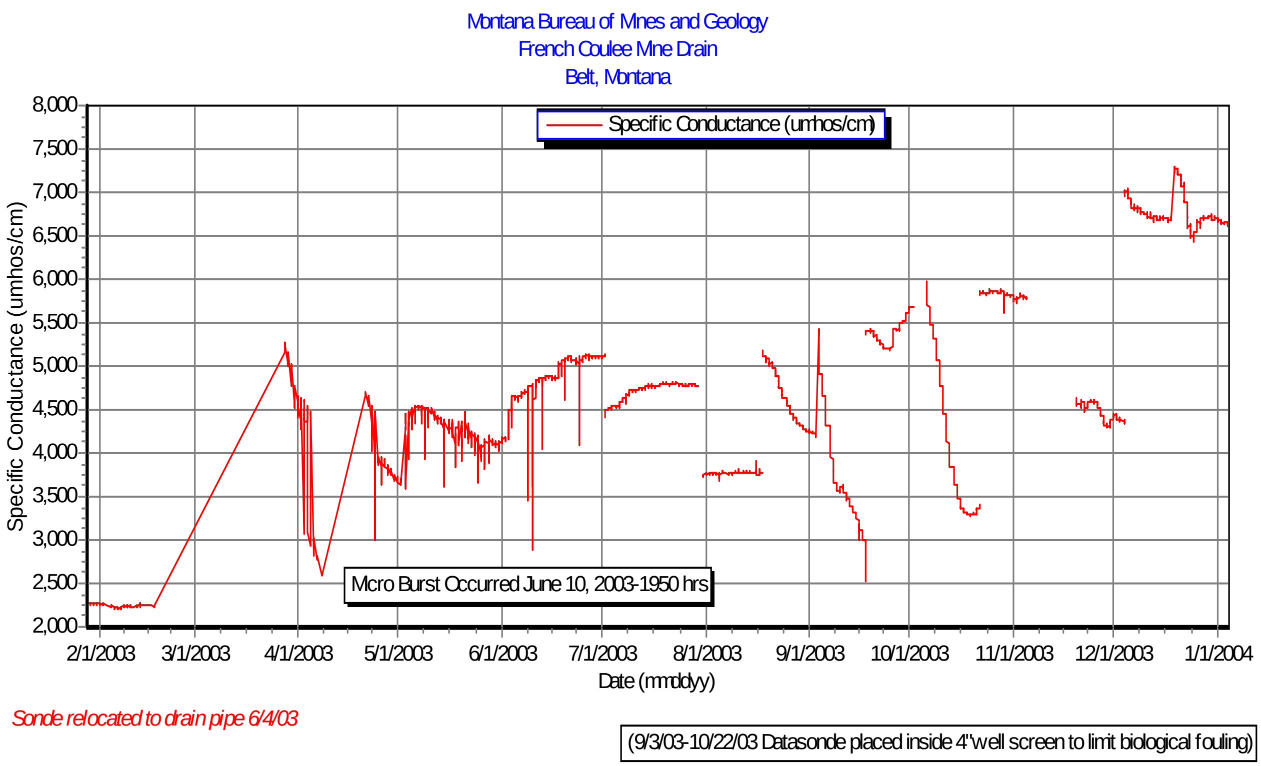
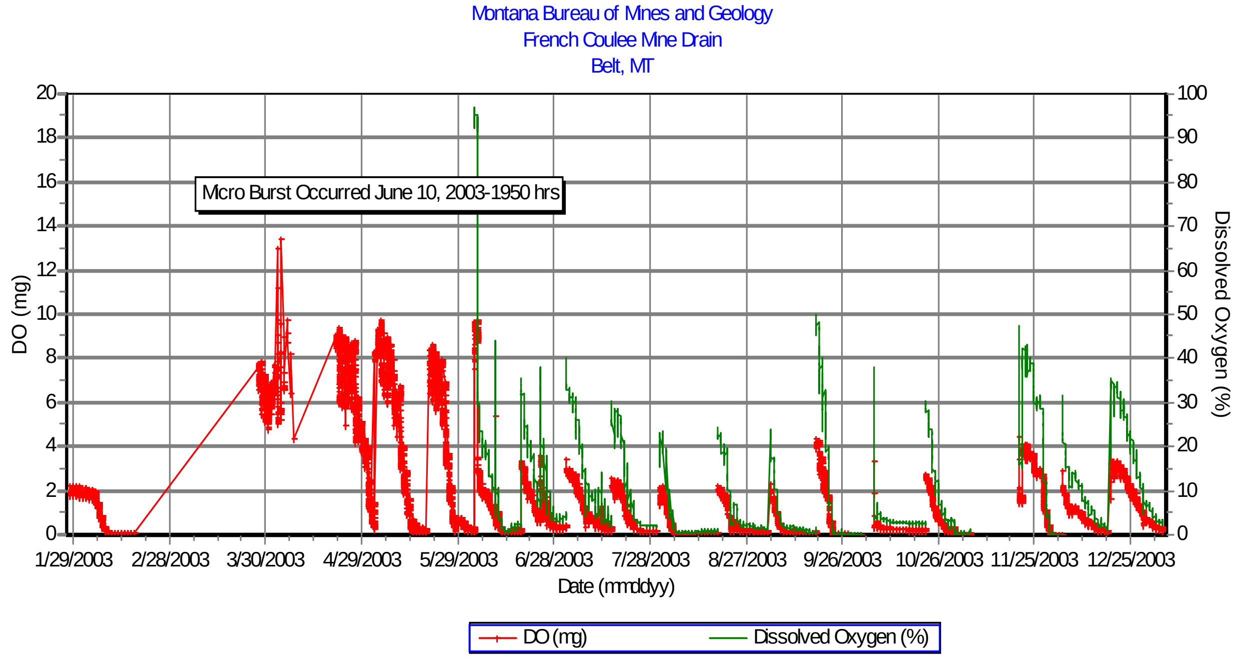
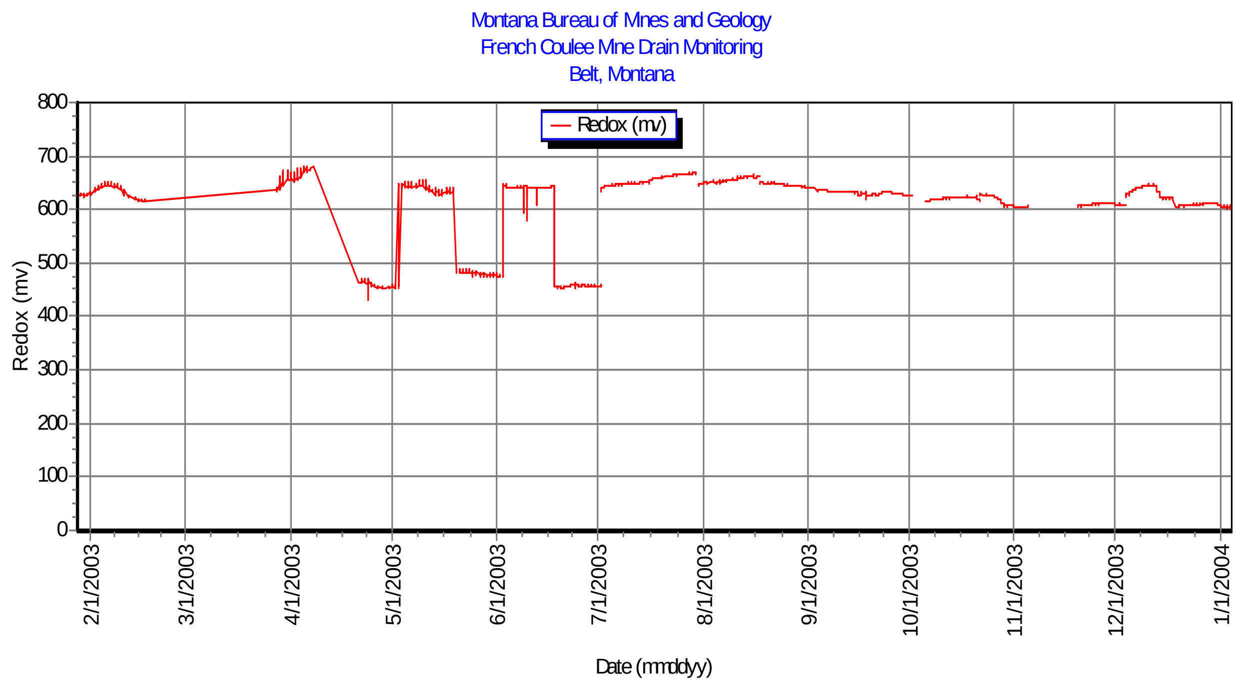


Figure 4.14. Graphs of pH - temperature (top 4.14a) and SC (bottom 4.14b) values from the French Coulee Mine drain.



Sonde relocated to drain pipe 6/4/03



Sonde relocated to drain pipe 6/4/03.

Figure 4.15. Graphs of DO-%DO (top 4.15a) and redox (bottom 4.15b) values from the French Coulee Mine drain.

installed in the discharge and the sonde placed inside it. While visually this appeared to reduce the bio-fouling, it had a negative effect on SC measurements. As can be seen in figure 4.14b, SC values dropped off continuously from the beginning of each deployment of the sonde for the periods from September 3, 2003 to October 22, 2003. Once the well screen was removed and the sonde placed directly back inside the discharge pipe this change no longer occurred. Based upon the data presented in tables 4.3 and 4.4 and the figures, it appears that the conditions of the water change much more than that of the Anaconda Mine water. However, when graphs are prepared using just one data point (measurement) per day the amount of variation is not as pronounced (figure 4.16a and 4.16b). The added variability at this site might partially be related to temperature changes based upon ambient temperatures.

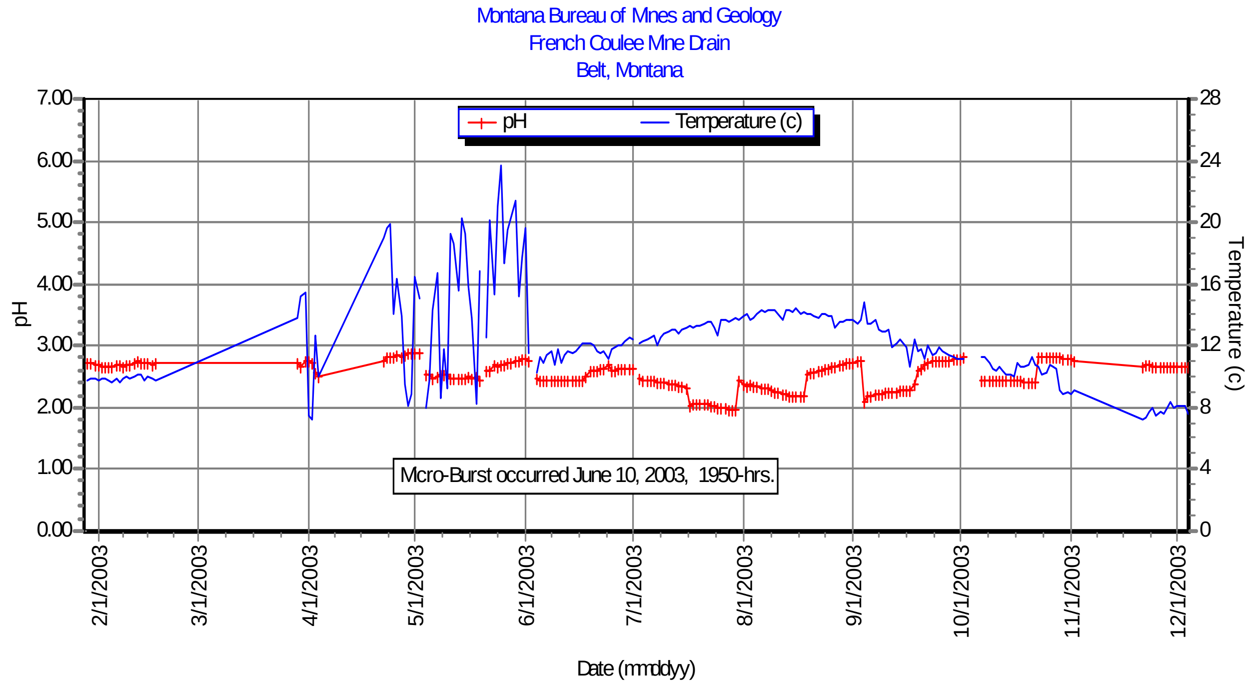
While more variability occurred at this site, there was no indication of seasonal influence, such as dilution in SC values or a rise in pH values that might occur following recharge from precipitation and recharge events.

4.2.3 Box Elder Creek Monitoring

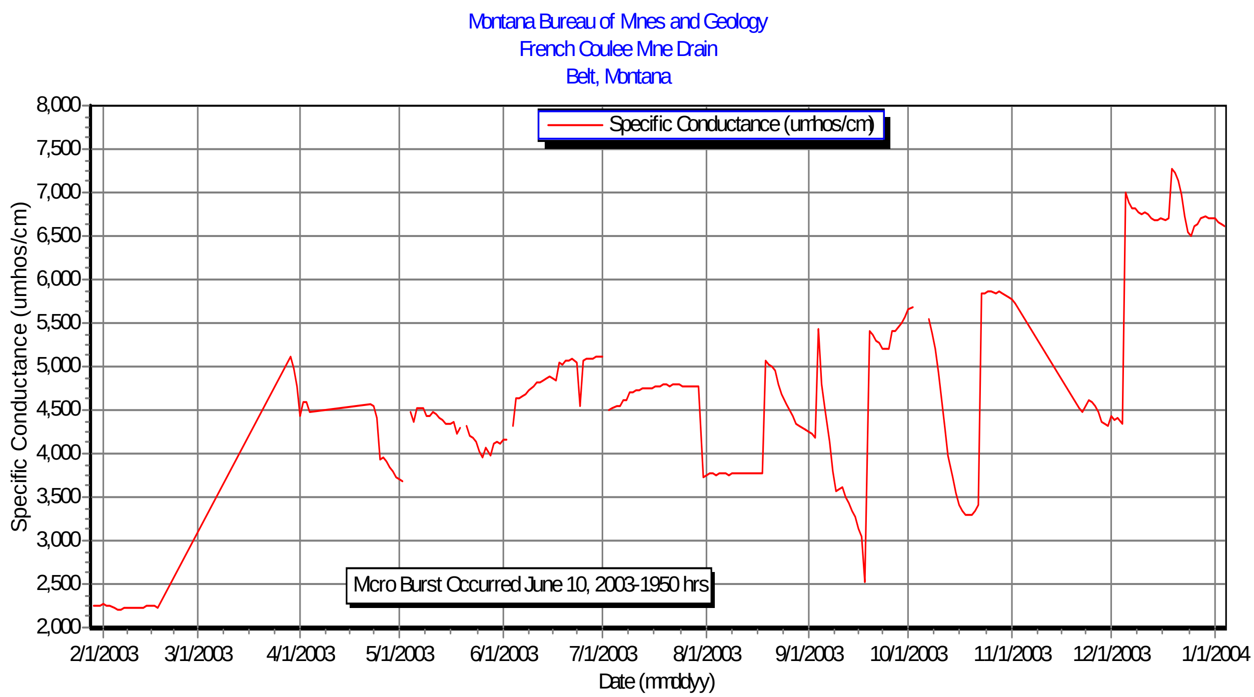
The multi-parameter probe at this site was originally installed just upstream of where the county road crosses Box Elder Creek, on John Harris' property. This was the one portion of the stream that was not completely frozen at that time. The monitoring site was relocated to the site of the upper flume on June 18, 2003, on Jim Larson's property. Table 4.5 contains a summary of monitoring statistics for this site.

	pH	SC (umhos/cm)	Temperature (0C)	DO (mg/L)	%DO (%sat)	Redox (mv)
Mean	8.17	612	8.37	8.15	80.8	553
Maximum	9.85	854	28.70	20.79	214.9	655
Minimum	6.61	304	-5.00	0.13	1.70	171
Number Readings	13,637	13,260	13,637	12,248	12,936	12,114

Table 4.5. Summary statistics for upper Box Elder Creek, January 28, 2003 through January 7, 2004.



Sonde relocated to drain pipe 6/4/03



Sonde relocated to drain pipe 6/4/03

(9/3/03-10/22/03 Datasonde placed inside 4"well screen to limit biological fouling)

Figure 4.16. Modified graphs of pH - temperature (top 4.16a) and SC (bottom 4.16b) values from the French Coulee Mine drain, using one point per day.

Water quality conditions are much different at this site, in comparison to physical parameter data for the Anaconda Mine and French Coulee Mine drains. Figures 4.17a and b through 4.18a and b show the trends for the monitored parameters.

Figure 4.17a shows pH values for the period of monitoring. For the most part pH values are between 7.80 and 8.20. The slight daily variations are most likely the result of temperature changes and increasing biological activity during daylight hours.

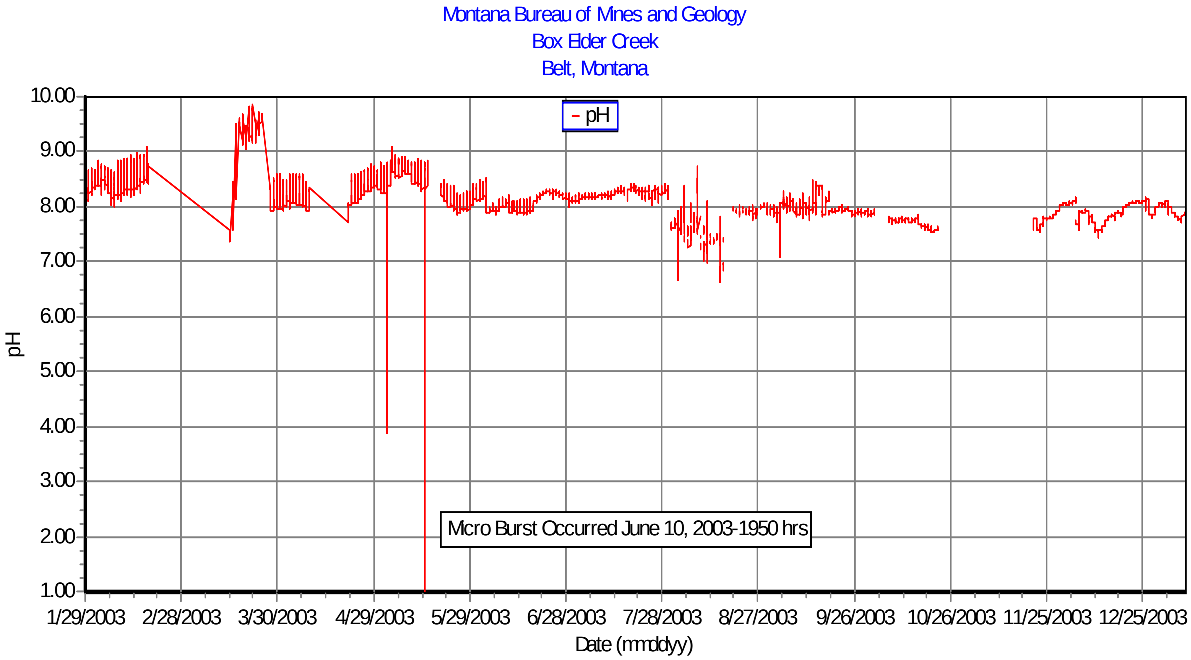
Daily and seasonal temperature changes are very noticeable on figure 4.17b. Temperatures rise in the spring and summer months before falling in the fall and winter. The stream temperature is near zero during much of the late fall and winter. These conditions and the low flows mentioned earlier resulted in periods where limited data were collected at this site. Occasionally the stream flow was too low and water depths too shallow to completely cover the monitoring probes, or the stream became completely frozen.

Figure 4.18a shows DO and percent DO values for the monitoring period. Seasonal and daily trends are readily apparent on this figure. The increased temperatures during the summer and the accompanying increase in biological activity in the stream resulted in a decrease in DO concentrations. However, the DO conditions are favorable for aquatic life and stream health.

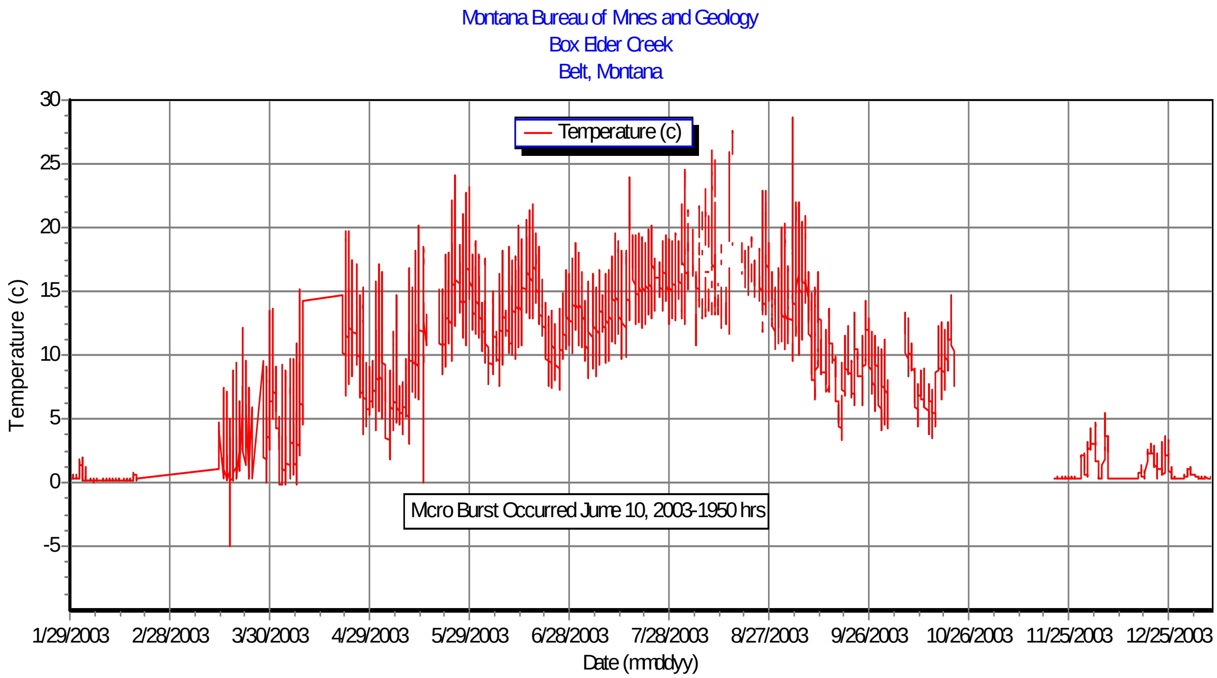
4.2.4 Summary of Physical Parameter Monitoring

Physical parameter monitoring of the two major acid mine discharges revealed a very stable condition of the water. No seasonal trends or changes occurred in either the Anaconda Mine discharge or the French Coulee Mine drain discharge. The greatest influence on data was the location of the monitoring sites. Once monitoring sites were moved to locations closer to the discharge, the amount of variation declined significantly.

This monitoring documents the severely impacted (degraded) nature of the water coming from these two sites. The low pH values and elevated SC values show this water to be extremely detrimental to most forms of aquatic life.

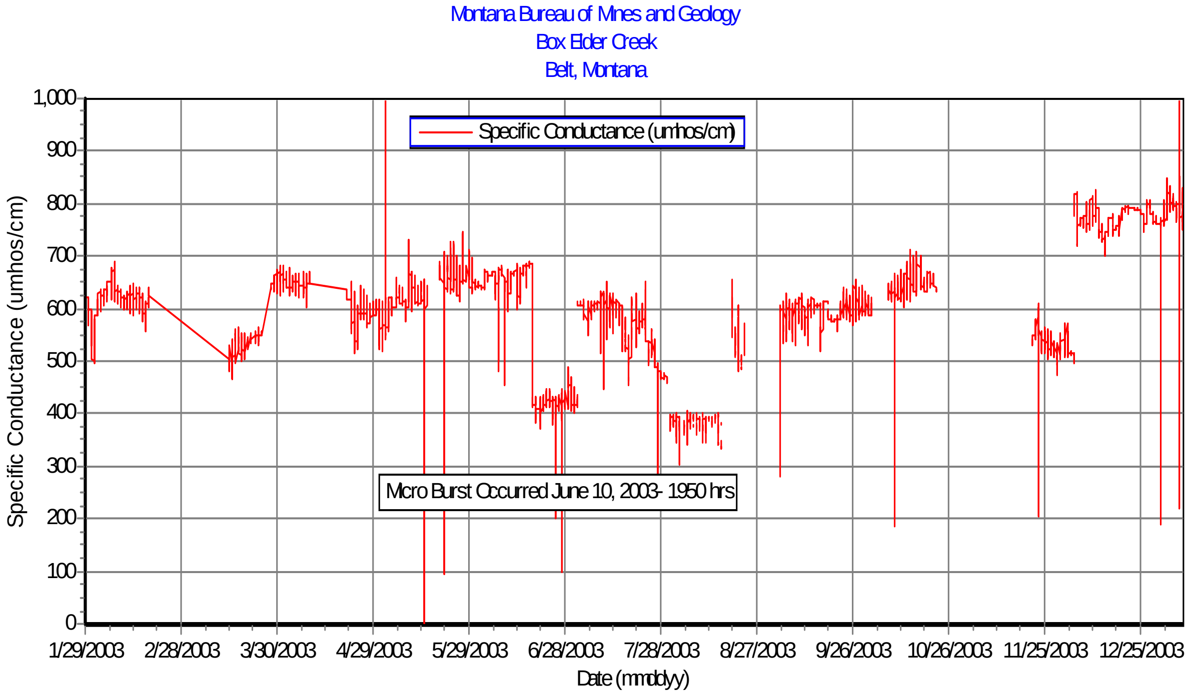


Sonde relocated to upper flume 6/18/03

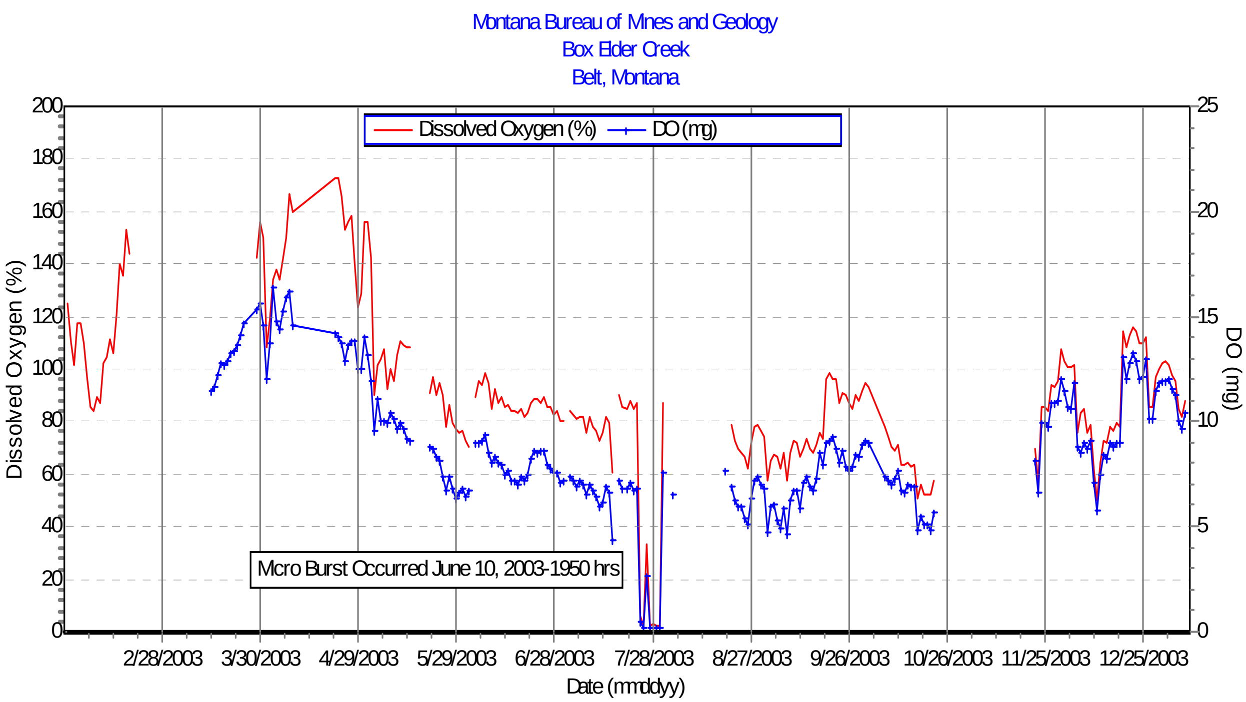


Sonde relocated to upper flume 6/18/03

Figure 4.17. Graphs of pH (top 4.17a) and temperature (bottom 4.17b) values from the upper Box Elder Creek Site.



Sonde relocated to upper flume 6/18/03



Sonde relocated to upper flume 6/18/03

Figure 4.18. Graphs of SC (top 4.18a) and DO - %DO (4.18b bottom) values from the upper Box Elder Creek site.

Conversely, monitoring of the Box Elder Creek drainage showed significant daily and seasonal trends, with the overall physical condition of the stream being good. The pH values are actually on the high side of those recommended for aquatic life (6.5 - 8.5). The elevated pH values are probably the result of the interaction of the stream with the material that composes the stream channel and banks. It may also be influenced by the pH of ground-water that discharges into the stream.

5.0 WATER-QUALITY SAMPLING

Water-quality samples were collected monthly through October at the three main monitoring locations: Anaconda Mine drain, French Coulee Mine drain, and Upper Box Elder Creek. Both dissolved and total recoverable samples were collected, during most sample events. Samples were collected periodically from other surface water sites. Two of these sites are associated with what is referred to as the Highway Drain shown on figure 5.1. It is believed the majority of the water flow at this site is from a series of horizontal drill holes under U. S. Highway 87. Other surface water samples were collected from various locations on Belt Creek and at the flume located on Lower Box Elder Creek.

Water quality samples were also collected twice from two domestic wells and a spring, while one sample from the town of Belt's No. 2 well was collected. Dissolved and total recoverable samples were collected from these locations also. Appendix A contains analytical results of the samples collected.

Note: *Several sites (Anaconda Mine Drain and French Coulee Drain) had considerable precipitates form during the digestion procedure for total recoverable analysis, which possibly resulted in these concentrations being less than dissolved.*

5.1.1 Anaconda Mine Drain Water Quality

Altogether, nine water-quality samples were collected and analyzed for common ions and trace metals at this site. Samples were collected at the same location where the continuous monitoring-multiparameter probes were located.

The water quality from this site is similar to other acid mine discharges in the Great Falls coal field, with low pH and high concentrations of iron, aluminum, and sulfate. The water is an iron calcium-sulfate type (FeCa-SO_4). This type water is unusual and typifies acid mine drainage. Little or no arsenic, copper, or lead

Figure 5.1 Locations of highway drain sample sites.

was detected in any of the samples from this site. Metals that were elevated above normal-background conditions were aluminum, cadmium, cobalt, iron, and zinc. Sulfate was the only elevated anion.

Due to the acidic nature of the water, close to 100 percent of the metals are in the dissolved form. Water quality results showed very little variation throughout the year. Figures 5.2, 5.3, and 5.4 show concentrations of both dissolved and total recoverable calcium, iron, and zinc for the various sample events. While the dissolved and total recoverable concentrations are very similar, there is one exception, that being the August sample event when total recoverable concentrations are double the dissolved concentrations.

5.1.2 French Coulee Mine Drain Water Quality

Nine water-quality samples were collected from this site also, for common ions and trace metals. All 9 samples were collected near the discharge pipe after flowing underneath the railroad tracks.

This water is an iron calcium-sulfate type ($FeCa\text{-}SO_4$), also. However, the percent iron is almost 50 percent greater than that of the Anaconda Mine discharge. The water is acidic with the sulfate concentrations twice that of the Anaconda Mine water. Iron and sulfate concentrations are five-fold those of the Anaconda Mine discharge, however, the discharge is only about 6 percent of the Anaconda, which results in a much lower loading rate to surface sources. This water has elevated concentrations of aluminum, arsenic, cadmium, and chromium. Zinc concentrations exceed those recommended for aquatic life. Results of all the sample events are contained in Appendix A, while Table 5.1 lists what parameters are exceeded.

	Drinking Water Primary/Secondary Standard	Aquatic Life Acute/Chronic Standard
Aluminum	Yes	Yes
Arsenic	Yes	No
Cadmium	Yes	Yes
Chromium	Yes	No
Copper	No	Yes
Iron	Yes	Yes
Manganese	Yes	-
Zinc	Yes	Yes

Table 5.1. French Coulee Mine discharge with one or more values in excess of drinking water and/or aquatic life standards.

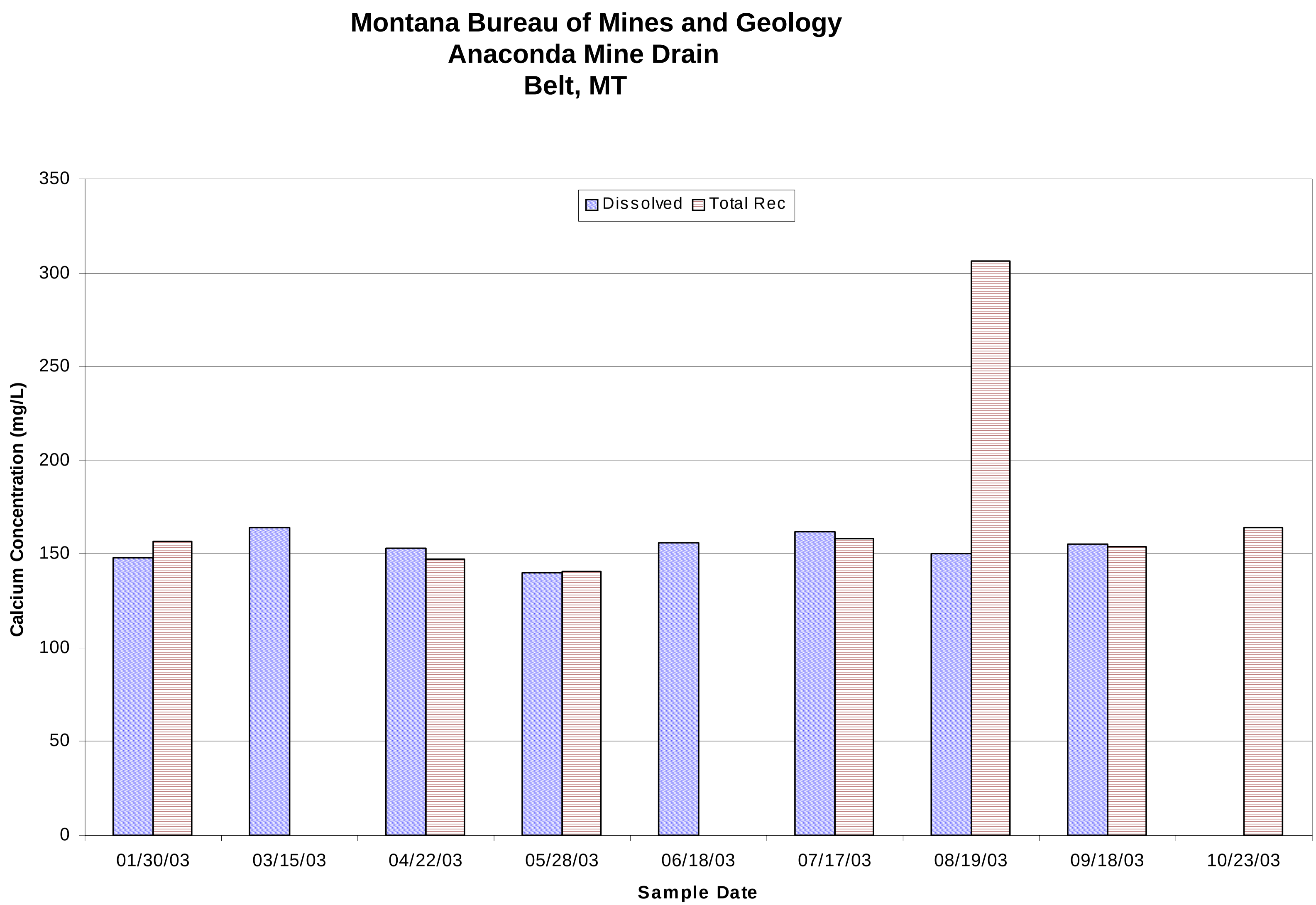


Figure 5.2 Anaconda Mine drain dissolved and total recoverable calcium concentrations.

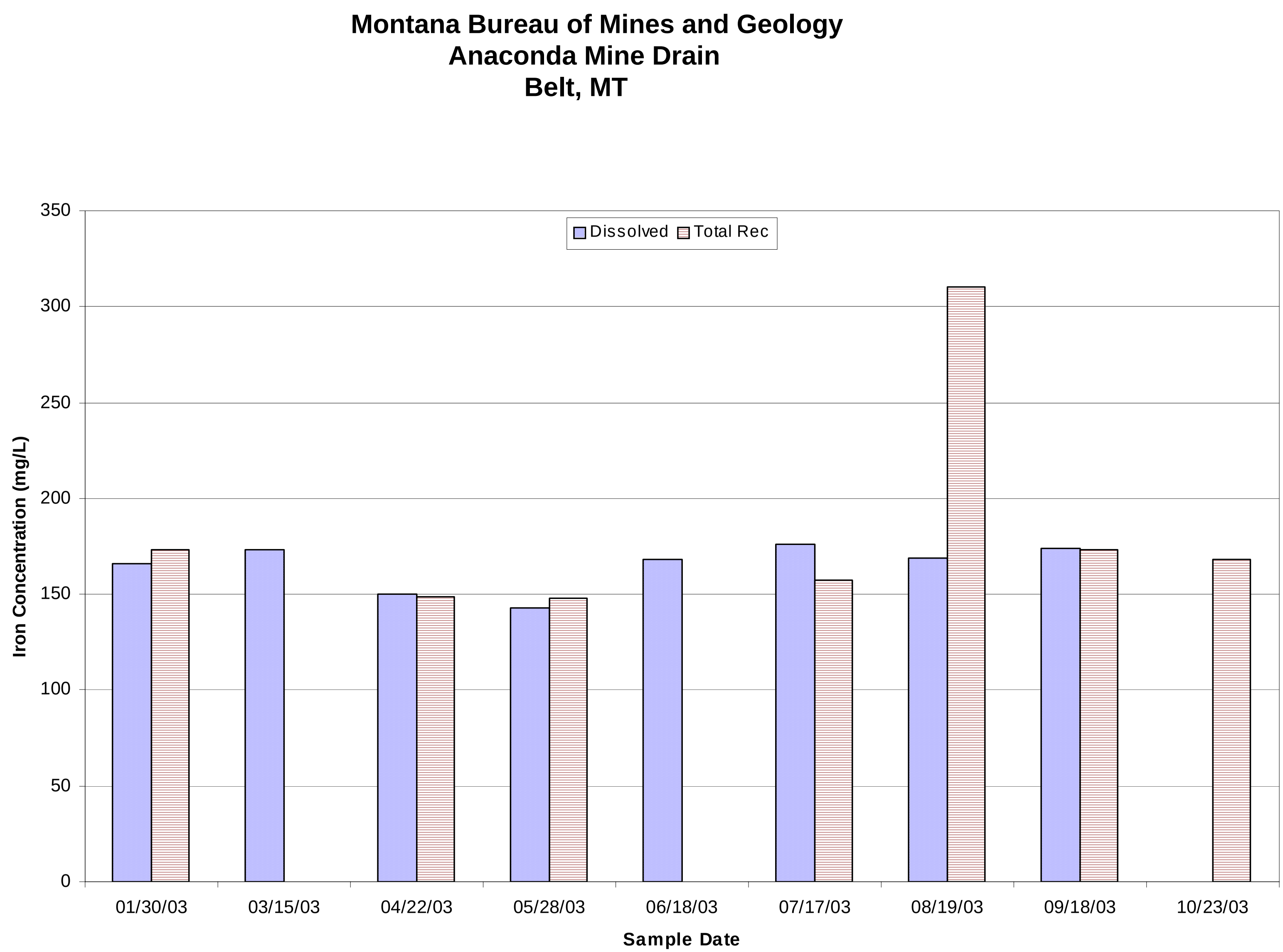


Figure 5.3 Anaconda Mine drain dissolved and total recoverable iron concentrations.

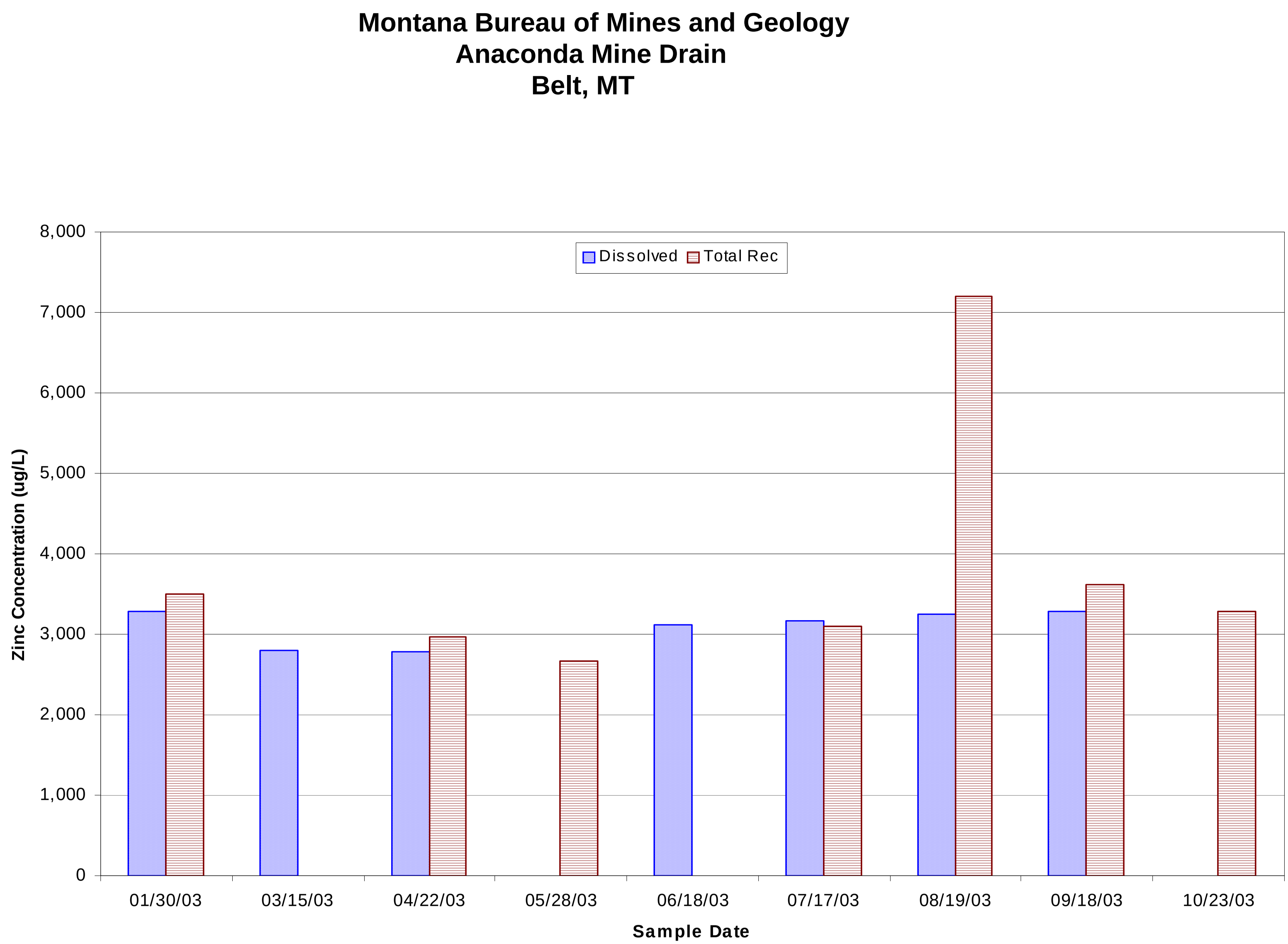


Figure 5.4 Anaconda Mine dissolved and total recoverable zinc concentrations.

Dissolved and total recoverable concentrations were similar, however, there appears to be some seasonal variation of some constituents. Figures 5.5, 5.6, and 5.7 show dissolved and total recoverable concentrations for calcium, iron, and zinc. Concentrations decreased through the spring and early-summer before rising again throughout late-summer and fall.

5.1.3 Upper Box Elder Creek Water Quality

Nine water-quality samples were collected for dissolved and total recoverable major ions and trace metal analysis at this site also. The water at this site is predominantly a calcium-bicarbonate type (Ca-HCO_3). Iron exceeds water-quality standards about 40 percent of the time, however, its concentrations are orders of magnitude lower than those from the Anaconda Mine and French Coulee Mine drains. From the physical parameters (i.e. pH, SC) to trace metals, the water quality at this site is much different than either the Anaconda or French Coulee sites. Water-quality results for this site are summarized in Appendix A.

5.1.4 Lower Box Elder Creek Water Quality

Water-quality samples were collected at the location of the lower flume on Box Elder Creek. The creek channel was dry from mid-June through the remainder of the year. Therefore, only two sets of samples were collected.

The water type at this location is a calcium-bicarbonate (Ca-HCO_3) with water-quality concentrations similar to those at the upper flume.

5.1.5 Highway Drain and Highway Drain Seep Water Quality

Water-quality samples were collected on a similar schedule as that of the three main sample sites, with one exception being the water coming from the highway drains (horizontal wells). This small seep emanating from a corroded culvert on the south bank was sampled during the summer sampling events only.

Water from the Highway Drain varies in water type between a magnesium calcium-bicarbonate

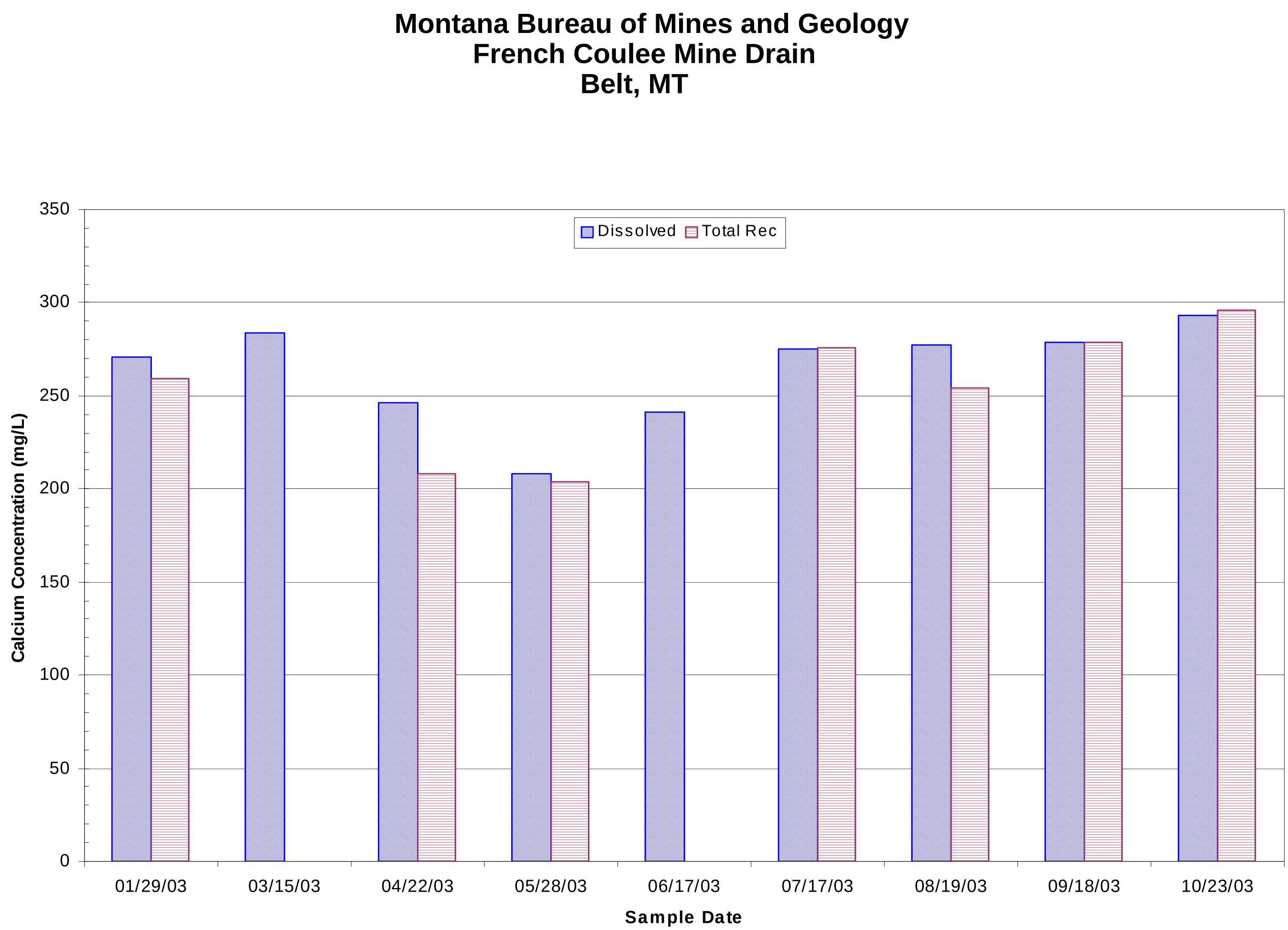


Figure 5.5 French Coulee drain dissolved and total recoverable calcium concentration.

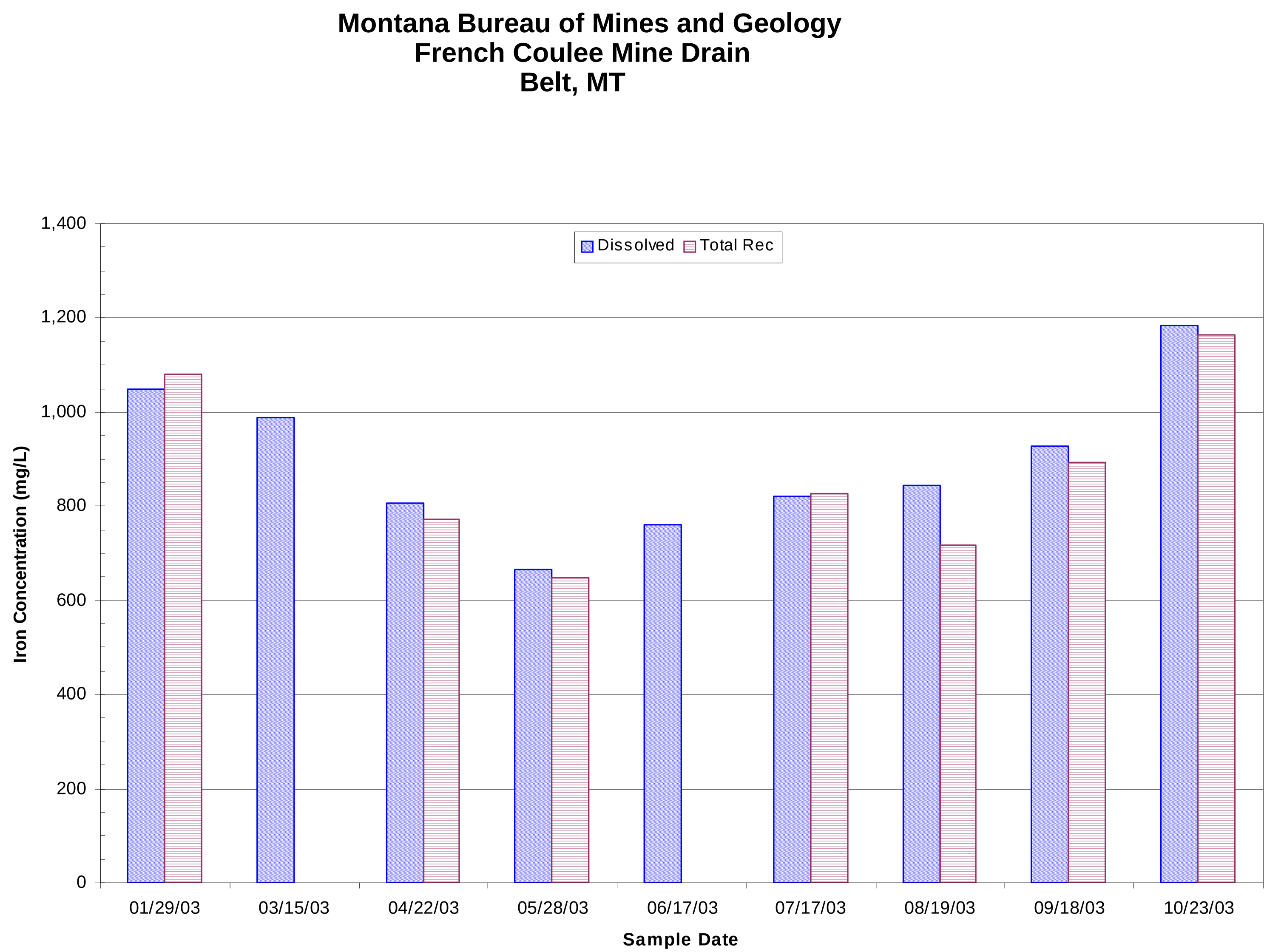


Figure 5.6 French Coulee drain dissolved and total recoverable iron concentration.

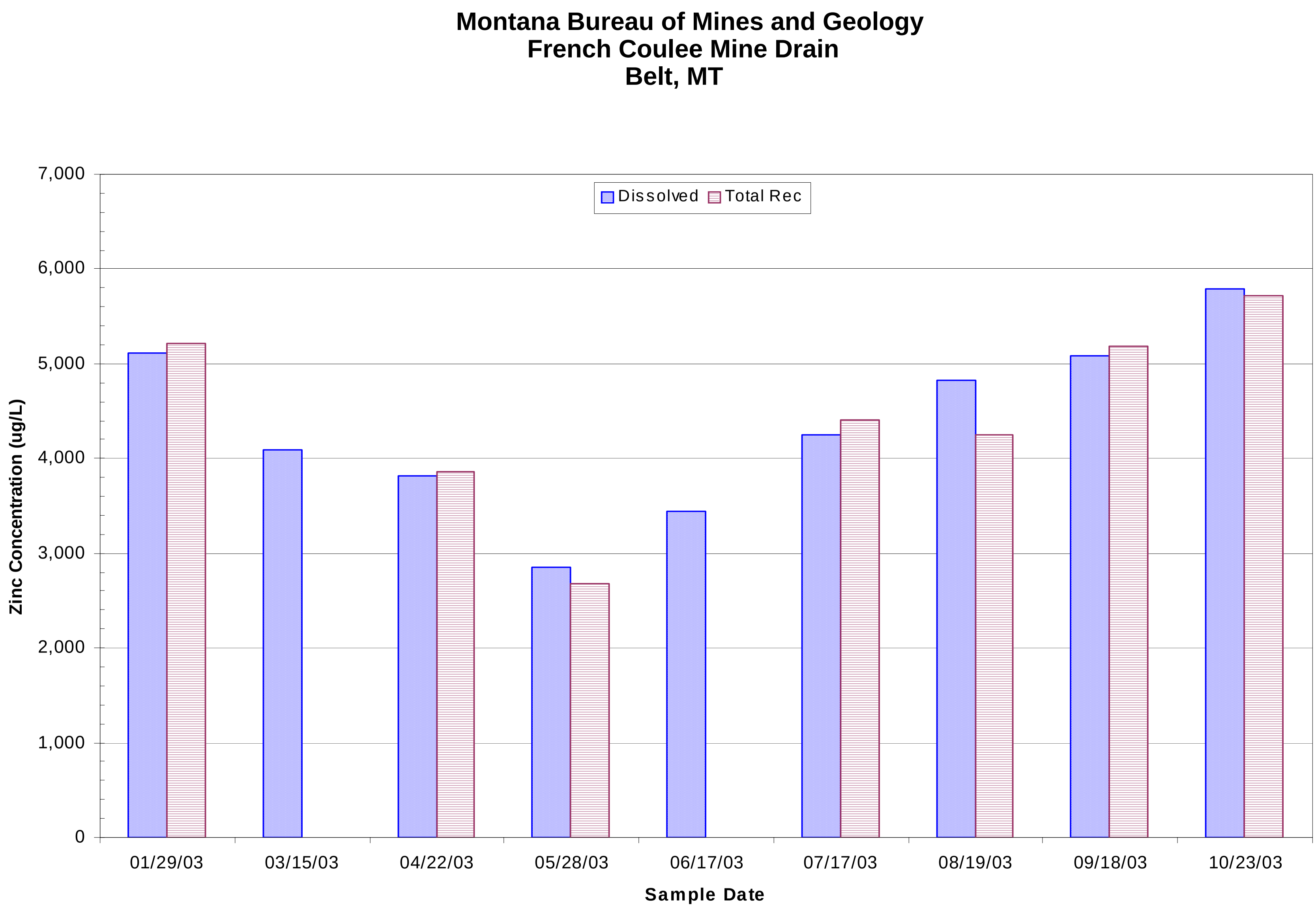


Figure 5.7 French Coulee drain dissolved and total recoverable zinc concentration.

($MgCa-HCO_3$) to a magnesium calcium-sulfate ($MgCa-SO_4$). Iron and manganese are the only parameters that exceed any water-quality standards. It should be noted that samples at this site were collected below where the water discharges from the Highway Drain seep. Therefore, flow from the seep can have considerable impact on both water type and concentrations, especially as flows in the drain decline.

The Highway Drain seep has a magnesium-sulfate ($Mg-SO_4$) water type, with elevated concentrations of sulfate. Concentrations of major cations, chloride, and sulfate are much higher at this site than those from the Highway Drain, itself. Copies of water-quality results are contained in Appendix A.

5.2 Ground-Water Water Quality

Water-quality samples were collected from three wells — those being the town of Belt's No. 1 well (also known as the creek well) which is completed in the Madison Limestone; the Larson Ranch well completed in the shallow alluvium adjacent to Box Elder Creek; and the Harris Ranch well which is completed in the Kootenai Formation. Table 5.2 has the well depths, aquifer, and water type for these three sites.

Well Name	Total Depth (ft)	Aquifer	Water Type
Belt No. 1	430	Madison	calcium-bicarbonate
Larson Ranch	32	Alluvium	calcium-bicarbonate
Harris Ranch	200	Kootenai	calcium-bicarbonate
Harris Spring	-		magnesium-bicarbonate

Table 5.2 Ground-water sample sites, aquifer and water-type summary

5.2.1 Ground-Water Isotope Data

Limited isotope data were collected for selected monitoring sites during periodic sample events. Samples were collected and analyzed primarily for tritium with several sample sets collected for both oxygen and deuterium. The primary reasons for collecting isotope data were for age-dating of sample water and identification of potential markers of source water recharging or discharging from the mine workings. Appendix

B contains results of isotope sampling.

Tritium is one method used for age-dating water. The age is based upon the decay of tritium concentrations in the atmosphere from atmospheric testing of nuclear bombs in the 1950's and 1960's. Table 5.3 lists tritium concentration and age of water based upon a linear interpretation of data contained in Hendry, 1988.

Tritium Concentration (Tu)	Age Interpretation (modified from Hendry, 1988)
>38	Average ground-water likely recharged during peak of thermo-nuclear testing between 1960-1965
4 - 38	Average ground water less than 50 years old
1 - 4	Average ground-water less than 35 years old
<1, >0.1	Average ground-water older than 45 years old
<0.1	Average ground-water older than 65 years old

Table 5.3. Tritium concentrations and related age of water

All of the tritium samples for the Belt sites fall within the 4 - 38 Tu concentration range, meaning the source of the water is less than 50 years old. The lowest Tu concentrations were in the Harris well, followed by the two town of Belt wells, while the highest concentrations were in Highway Drain seep and Highway Drain. What is interesting about these concentrations are those found in the two town wells, which are completed into the Madison Limestone at depths between 370 and 430 feet below ground surface.

The Madison Formation receives most of its recharge in the Little Belt Mountains to the southeast. The Madison is well known for its good water quality and abundant yield. Giant Springs in Great Falls, discharges from the Madison at flows in excess of 130,000 gpm, making it one of the larger springs in the country (Patton, 1996). For decades, it has been believed that the water in the Madison was very old (perhaps hundreds of years), but the results of the tritium samples collected from the two town wells indicate otherwise. This indicates that the Madison receives substantial recharge of younger water from the overlying aquifers. The cross sections shown on Plate 1, indicate the absence of the Big Snowy Group which separates the Kootenai, Morrison, and Swift Formations from the Madison to the south. This allows younger water in the upper formations to move downward, recharging the Madison in this area. The difference in water-level elevations in the Belt area indicate a downward gradient from the Kootenai into the Madison.

6.0 MULTI-SPECTRAL ANALYSIS

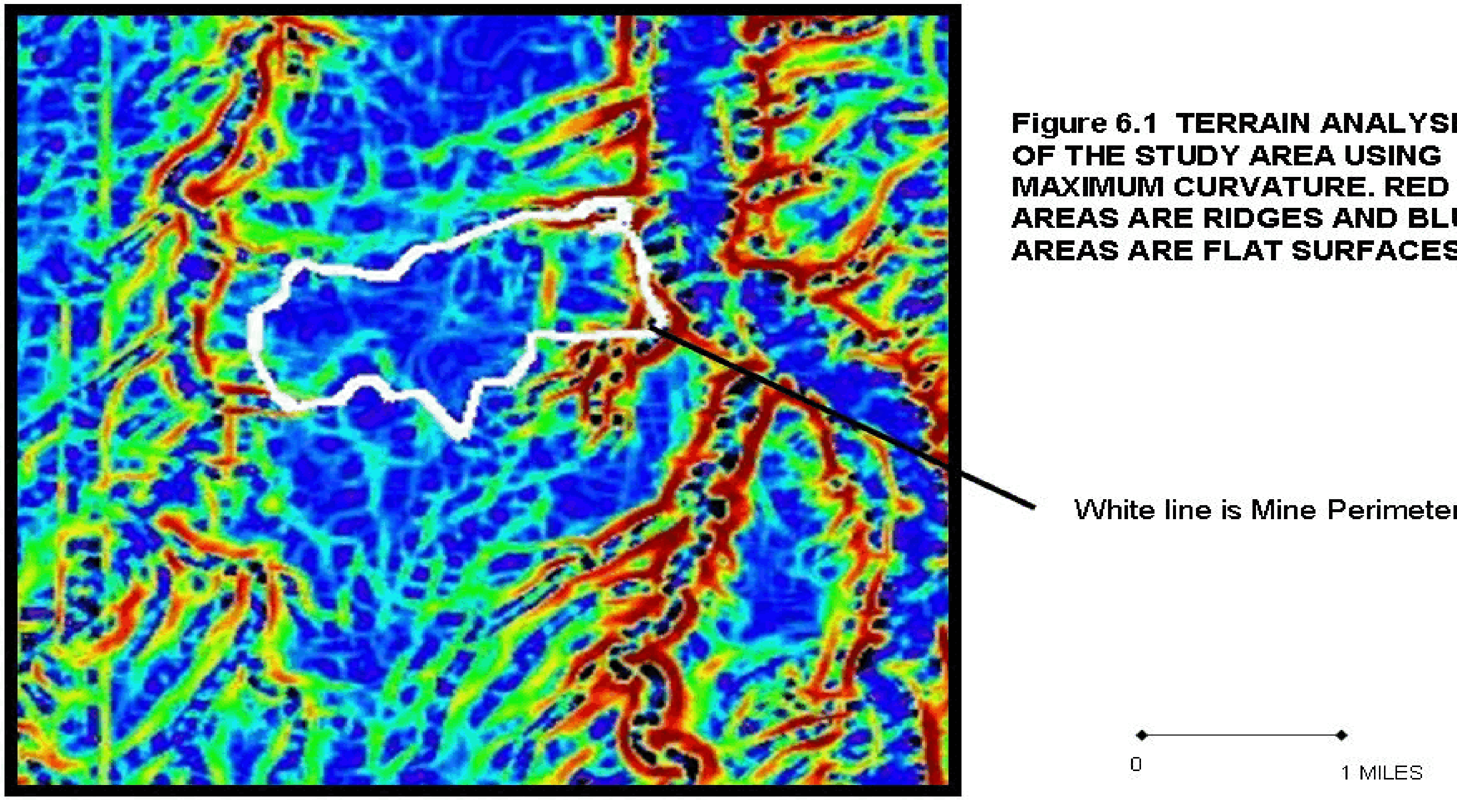
Multi-spectral analysis was used to identify possible surface water infiltration and other environmental factors contributing to the acid mine drainage problem in the Belt study area. Satellite images in various formats, were acquired and ENVI 3.5 software, by Research Systems Inc., was used to process and analyze the satellite data. The images used in the analysis were Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) used for viewing the study area in detail, Land Satellite Multispectral Scanner (LandSat MSS) for change detection over three decades, Land Satellite 7 Enhanced Thermatic Mapper Plus (LandSat 7 ETM+) for change detection over a growing season and for thermal analysis.

The uses of these different formats are discussed in the following sections.

6.1 ASTER Image

The ASTER image used in this study provides a detailed view of the study area because of its 15 meter resolution in the visible bands. It was used to provide an infrared image for various maps of the study area (figure 3.4). If an area of interest was identified using one of the other formats, a more detailed look at the area with the ASTER image was possible. At the time of the study, only one image of the area was available from National Aeronautics and Space Administration (NASA), so any change detection using this format was not possible.

The ASTER data also provide the best image for terrain analysis and for draping of a Digital Elevation Model (DEM) to perform 3-D imaging. In figure 6.1, Maximum Curvature, a topographical modeling procedure, was used on the DEM of the area. This procedure highlights the drainage network in the study



Maximum Curvature

Figure 6.1 TERRAIN ANALYSIS OF THE STUDY AREA USING MAXIMUM CURVATURE. RED AREAS ARE RIDGES AND BLUE AREAS ARE FLAT SURFACES

area. This image shows some interesting patterns that may show a southwest-northeast trending fault line, reported to be located at the north boundary of the mine.

6.2 Land Sat MSS

Land Sat MSS data were used to detect any changes over the past three decades. Using these images, a comparison of changes in land use and vegetation growth was possible, to determine if they had any affect on the study area.

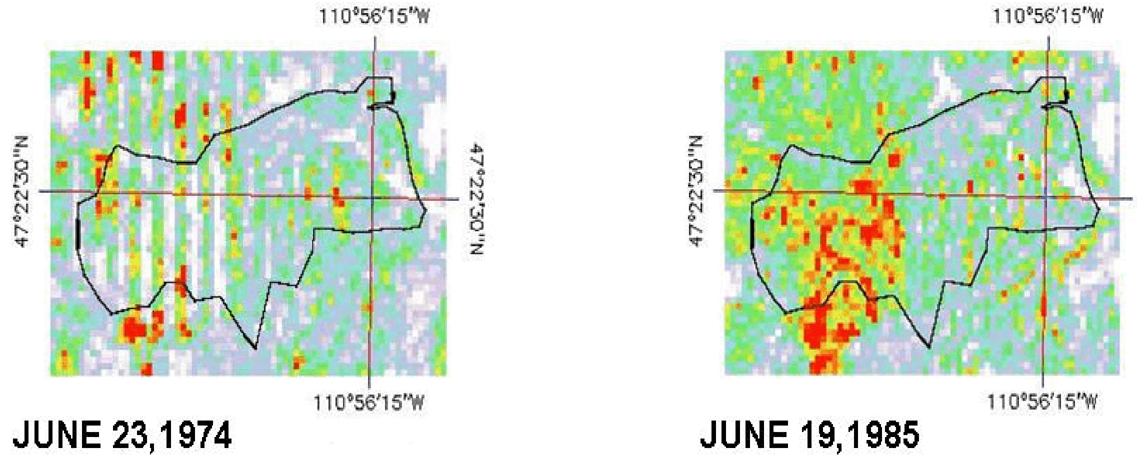
The Normalized Difference Vegetation Index (NDVI) (figure 6.2) was used to determine the areas of the healthiest vegetation in all three of the images. The NDVI is a ratio that shows the healthiest vegetation in red. The comparison of the images shows a change in patterns in the land use over the mine. The pattern in the 70’s image shows row crops in the west side of the mine, and the same area is fallow in the 90’s image.

LandSat MSS images are the best for change detection due to the available images dating to the 1970’s, but lack the resolution (80 meters) to see detail.

6.3 Land Sat ETM+

Land Sat ETM+ data were used in the change detection over a growing season and for spring detection. The three images used were dated May, July and November of 2002. The November image was used because the images in the early fall were of poor quality.

With these images, a tasseled cap analysis (figure 6.3) was used to see changes in vegetation growth and determine if there were areas where vegetation appeared earlier and remained longer in the growing season that may show the location of springs or other areas of mine drainage. The analysis showed that vegetation started earlier in the spring and lasted longer in the fall in the areas of known ground-water discharge.



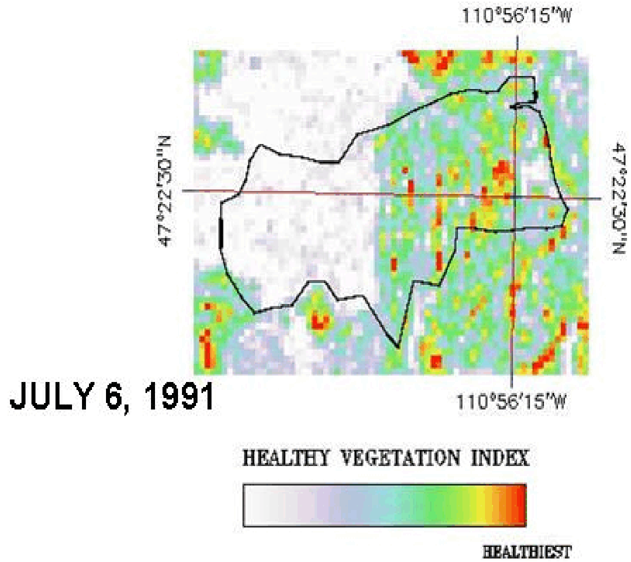
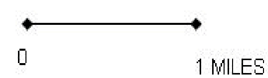


Figure 6.2 The NDVI analysis shows areas of healthy vegetation and also shows changes in land use



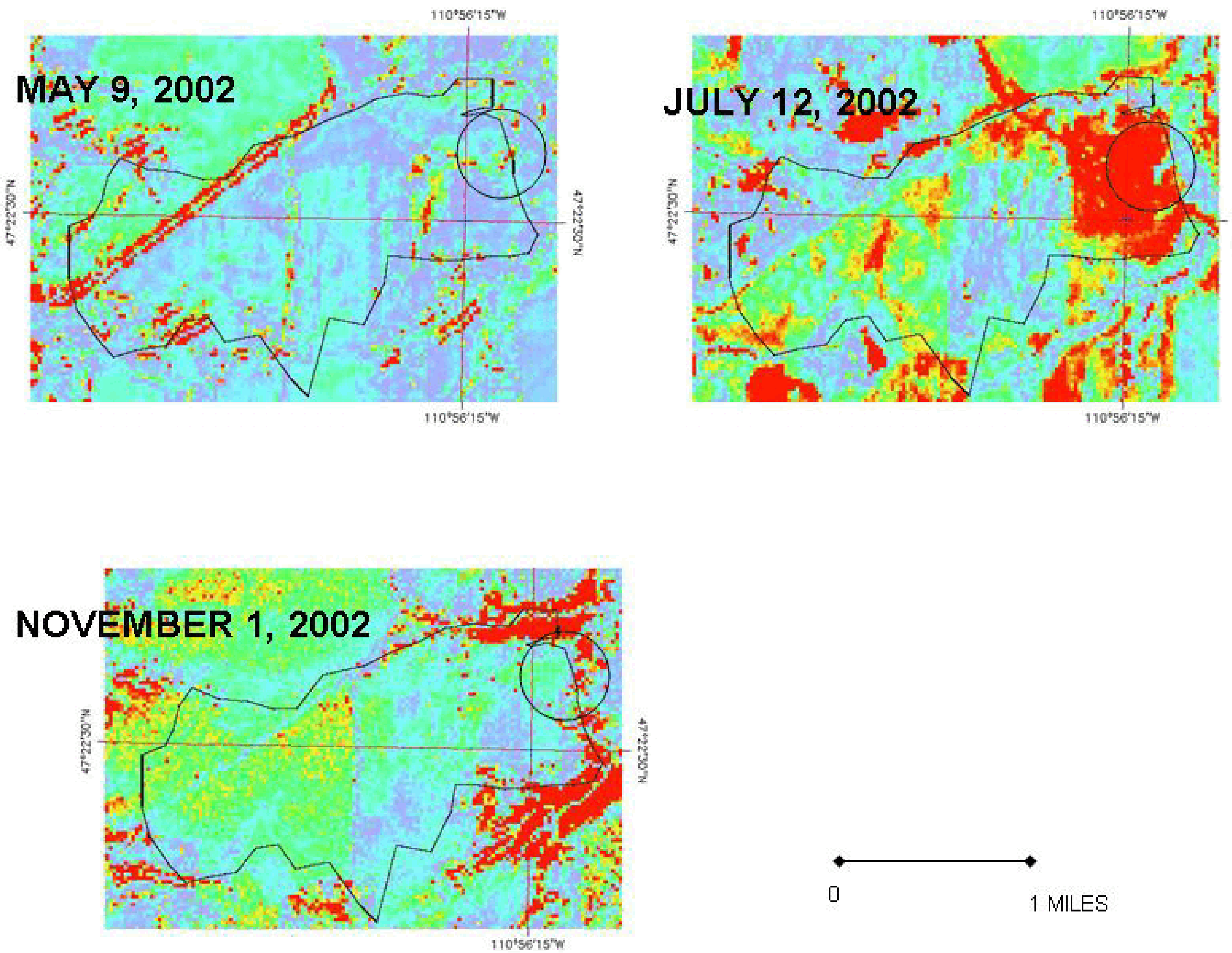


Figure 6.3. Tasseled cap analysis shows growth in the early spring and late fall at one of mines discharge locations.

6.4 Thermal Image Analysis

LandSat ETM+ thermal band was used to detect soil moisture in the study area (figure 6.4). Using the thermal band 6, areas of moist soils appear cooler (light green) on the images. This analysis showed four moist areas (numbered in image) in and around the mine's perimeter, three (area 2,3,4) that didn't appear in any of the previous analysis. After looking at the orthophoto of the area, the moist areas were determined to be depressions on the surface, usually at the upper section of a drainage.

6.5 Conclusion

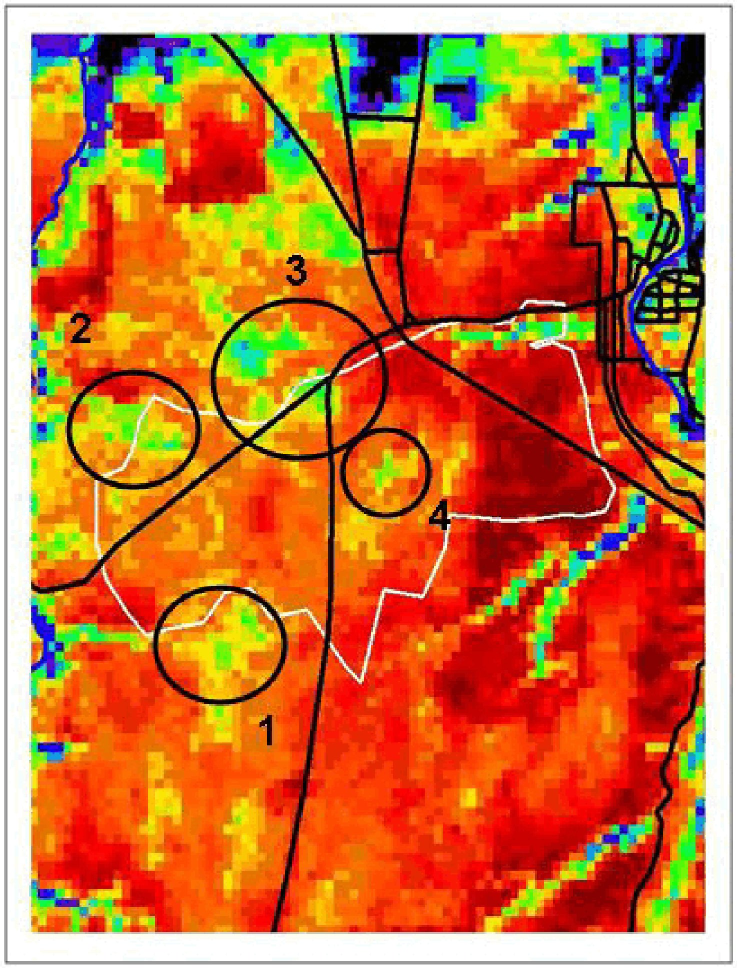
From the analysis mentioned above, several features have been identified that could contribute to the AMD problem in the Belt area. From the change detection study with the LandSat MSS images, changes in land use can be seen that may contribute to surface water infiltration.

The analyses of the LandSat ETM+ images, vegetation appears earlier and remains later in and around the mine drainage areas. The analysis showed no new areas of AMD at this resolution.

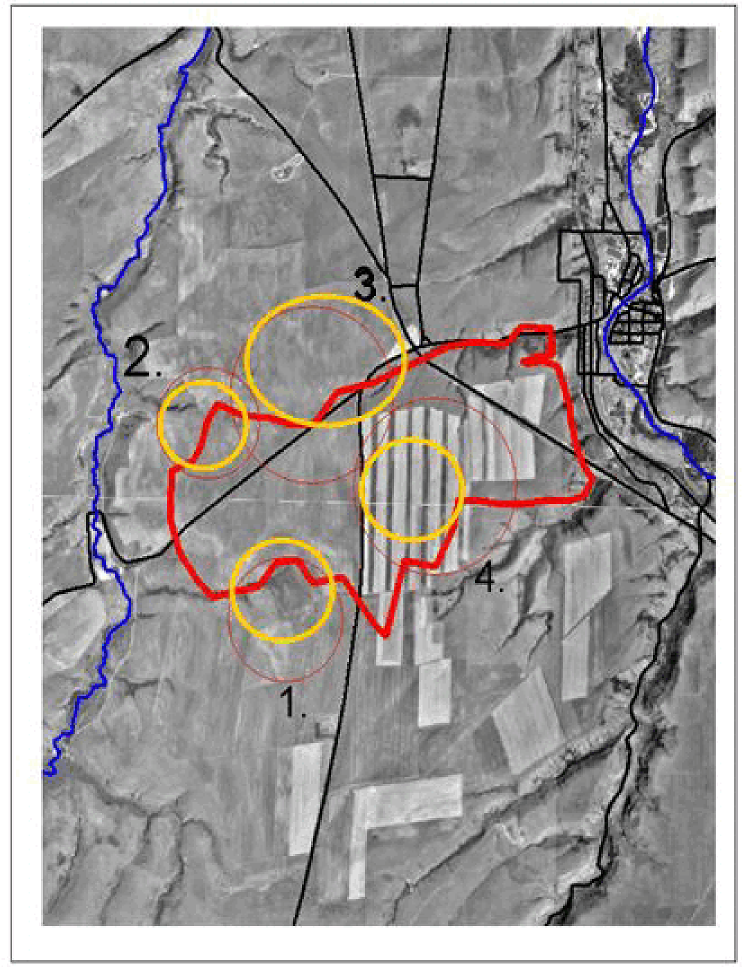
The thermal image analyses show that there are several depressions in and around the study area that hold moisture, which may contribute to surface water infiltration. Some of these depressions are near the fault line north of the mine perimeter.

The spectral analysis of the Belt study area was done with images of 15 - 80 meter resolution. The acquisition of images with better resolution (0.5 - 5m) may allow for more detailed analysis of the study area. Further research into various formats such as from an airborne platform, Airborne Visible InfraRed Imaging Spectrometer (AVIRIS), or Airborne Imaging Spectrometer for Applications (ASIA) would help in the location, monitoring and remediation of the study area.

The National Energy Technology Laboratory (NETL) has developed an airborne platform that uses thermal infrared imaging, Electro-Magnetic Conductivity and Total Field Magnetics to identify faults, acid mine drainage plumes and groundwater discharge zones. Appendix (C) shows the Abstract and Outline of this technique.



THERMAL IMAGE



ORTHOPHOTO

Figure 6.4. Shows areas of moist soils, (circled and numbered) that may contribute to surface water infiltration. The orthophoto.

7.0 3-D MODEL DEVELOPMENT

The 3-D modeling of the Belt area was created using ArcView 3.3 Software. Two extensions were also employed: 3-D Analyst and Spatial Analyst. With these extensions, data can be given an elevation value and viewed in simulated 3-D. This is valuable in order to visualize relationships between data that may not be apparent from a two dimensional map.

This project involved the creation of several new sets of data and incorporating DEMs (digital elevation models), roads, streams, land use, and existing well data in the model. New geologic mapping at 1:24,000-scale was completed and used in the model. Imagery in the form of digital ortho quarter quadrangles (DOQQs) and Tiffs were also used. A shapefile based upon a map from 1946 was created of the Anaconda Mine workings. A grid was created from known elevations of the workings and the shapefile was given the elevation values from this grid. The data from several coal exploration wells were converted into shape files.

Other grids were created using well data from the Bureau's GWIC database. These included a grid of the Madison Formation and the coal horizon. The elevations for the grids were extrapolated from the well data as well as known outcrop elevations. Both grids showed outcrops to the south and a gradual dip in a northerly direction. They also showed some anomalies in elevation (small peaks and valleys).

Another grid was created using the static water level (SWL) of shallow wells in the area.

In ArcView, these various layers can be turned on and off and viewed from many different angles. The views can be exported and saved as image files. The complete 3-D model is contained on the compact disk (CD) that accompanies this report.

8.0 CONCLUSIONS AND RECOMMENDATIONS

Through the course of the past several years, considerable information has been gained on the discharge of water from the Anaconda Mine drain and the local geology and hydrogeology. This study was intended to pull together all of the known geologic and hydrologic information for the area in a format that would enable an evaluation of what data gaps existed, so a workable solution could be found to solve the acid mine drainage problem. The 3-D Model contained on the enclosed CD goes a long way towards this goal. In one graphic display, it is possible to visually see the relationship of the underground mine workings, geologic formations above and below the mine, as well as local water levels.

An approximate estimate of the recharge area for the Anaconda Mine has been identified. Based upon gross estimates of recharge (assuming 10 percent of precipitation infiltrates), it is possible that up to 0.5 cfs (225 gpm) is coming from the overlying Kootenai Formation. This quantity is sufficient to maintain the consistent discharge of 130 gpm coming from this site. However, the lack of seasonal changes in flow are unusual, as it would be expected that with the source of recharge being the overlying alluvial material and Kootenai Formation, the influence of snow melt and precipitation would be seen in flow variations. Likewise, an influence from the recent drought would be more noticeable. It is possible that the numerous springs in the drainages actually control ground-water recharge to the mine workings. That is, when increased precipitation occurs, the excess recharge is carried away by increased flows in the springs, leaving the amount of water entering the deeper system somewhat consistent.

In order to fully define the recharge area and predominant flow patterns, additional monitoring wells are necessary. These wells will also help document the relationship in water levels between the alluvium, Kootenai and Madison Formations. Continued monitoring of discharges from the Anaconda Mine drain and French Coulee Mine drain are also necessary.

In order to accomplish the project goals of identifying recharge to the mine workings, it is recommended that an additional 10 to 12 monitoring wells be installed at the locations shown on figure 8.1. Two or three multiple-depth wells will be installed at each location. These nested wells will be completed in the upper portion of the overlying Kootenai Formation, at a depth similar to that of the mine workings, and into the Madison Formation underneath the mine. Continuous water levels will be collected from each group of wells to determine response to precipitation events and vertical, as well as horizontal gradients.

Continuous monitoring of the discharge from the Anaconda Mine should continue with the location moved closer to the actual discharge point, if possible. A flume should be installed in the French Coulee

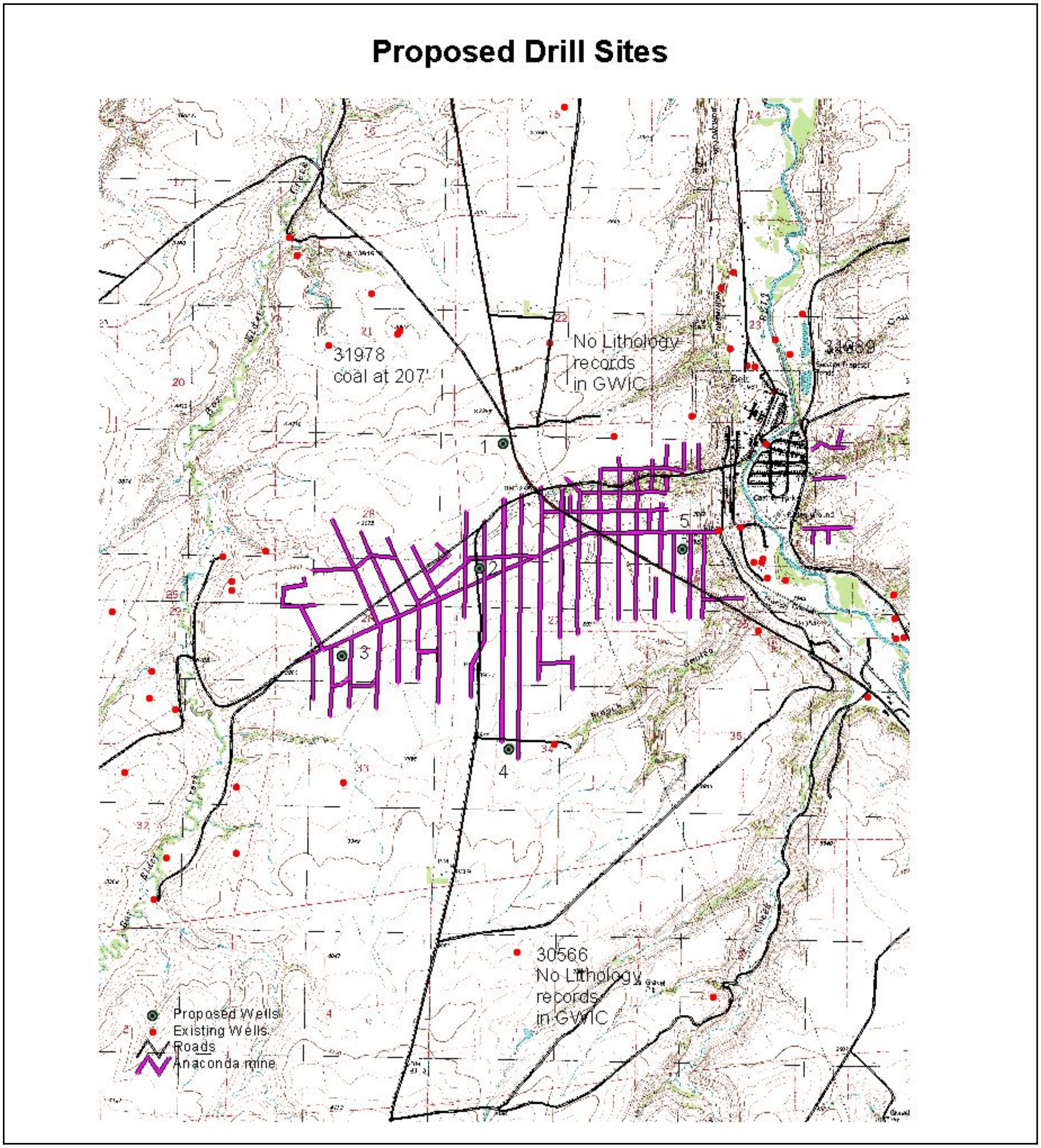


Figure 8.1 Location of proposed monitoring wells.

drainage and flows monitored on a continuous basis.

In addition to the above, measured discharge from springs in the area should be monitored to determine their flow response to precipitation and recharge events. Flow monitoring of the Box Elder Creek drainage should also continue.

Water-quality monitoring and sampling would also be part of a continuing program. Water-quality samples should be collected from the newly installed monitoring wells, plus the key sites discussed in this study.

The new information should then be included in the 3-D model which will help determine the methods necessary to mitigate the discharge of acidic mine water from the Anaconda Mine. These same practices can then be used at other abandoned coal mines with acid drainage problems throughout the Great Falls-Lewistown coal fields.

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APPENDIX A

Inorganic Water Quality Data

Note: Due to laboratory practices during most of 2003 samples for total recoverable concentrations were run at a different time than samples for dissolved concentrations. This practice resulted in different equipment calibrations and resulted in total recoverable sample concentrations that were less than dissolved concentrations at several sites. This was especially apparent where concentrations were near instrument detection limits. Several sites (Anaconda Mine Drain and French Coulee Drain) had considerable precipitates form during the digestion procedure for total recoverable analysis, which possibly resulted in these concentrations being less than dissolved concentrations.

Appendix A
Inorganic Water Quality Data

Belt, MT Project
Water Quality Results
(All concentrations are dissolved, unless otherwise noted)

					PHYSICAL PARAMETERS									Water Type PERCENT MEQ/L					
Analy. Lab	Lab No.	DATE (mm/dd/yy)	TIME (HRS)	Flow (gpm)	FIELD SC (uMHOS)	pH	ORP (MV)	DO (mg/l)	Temp (C)	LAB SC (uMHOS)	pH	Hardness (mg/l)	Alkalinity (mg/l)	Ca	Mg	Na	Fe	HCO3	SO4
Anaconda Mine Drain		**M: 200616**																	
MBMG	2003Q0848	01/30/03	11:30	220	2,290	2.99	627	2.91	9.8	2,285	3.01	652	0	22.0	16.8	1.3	26.5	0.0	100.0
Total Rec	2003Q0849	01/30/03	11:30									677		23.0	16.7	1.4	27.3		
MBMG	2003Q0866	03/15/03	11:15	155	2,220	3.01	626	2.75	10.7	2,280	2.97	699	0	23.2	16.4	1.3	26.3	0.0	99.4
MBMG	2003Q1018	04/22/03	15:45	140	2,260	2.89	639	2.60	7.5	2,265	2.95	669	0	23.7	17.8	1.5	25.0	0.0	100.0
Total Rec	2003Q1019	04/22/03	15:45									633	0	23.6	17.1	1.4	25.7		
MBMG	2003Q1079	05/28/03	18:30	140	2,350	2.84	623	1.80	11.3	2,120	3.03	627	0	22.5	17.9	1.5	24.8	0.0	99.0
Total Rec	2003Q1080	05/28/03	18:30									621	0	22.7	17.4	1.4	25.6		
MBMG	2003Q1163	06/18/03	11:50	148	1,425	2.88	631	2.51	9.9	2,080	2.88	688	0	22.1	16.9	1.3	25.6	0.0	99.5
MBMG	2004Q0029	07/17/03	17:45	140	--	--	--	--	--	2,090	2.79	706	0	23.0	17.2	1.3	23.7	0.0	99.7
Total Rec	2004Q0030	07/17/03	17:45									684		34.6	25.4	1.9	37.0		
MBMG	2004Q0103	08/19/03	16:30	155	2,355	2.58	607	2.10	9.9	2,290	2.80	671	0	21.2	16.8	1.3	25.7	0.0	98.9
Total Rec	2004Q0104	08/19/03	16:30									1,365		33.6	26.5	2.1	36.7		
MBMG	2004Q0147	09/18/03	18:45	155	2,390	2.70	623	1.54	9.9	2,350	2.93	672	0	21.3	15.7	1.2	25.7	0.0	99.7
Total Rec	2004Q0148	09/18/03	18:45									683		32.6	25.3	2.0	39.4		
MBMG	2004Q0241	10/23/03	16:20	140	2,300	2.99	264	1.83	9.9	2,290	3.01	713	0	23.3	15.5	1.2	25.8	0.0	99.8
Total Rec	2004Q0242	10/23/03	16:20									701		34.5	24.5	1.9	38.1		
		Mean		155	2,199	2.86	580	2.26	9.9	2,228	2.93	716	0.0	25.4	19.0	1.5	28.7	0.0	99.6
		Maximum		220	2,390	3.01	639	2.91	11.3	2,350	3.03	1365	0.0	34.6	26.5	2.1	39.4	0.0	100.0
		Minimum		140	1,425	2.58	264	1.54	7.5	2,080	2.79	621	0.0	21.2	15.5	1.2	23.7	0.0	98.9
		Number		9	9	9	9	9	9	9	9	16	11	16	16	16	16	9	9
French Coulee Drain		**M: 200615**																	
MBMG	2003Q0846	01/29/03	14:00	8.0	5,620	2.70	628	4.73	7.0	5,625	2.75	1,158	0.0	9.9	7.0	0.4	41.3	0.0	100.0
Total Rec	2003Q0847	01/29/03	14:00									1,112		9.6	6.9	0.4	43.1		
MBMG	2003Q0865	03/15/03	10:45	7.7	5,030	2.68	650	3.75	7.2	5,150	2.71	1,211	0.0	10.9	7.7	0.4	40.7	0.0	100.0
MBMG	2003Q1020	04/22/03	14:55	9.0	4,660	2.68	659	3.12	9.7	4,800	2.70	1,071	0.0	11.1	8.3	0.5	39.3	0.0	100.0
Total Rec	2003Q1021	04/22/03	14:55									1,062		11.3	8.4	0.6	38.5		
MBMG	2003Q1081	05/28/03	18:00	11.0	4,410	2.62	655	3.54	12.2	3,960	2.78	943	0.0	11.6	9.5	0.9	39.9	0.0	99.2
Total Rec	2003Q1082	05/28/03	18:00									925		11.6	9.4	0.9	39.5		
MBMG	2003Q1164	06/18/03	11:20	8.6	2,820	2.63	653	4.42	12.2	4,030	2.66	1,071	0.0	11.5	9.0	0.7	39.2	0.0	100.0
MBMG	2004Q0031	07/17/03	17:10	10.0	--	--	--	--	--	4,400	2.40	1,205	0.0	11.8	8.9	0.5	38.0	0.0	99.8
Total Rec	2004Q0032	07/17/03	17:10									1,211		19.8	15.0	0.9	63.8		
MBMG	2004Q0095	08/19/03	16:00	8.5	5,180	2.36	639	3.15	14.3	4,810	2.54	1,194	0.0	11.3	8.2	0.5	37.1	0.0	99.1
Total Rec.	2004Q0096	08/19/03										1,128		20.5	15.9	0.9	55.9		
MBMG	2004Q0149	09/18/03	19:05	8.1	5,690	2.41	636	5.97	11.3	5,080	2.76	1,215	0.0	10.9	8.1	0.4	39.1	0.0	99.8
Total Rec	2004Q0150	09/18/03	19:05									1,224		19.0	14.3	0.8	65.4		
MBMG	2004Q00235	10/23/03	15:50	8.5	5,800	2.73	288	3.72	10.3	5,600	2.71	1,254	0.0	9.4	6.7	0.3	40.9	0.0	99.8
Total Rec	2004Q0236	10/23/03	15:50									1,266		16.7	11.9	0.5	70.5		
		Mean		8.8	4,901	2.60	601	4.05	10.5	4,828	2.67	1,141	0.0	12.9	9.7	0.6	45.8	0.0	99.7
		Maximum		11.0	5,800	2.73	659	5.97	14.3	5,625	2.78	1,266	0.0	20.5	15.9	0.9	70.5	0.0	100.0
		Minimum		7.7	2,820	2.36	288	3.12	7.0	3,960	2.40	925	0.0	9.4	6.7	0.3	37.1	0.0	99.1
		Number		9	9	9	9	9	9	9	9	16	9	16	16	16	16	9	9

Appendix A
Inorganic Water Quality Data

Belt, MT Project
Water Quality Results
(All concentrations are dissolved, unless ot

Analy. Lab	Lab No.	DATE (mm/dd/yy)	Ca (mg/l)	Mg (mg/l)	Na (mg/l)	K (mg/l)	Fe (mg/l)	Mn (mg/l)	SiO2 (mg/l)	HCO3 (mg/l)	CO3 (mg/l)	Cl (mg/l)	SO4 (mg/l)	NO3-N (mg/l)	NO2-N (mg/l)	F (mg/l)	Oxygen 18O	Deuterium 2H	Tritium TU	Tritium Pico curies/L
Anaconda Mine Drain		**M: 200616**																		
MBMG	2003Q0848	01/30/03	148	68.6	10.3	3.2	166	0.403	52.6	0.0	0.0	<10	1,920	<1.0	<1.0	<1.0			14.20	44.72
Total Rec	2003Q0849	01/30/03	157	69.2	10.5	3.3	173	0.400												
MBMG	2003Q0866	03/15/03	164	70.4	10.5	3.3	173	0.500	52.5	0.0	0.0	5.8	1,934	<0.5	<0.5	1.83				
MBMG	2003Q1018	04/22/03	153	69.7	10.9	2.8	150	0.363	49.9	0.0	0.0	<10	1,900	<1.0	<1.0	<1.0				
Total Rec	2003Q1019	04/22/03	147	64.6	10.0	2.9	149	0.371												
MBMG	2003Q1079	05/28/03	140	67.5	10.8	2.8	143	0.375	52.5	0.0	0.0	7.5	1,523	<0.5	<0.5	1.87	-18.04		16.00	50.38
Total Rec	2003Q1080	05/28/03	141	65.3	10.2	2.6	148	0.376												
MBMG	2003Q1163	06/18/03	156	72.5	10.7	2.9	168	0.426	53.2	0.0	0.0	4.7	1,606	<0.25	<0.25	0.55				
MBMG	2004Q0029	07/17/03	162	73.3	10.5	3.0	155	0.426	53.0	0.0	0.0	<12.5	1,610	<1.25	<1.25	2.18	-18.22		16.00	50.38
Total Rec	2004Q0030	07/17/03	158	70.4	10.2	2.9	157	0.428												
MBMG	2004Q0103	08/19/03	150	72.0	10.5	3.2	169	0.435	53.8	0.0	0.0	8.6	1,851	<0.5	<0.5	3.71				
Total Rec	2004Q0104	08/19/03	306	146.0	22.3	6.4	310	0.824												
MBMG	2004Q0147	09/18/03	155	69.3	10.2	3.2	174	0.412	57.3	0.0	0.0	<5	1,905	<0.5	<0.5	2.15				
Total Rec	2004Q0148	09/18/03	154	72.5	10.9	3.2	173	0.423												
MBMG	2004Q0241	10/23/03	168	71.2	9.9	3.1	173	0.411	58.5	0.0	0.0	<5	2,025	<0.5	<0.5	1.78				
Total Rec	2004Q0242	10/23/03	164	70.7	10.3	3.2	168	0.416												
		Mean	164	74.6	11	3.25	172	0.44	53.7	0.0	0.0	6.64	1,808	#DIV/0!	#DIV/0!	2.01	-18.13	#DIV/0!	15.40	48.5
		Maximum	306	146.0	22	6.44	310	0.82	58.5	0.0	0.0	8.60	2,025	0	0	3.71	-18.04	0.00	16.00	50.4
		Minimum	140	64.6	10	2.55	143	0.36	49.9	0.0	0.0	4.65	1,523	0	0	0.55	-18.22	0.00	14.20	44.7
		Number	16	16	16	16	16	16	9	9	9	9	9	9	9	9	2	0	3	3
French Coulee Drain		**M: 200615**																		
MBMG	2003Q0846	01/29/03	271	117.0	11.7	5.4	1,050	0.960	101.0	0.0	0.0	<50	7,990	<5.0	<5.0	<5.0			15.30	48.18
Total Rec	2003Q0847	01/29/03	259	113.0	12.0	5.3	1,080	0.900												
MBMG	2003Q0865	03/15/03	284	122.0	12.2	5.4	989	0.988	97.6	0.0	0.0	<50	6,975	<5.0	<5.0	<5.0				
MBMG	2003Q1020	04/22/03	246	111.0	13.5	4.2	808	0.703	90.0	0.0	0.0	<125	6,198	<12.5	<12.5	<12.5				
Total Rec	2003Q1021	04/22/03	244	110.0	14.0	4.2	771	0.694												
MBMG	2003Q1081	05/28/03	208	103.0	17.6	3.4	665	0.531	85.2	0.0	0.0	16.3	4,400	<1	<1	5.84	-17.98		19.50	61.41
Total Rec	2003Q1082	05/28/03	204	101.0	18.0	3.3	647	0.535												
MBMG	2003Q1164	06/18/03	241	114.0	16.6	3.3	761	0.650	89.8	0.0	0.0	<50	5,226	<5	<0.25	<5				
MBMG	2004Q0031	07/17/03	275	126.0	14.4	2.8	821	0.833	103.0	0.0	0.0	<25	5,750	<2.5	<2.5	3.46	-18.04		17.20	54.16
Total Rec	2004Q0032	07/17/03	276	127.0	14.9	3.2	828	0.830												
MBMG	2004Q0095	08/19/03	277	122.0	13.8	4.2	843	0.888	106.0	0.0	0.0	29.6	6,891	<2.5		9.91				
Total Rec.	2004Q0096	08/19/03	254	120.0	13.5	3.3	717	0.838												
MBMG	2004Q0149	09/18/03	279	126.0	13.2	<5	929	0.902	105.4	0.0	0.0	<25	7,133	<2.5	<2.5	6.79				
Total Rec	2004Q0150	09/18/03	279	128.0	13.7	3.6	894	0.921												
MBMG	2004Q00235	10/23/03	293	127.0	10.8	3.7	1,185	1.030	109.0	0.0	0.0	<25	8,152	<2.5	<2.5	7.94				
Total Rec	2004Q0236	10/23/03	296	128.0	10.9	3.5	1,164	1.060												
		Mean	262	118	13.8	3.9	885	0.83	98.6	0.00	0.00	22.95	6,524	#DIV/0!	#DIV/0!	6.79	-18.01	#DIV/0!	17.33	54.6
		Maximum	296	128	18.0	5.4	1,185	1.06	109.0	0.00	0.00	29.60	8,152	0.00	0.00	9.91	-17.98	0.00	19.50	61.4
		Minimum	204	101	10.8	2.8	647	0.53	85.2	0.00	0.00	16.30	4,400	0.00	0.00	3.46	-18.04	0.00	15.30	48.2
		Number	16	16	16	16	16	16	9	9	9	9	9	9	8	9	2	0	3	3

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(All concentrations are dissolved, unless ot

DISSOLVED CONCENTRATION

Analy. Lab	Lab No.	DATE (mm/dd/yy)	Al (ug/l)	Ag (ug/l)	As (ug/l)	B (ug/l)	Cd (ug/l)	Co (ug/l)	Cr (ug/l)	Cu (ug/l)	Li (ug/l)	Mo (ug/l)	Ni (ug/l)	Pb (ug/l)	Se (ug/l)	Sr (ug/l)	Ti (ug/l)	U (ug/l)	Zn (ug/l)
Anaconda Mine Drain		**M: 200616**																	
MBMG	2003Q0848	01/30/03	99,000	<5	<5	<150	6.59	265	28.3	<50	208	<10	618	<10	<5	1,630	1.84	2.79	3,280
Total Rec	2003Q0849	01/30/03	94,100	<10	<10		4.90	320	27.8	<20	213	<100	744	<20	<10	1,810	2.60	<5	3,500
MBMG	2003Q0866	03/15/03	102,000	<10	<10	111	<10	292	31.5	15.7	219	<10	777	<20	<10	1,780	<5	--	2,800
MBMG	2003Q1018	04/22/03	90,700	<5	<5	118	3.96	222	23.3	<10	192	<50	398	<10	<5	1,510	<1	<2.5	2,790
Total Rec	2003Q1019	04/22/03	88,500	<5	<5		4.08	222	24.0	<10	187	<50	667	<10	<5	1,560	1.13	2.53	2,970
MBMG	2003Q1079	05/28/03	90,850	<5	<5	95	3.52	245	27.0	11.4	190	<50	416	<10	<5	1,598	<1	2.94	2,817
Total Rec	2003Q1080	05/28/03	89,233	<5	<5		3.78	259	28.2	17.2	178	<10	443	<10	<5	1,528	<1	2.99	2,671
MBMG	2003Q1163	06/18/03	106,252	<5	<2	102	26.00	250	27.7	10.9	206	<10	450	<10	<5	1,930	<1	3.01	3,121
MBMG	2004Q0029	07/17/03	107,767	<5	<5	97	4.13	255	27.7	<10	210	<10	438	<10	<5	1,700	<1	2.73	3,171
Total Rec	2004Q0030	07/17/03		<5	7.59		27.30	254	27.7	<10	207	<50	772	<10	8.12	1,709	1.86	2.77	3,096
MBMG	2004Q0103	08/19/03	108,575	<5	<5	105	4.68	264	30.0	<10	212	<10	485	<10	<5	1,876	<1	2.74	3,249
Total Rec	2004Q0104	08/19/03		<5	<5		28.30	262	28.7	<10	459	<50	462	<10	<5	3,417	<10	2.73	3,090
MBMG	2004Q0147	09/18/03	116,063	<5	<5	109	5.33	260	38.4	<10	217	<10	454	<10	<5	1,806	<1	2.90	3,283
Total Rec	2004Q0148	09/18/03		<5	<5		32.00	291	28.2	<10	230	<50	436	<10	<5	1,882	<5	2.80	3,618
MBMG	2004Q0241	10/23/03	105,949	<5	<5	<150	4.39	265	29.5	<10	217	<10	430	<10	<5	1,873	<1	2.64	3,229
Total Rec	2004Q0242	10/23/03		<5	<5		4.37	262	29.1	<10	220	<10	459	<10	<5	1,904	<1	2.74	3,276
		Mean	99,916	#DIV/0!	7.6	105	10.9	262	28.6	13.8	223	#DIV/0!	528	#DIV/0!	8.12	1,845	1.86	2.79	3,123
		Maximum	116,063	0.0	7.6	118	32.0	320	38.4	17.2	459	0.00	777	0.00	8.12	3,417	2.60	3.01	3,618
		Minimum	88,500	0.0	7.6	95	3.5	222	23.3	10.9	178	0.00	398	0.00	8.12	1,510	1.13	2.53	2,671
		Number	12	16	16	9	16	16	16	16	16	16	16	16	16	16	16	16	16
French Coulee Drain		**M: 200615**																	
MBMG	2003Q0846	01/29/03	505,000	<10	65.6	<300	16.80	368	131.0	<200	684	<100	974	<20	<10	2,720	<10	16.00	5,120
Total Rec	2003Q0847	01/29/03	481,000	<10	61.6		6.90	470	123.0	46.8	697	<100	927	<20	<10	2,860	2.90	15.80	5,210
MBMG	2003Q0865	03/15/03	470,000	<10	51.8	178	10.70	363	130.0	97.5	659	<50	1,080	<20	<10	2,880	<25	--	4,090
MBMG	2003Q1020	04/22/03	402,000	<10	29.5	<300	<10	287	95.4	93.9	547	<100	819	<20	<10	2,520	<10	12.20	3,820
Total Rec	2003Q1021	04/22/03	397,000	<10	29.6		<10	267	92.2	86.0	540	<100	830	<20	<10	2,500	<10	12.10	3,860
MBMG	2003Q1081	05/28/03	305,844	<10	24.1	<300	<10	240	80.3	42.9	415	<100	356	<20	<10	2,119	<10	14.00	2,845
Total Rec	2003Q1082	05/28/03	304,070	<10	25.0		25.80	257	85.3	45.9	419	<100	406	<20	<10	2,030	<10	14.80	2,679
MBMG	2003Q1164	06/18/03	368,398	<5	27.5	<150	33.70	227	80.7	31.3	488	<50	778	<10	<5	2,592	<5	15.50	3,446
MBMG	2004Q0031	07/17/03	422,685	<10	28.3	<300	<10	240	92.0	31.0	589	<100	344	<20	<10	2,974	<10	16.30	4,245
Total Rec	2004Q0032	07/17/03		<5	29.5		<10	249	93.3	30.0	598	<50	345	<10	<5	2,954	<10	16.80	4,404
MBMG	2004Q0095	08/19/03	467,327	<10	31.7	<300	54.50	330	123.0	41.6	640	<100	1,074	<20	<10	3,035	<10	15.90	4,819
Total Rec.	2004Q0096	08/19/03		78.30	31.7		50.40	320	121.0	41.4	654	<100	546	<20	<10	2,756	<10	15.80	4,246
MBMG	2004Q0149	09/18/03	473,245	<10	27.7	<300	55.00	339	125.0	41.2	667	<100	539	<20	<10	3,154	<100	16.40	5,082
Total Rec	2004Q0150	09/18/03		<10	26.8		58.60	402	122.0	38.5	696	<100	551	<20	<10	3,116	<10	16.00	5,182
MBMG	2004Q00235	10/23/03	595,625	<10	45.1	<300	<10	406	152.0	26.7	714	<100	556	<20	<10	3,410	<10	19.50	5,787
Total Rec	2004Q0236	10/23/03		<10	44.0		<10	399	152.0	39.6	758	<100	577	<20	<10	3,312	<100	18.10	5,723
		Mean	432,683	78.3	36.2	178	34.7	323	112.4	49.0	610	#DIV/0!	669	#DIV/0!	#DIV/0!	2,808	2.90	15.68	4,410
		Maximum	595,625	78.3	65.6	178	58.6	470	152.0	97.5	758	0.00	1,080	0.00	0.00	3,410	2.90	19.50	5,787
		Minimum	304,070	78.3	24.1	178	6.9	227	80.3	26.7	415	0.00	344	0.00	0.00	2,030	2.90	12.10	2,679
		Number	12	16	16	9	16	16	16	16	16	16	16	16	16	16	16	16	16

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Water Quality Results
(All concentrations are dissolved, unless otherwise noted)

Analy. Lab	Lab No.	DATE (mm/dd/yy)	TIME (HRS)	Flow (gpm)	PHYSICAL PARAMETERS FIELD SC (uMHOS)	pH	ORP (MV)	DO (mg/l)	Temp (C)	LAB SC (uMHOS)	pH	Hardness (mg/l)	Alkalinity (mg/l)	Water Type PERCENT MEQ/L Ca	Mg	Na	Fe	HCO3	SO4
Highway Drain		**M:200617**																	
MBMG	2003Q0850	01/30/03	14:10		610	7.79	82	11.09	3.5	659	7.93	327	283	46.3	46.4	6.0	0.3	74.8	20.0
Total Rec	2003Q0851	01/30/03	14:10									326		46.7	44.6	5.9	1.4		
MBMG	2003Q0863	03/15/03	13:15		440	8.17	144	10.9	4.1	494	7.88	254	212	48.7	43.3	5.7	0.6	82.1	15.9
MBMG	2003Q1024	04/22/03	14:00		605	7.78	114	10.8	8.6	607	7.82	307	265	46.6	46.2	6.0	0.1	75.4	19.3
Total Rec	2003Q1025	04/22/03	14:00									324		46.0	46.0	5.9	0.9		
MBMG	2003Q1083	05/28/03	17:25		740	8.13	50	9.05	13.6	784	7.71	376	292	45.7	47.2	5.9	0.0	70.0	26.2
Total Rec	2003Q1084	05/28/03	17:25									397		45.7	46.7	5.4	1.0		
MBMG	2003Q1165	06/17/03	17:45		460	8.07	42	11.05	15.1	700	7.78	416	311	44.2	49.2	5.4	0.0	70.8	25.7
MBMG	2004Q0027	07/17/03	14:50	1.8	--	--	--	--	--	1,410	7.80	803	338	44.7	50.0	4.2	0.2	40.2	56.7
Total Rec	2004Q0028	07/17/03	14:50									791		42.9	49.6	4.0	2.7		
MBMG	2004Q0099	08/19/03	17:45	0.6	790	7.66	304	9.6	10.6	1,510	7.69	1,004	288	42.5	51.9	4.1	0.5	26.9	68.8
Total Rec	2004Q0100	08/19/03										927		42.7	50.5	4.4	1.4		
MBMG	2004Q0151	09/19/03	10:05	5.8	860	7.74	116	9.57	9.3	1,020	8.13	498	323	43.4	50.2	5.6	0.0	59.3	37.9
Total Rec	2004Q0152	09/19/03	10:05									453		43.9	43.2	6.0	1.1		
		Mean		2.7	644	7.91	122	10.29	9.3	898	7.84	514	289	45.0	47.5	5.3	0.7	62.4	33.8
		Maximum		5.8	860	8.17	304	11.09	15.1	1,510	8.13	1004	338	48.7	51.9	6.0	2.7	82.1	68.8
		Minimum		0.6	440	7.66	42	9.05	3.5	494	7.69	254	212	42.5	43.2	4.0	0.0	26.9	15.9
		Number		3	8	8	8	8	8	8	8	14	8	14	14	14	14	8	8
HWD-Seep		**M:204710**																	
MBMG	2004Q0025	07/17/03	14:15	0.3	--	--	--	--	--	3,340	7.05	2,609	274	40.8	55.1	3.3	0.1	10.6	84.9
Total Rec	2004Q0026	07/17/03	14:15									2,628		41.0	55.2	3.5	0.0		
MBMG	2004Q0090	08/19/03	18:10	0.2	--	--	--	--	--	3,350	7.62	2,518	405	40.6	55.0	3.6	0.1	15.0	81.1
Total Rec	2004Q0213	08/19/03										2,567		39.2	56.2	3.9	0.1		
MBMG	2004Q0153	09/19/03	10:30	0.2	3,510	7.40	210	9.11	10.4	3,520	7.68	2,563	334	41.3	54.5	3.5	0.0	12.5	82.3
Total Rec	2004Q0154	09/18/03	10:30									2,557		40.9	54.6	3.7	0.1		
		Mean		0.2	3,510	7.40	210	9.11	10.4	3,403	7.45	2,574	338	40.7	55.1	3.6	0.0	12.7	82.8
		Maximum		0.3	3,510	7.40	210	9.11	10.4	3,520	7.68	2,628	405	41.3	56.2	3.9	0.1	15.0	84.9
		Minimum		0.2	3,510	7.40	210	9.11	10.4	3,340	7.05	2,518	274	39.2	54.5	3.3	0.0	10.6	81.1
		Number		3	3	3	3	3	3	3	3	6	3	6	6	6	6	3	3

Appendix A
Inorganic Water Quality Data

Belt, MT Project
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(All concentrations are dissolved, unless ot

Analy. Lab	Lab No.	DATE (mm/dd/yy)	Ca (mg/l)	Mg (mg/l)	Na (mg/l)	K (mg/l)	Fe (mg/l)	Mn (mg/l)	SiO2 (mg/l)	HCO3 (mg/l)	CO3 (mg/l)	Cl (mg/l)	SO4 (mg/l)	NO3-N (mg/l)	NO2-N (mg/l)	F (mg/l)	Oxygen 18O	Deuterium 2H	Tritium TU	Tritium Pico curies/L
Highway Drain		**M:200617**																		
MBMG	2003Q0850	01/30/03	65.3	39.8	9.7	1.7	0.38	0.068	9.0	345	0.0	2.5	73	4.09	<0.05	0.52			26.00	81.87
Total Rec	2003Q0851	01/30/03	66.7	38.7	9.6	1.7	1.90	0.100												
MBMG	2003Q0863	03/15/03	53.8	29.0	7.2	2.7	0.65	0.040	8.6	259	0.0	2.6	40	3.78	<0.05	0.56				
MBMG	2003Q1024	04/22/03	61.7	37.1	9.1	1.8	0.16	0.066	8.2	323	0.0	2.5	65	3.70	<0.05	0.67				
Total Rec	2003Q1025	04/22/03	64.8	39.3	9.5	1.8	1.15	0.064												
MBMG	2003Q1083	05/28/03	74.1	46.4	11.0	2.4	0.05	0.083	9.6	356	0.0	4.0	105	2.41	<0.05	0.63	-16.52		23.60	74.32
Total Rec	2003Q1084	05/28/03	78.6	48.7	10.6	2.3	1.59	0.083												
MBMG	2003Q1165	06/17/03	78.8	53.2	11.0	3.0	0.04	0.093	10.6	379	0.0	4.8	108	1.88	<0.05	0.61				
MBMG	2004Q0027	07/17/03	152.0	103.0	16.5	4.6	0.70	0.147	13.3	412	0.0	14.8	457	1.22	<0.25	0.52				
Total Rec	2004Q0028	07/17/03	147.0	103.0	15.8	4.4	8.45	0.212												
MBMG	2004Q0099	08/19/03	181.0	134.0	20.1	5.8	2.12	0.196	12.4	351	0.0	26.1	706	1.04		1.87				
Total Rec	2004Q0100	08/19/03	170.0	122.0	20.2	5.8	5.26	0.203												
MBMG	2004Q0151	09/19/03	92.5	64.8	13.6	2.3	0.04	0.108	12.4	393	0.0	7.1	198	1.16	<0.1	0.45				
Total Rec	2004Q0152	09/19/03	86.3	57.6	13.6	2.2	1.97	0.118												
		Mean	98.0	65.5	12.7	3.0	1.75	0.11	10.5	352	0.0	8.1	219	2.41	#DIV/0!	0.73	-16.52	#DIV/0!	24.80	78.1
		Maximum	181.0	134.0	20.2	5.8	8.45	0.21	13.3	412	0.0	26.1	706	4.09	0.00	1.87	-16.52	0.00	26.00	81.9
		Minimum	53.8	29.0	7.2	1.7	0.04	0.04	8.2	259	0.0	2.5	40	1.04	0.00	0.45	-16.52	0.00	23.60	74.3
		Number	14	14	14	14	14	14	8	8	8	8	8	8	7	8	1	0	2	2
HWD-Seep		**M:204710**																		
MBMG	2004Q0025	07/17/03	445.0	364.0	41.7	11.0	0.89	0.035	10.9	334	0.0	79.2	2,116	1.91	<0.25	<0.25	-17.36		31.90	100.45
Total Rec	2004Q0026	07/17/03	451.0	365.0	43.6	11.6	1.20	0.039												
MBMG	2004Q0090	08/19/03	428.0	352.0	43.9	11.5	0.53	0.033	10.7	494	0.0	74.8	2,105	--	--	--				
Total Rec	2004Q0213	08/19/03	423.0	367.0	47.7	12.0	0.54	0.035												
MBMG	2004Q0153	09/19/03	443.0	354.0	43.2	11.2	0.44	0.042	10.0	408	0.0	83.8	2,105	1.95	<0.5	4.63				
Total Rec	2004Q0154	09/18/03	439.0	355.0	45.9	12.7	0.55	0.043												
		Mean	438.2	359.5	44.3	11.7	0.69	0.038	10.5	412	0.0	79.3	2,109	1.93	#DIV/0!	4.63	-17.4	#DIV/0!	31.9	100.5
		Maximum	451.0	367.0	47.7	12.7	1.20	0.043	10.9	494	0.0	83.8	2,116	1.95	0	4.63	-17.4	0.0	31.9	100.5
		Minimum	423.0	352.0	41.7	11.0	0.44	0.033	10.0	334	0.0	74.8	2,105	1.91	0	4.63	-17.4	0.0	31.9	100.5
		Number	6	6	6	6	6	6	3	3	3	3	3	3	3	3	1	0	1	1

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DISSOLVED CONCENTRATION

Analy. Lab	Lab No.	DATE (mm/dd/yy)	Al (ug/l)	Ag (ug/l)	As (ug/l)	B (ug/l)	Cd (ug/l)	Co (ug/l)	Cr (ug/l)	Cu (ug/l)	Li (ug/l)	Mo (ug/l)	Ni (ug/l)	Pb (ug/l)	Se (ug/l)	Sr (ug/l)	Ti (ug/l)	U (ug/l)	Zn (ug/l)
Highway Drain		**M:200617**																	
MBMG	2003Q0850	01/30/03	68	<1	<1	31.5	1.2	<2	<2	<2	21	<10	3.7	<2	2.43	442	<1	4.57	3.7
Total Rec	2003Q0851	01/30/03	363	<1	<1		<1	<2	<2	<2	20	<10	<2	<2	1.70	503	3.60	4.66	19.3
MBMG	2003Q0863	03/15/03	136	<1	<1	<30	<1	<2	<2	<2	18	<10	2.8	<2	2.02	342	<5	--	5.3
MBMG	2003Q1024	04/22/03	87	<1	<1	<30	<1	<2	<2	<2	19	<10	2.3	<2	1.82	436	<1	4.06	2.3
Total Rec	2003Q1025	04/22/03	167	<1	<1		<1	<2	<2	<2	20	<10	2.5	<2	1.63	452	<1	4.21	18.1
MBMG	2003Q1083	05/28/03	113	<1	<1	<30	<1	<2	2.0	<2	25	<10	3.2	<2	1.25	547	<1	4.81	3.9
Total Rec	2003Q1084	05/28/03	240	<1	<1		<1	<2	<2	<2	23	<10	3.1	<2	1.44	532	<1	5.29	24.7
MBMG	2003Q1165	06/17/03	137	<1	<1	45.3	<1	<2	<2	<2	27	<10	3.4	<2	1.35	586	<1	4.86	3.5
MBMG	2004Q0027	07/17/03	<30	<5	<5	33.4	<1	<2	<10	<5	40	<10	4.1	<10	<5	852	<1	6.21	33.7
Total Rec	2004Q0028	07/17/03		<5	<5		<5	<10	<10	<10	38	<50	<10	<10	<5	858	5.93	5.99	88.8
MBMG	2004Q0099	08/19/03	<30	<1	<1	59.5	<1	3.2	<2	<2	47	<10	10.4	<2	3.80	1,041	<1	8.44	65.7
Total Rec	2004Q0100	08/19/03		6.56	<1		<1	3.5	<2	<2	49	<10	10.5	<2	3.40	1,045	4.19	8.80	106.3
MBMG	2004Q0151	09/19/03	46	<1	<1	51.7	<1	<2	<2	<2	30	<10	4.7	<2	2.10	621	<1	5.45	4.8
Total Rec	2004Q0152	09/19/03		<1	1.24		<1	<2	<2	<2	30	<10	7.6	<2	2.43	594	1.42	5.44	21.3
		Mean	151	7	1.24	44.3	1.2	3.3	2.0	#DIV/0!	29	#DIV/0!	4.9	#DIV/0!	2.11	632	3.79	5.60	28.7
		Maximum	363	7	1.24	59.5	1.2	3.5	2.0	0.0	49	0.0	10.5	0	3.80	1045	5.93	8.80	106.3
		Minimum	46	7	1.24	31.5	1.2	3.2	2.0	0.0	18	0.0	2.3	0	1.25	342	1.42	4.06	2.3
		Number	11	14	14	8	14	14	14	14	14	14	14	14	14	14	14	14	14
HWD-Seep		**M:204710**																	
MBMG	2004Q0025	07/17/03	<150	<5	<5	<150	<5	<10	<10	<10	69	<50	<10	<10	<5	2,224	<5	22.00	254
Total Rec	2004Q0026	07/17/03		<5	<5		<5	<10	<10	<10	72	<50	13.0	<10	<5	2,391	<10	21.80	255
MBMG	2004Q0090	08/19/03	322		<50	<150	<5	<10	<50	<25	80	<50	<10	<50	<75	2,174	<5	--	337
Total Rec	2004Q0213	08/19/03		<5	<5		<5	<10	<10	<10	97	<50	13.2	<10	<5	2,232	<10	21.70	284
MBMG	2004Q0153	09/19/03	<300	<10	<10	<300	<10	<20	<20	<20	73	<100	<20	<20	<10	2,355	<10	23.30	161
Total Rec	2004Q0154	09/18/03		<10	<10		<10	<20	<20	<20	84	<100	29.9	<20	<10	2,384	<10	23.10	160
		Mean	322	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	79	#DIV/0!	18.7	#DIV/0!	#DIV/0!	2,293	#DIV/0!	22.38	242
		Maximum	322	0	0	0	0.0	0.0	0.0	0.0	97	0	29.9	0	0	2,391	0.00	23.30	337
		Minimum	322	0	0	0	0.0	0.0	0.0	0.0	69	0	13.0	0	0	2,174	0.00	21.70	160
		Number	3	5	6	3	6	6	6	6	6	6	6	6	6	6	6	6	6

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Belt, MT Project
Water Quality Results
(All concentrations are dissolved, unless otherwise noted)

Analy. Lab	Lab No.	DATE (mm/dd/yy)	TIME (HRS)	Flow (gpm)	PHYSICAL PARAMETERS FIELD SC (uMHOS)	pH	ORP (MV)	DO (mg/l)	Temp (C)	LAB SC (uMHOS)	pH	Hardness (mg/l)	Alkalinity (mg/l)	Water Type PERCENT MEQ/L Ca	Mg	Na	Fe	HCO3	SO4
Box Elder Creek, Harris Ranch			**M:200614**																
MBMG	2003Q0844	01/29/03	16:15	300	615	7.89	267	15.20	0.4	685	8.10	341	316	48.8	44.7	5.8	0.0	80.9	12.3
Total Rec	2003Q0845	01/29/03	16:15									332		49.6	43.7	5.8	0.1		
MBMG	2003Q0864	03/15/03	12:00	600	585	8.15	365	10.10	3.5	595	8.06	339	289	53.8	38.0	5.4	0.1	77.9	15.4
MBMG	2003Q1022	04/22/03	16:41		670	8.69	306	11.74	18.6	665	8.29	350	318	49.6	43.0	6.3	0.0	80.5	14.1
Total Rec	2003Q1023	04/22/03	16:41									336		49.4	43.0	6.4	0.1		
		Mean		450	623	8.24	313	12.35	7.5	648	8.15	340	308	50.2	42.5	5.9	0.1	79.8	13.9
		Maximum		600	670	8.69	365	15.20	18.6	685	8.29	350	318	53.8	44.7	6.4	0.1	80.9	15.4
		Minimum		300	585	7.89	267	10.10	0.4	595	8.06	332	289	48.8	38.0	5.4	0.0	77.9	12.3
		Number		2	3	3	3	3	3	3	3	5	3	5	5	5	5	3	3
Upper Box Elder Creek, Larson Ranch				**M:203450**															
MBMG	2003Q1085	05/28/03	15:50	103	675	8.10	240	7.32	19.0	680	8.13	336	287	53.5	38.6	6.7	0.0	77.6	16.6
Total Rec	2003Q1086	05/28/03	15:50									339		53.3	38.6	6.6	0.2		
MBMG	2003Q1166	06/17/03	17:15	72	400	7.89	299	7.81	18.2					53.2	39.6	6.2	0.6		
MBMG	2004Q0033	07/17/03	12:20	6						835	6.44	322	236	48.5	43.1	7.4	0.0	73.4	17.4
Total Rec	2004Q0034	07/17/03	12:20									361		49.6	37.6	6.6	1.0		
MBMG	2004Q0097	08/19/03	11:20	8	620	7.85	253	7.93	15.6	625	8.09	322	271	49.3	43.4	6.2	0.0	80.4	12.6
Total Rec	2004Q0098	08/19/03	11:20									320		49.6	42.2	6.2	0.9		
MBMG	2004Q0155	09/18/03	18:05	14	620	7.58	245	9.13	8.7	700	7.88	328	270	49.5	43.4	6.0	0.0	82.3	12.9
Total Rec	2004Q0156	09/18/03	18:05									317		48.2	43.4	6.3	0.9		
MBMG	2004Q0237	10/23/03	11:15	14	660	7.71	66	6.95	9.3	730	7.89	356	293	51.2	41.9	5.9	0.0	74.4	13.5
Total Rec	2004Q0238	10/23/03	11:15									360		51.0	41.7	5.9	0.5		
		Mean		36	595	7.83	221	7.83	14.2	714	7.69	336	271	50.6	41.2	6.4	0.4	77.6	14.6
		Maximum		103	675	8.10	299	9.13	19.0	835	8.13	361	293	53.5	43.4	7.4	1.0	82.3	17.4
		Minimum		6	400	7.58	66	6.95	8.7	625	6.44	317	236	48.2	37.6	5.9	0.0	73.4	12.6
		Number		6	5	5	5	5	5	5	5	10	5	11	11	11	11	5	5
Lower Box Elder Creek			**M:203451**																
MBMG	2003Q1087	05/28/03	16:45	112	680	8.20	236	5.73	24.5	645	8.02	342	291	50.7	42.0	6.1	0.0	81.6	14.4
Total Rec	2003Q1088	05/28/03	16:45									342		50.4	42.6	5.9	0.1		
MBMG	2003Q1162	06/17/03	16:05	22	395	8.15	286	7.88	23.3	590	8.21	357	294	49.2	47.8	5.7	0.0	83.0	13.4
		Mean		67	538	8.18	261	6.81	23.9	618	8.12	347	293	50.1	44.1	5.9	0.1	82.3	13.9
		Maximum		112	680	8.20	286	7.88	24.5	645	8.21	357	294	50.7	47.8	6.1	0.1	83.0	14.4
		Minimum		22	395	8.15	236	5.73	23.3	590	8.02	342	291	49.2	42.0	5.7	0.0	81.6	13.4
		Number		2	2	2	2	2	2	2	2	3	2	3	3	3	3	2	2

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Belt, MT Project
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(All concentrations are dissolved, unless ot

Analy. Lab	Lab No.	DATE (mm/dd/yy)	Ca (mg/l)	Mg (mg/l)	Na (mg/l)	K (mg/l)	Fe (mg/l)	Mn (mg/l)	SiO2 (mg/l)	HCO3 (mg/l)	CO3 (mg/l)	Cl (mg/l)	SO4 (mg/l)	NO3-N (mg/l)	NO2-N (mg/l)	F (mg/l)	Oxygen 18O	Deuterium 2H	Tritium TU	Tritium Pico curies/L
Box Elder Creek, Harris Ranch																				
MBMG	2003Q0844	01/29/03	71.3	39.7	9.7	1.7	0.04	0.003	9.8	386	0.0	6.1	46	4.83	<0.05	0.37			18.60	58.57
Total Rec	2003Q0845	01/29/03	70.8	37.8	9.5	1.6	0.10	0.005												
MBMG	2003Q0864	03/15/03	79.4	34.1	9.3	6.8	0.10	0.066	10.3	353	0.0	9.6	55	3.06	<0.05	0.33				
MBMG	2003Q1022	04/22/03	75.1	39.5	11.0	2.9	0.04	0.012	4.4	388	0.0	8.3	53	2.41	--	0.48				
Total Rec	2003Q1023	04/22/03	71.9	38.0	10.7	2.8	0.08	0.015												
		Mean	73.7	37.8	10.0	3.1	0.07	0.020	8.2	375	0.0	8.0	51	3.43	#DIV/0!	0.39			18.60	58.6
		Maximum	79.4	39.7	11.0	6.8	0.10	0.066	10.3	388	0.0	9.6	55	4.83	0.00	0.48			18.60	58.6
		Minimum	70.8	34.1	9.3	1.6	0.04	0.003	4.4	353	0.0	6.1	46	2.41	0.00	0.33			18.60	58.6
		Number	5	5	5	5	5	5	3	3	3	3	3	3	3	3			1	1
Upper Box Elder Creek, Larson Ranch																				
MBMG	2003Q1085	05/28/03	78.2	34.2	11.2	2.9	0.04	0.052	9.2	351	0.0	7.9	59	2.51	<0.05	0.40	-17.11		20.20	63.61
Total Rec	2003Q1086	05/28/03	78.7	34.5	11.1	2.9	0.34	0.074												
MBMG	2003Q1166	06/17/03	84.4	38.1	11.3	2.6	0.05	0.032	12.8											
MBMG	2004Q0033	07/17/03	68.2	36.8	11.9	2.4	0.03	0.024	11.8	287	0.0	8.8	54	4.59	0.11	0.37				
Total Rec	2004Q0034	07/17/03	78.4	40.1	11.9	2.5	1.47	0.199												
MBMG	2004Q0097	08/19/03	68.6	36.6	9.9	2.2	0.04	0.023	12.1	330	0.0	7.1	41	3.41	--	0.51			19.80	62.35
Total Rec	2004Q0098	08/19/03	69.3	35.7	10.0	2.4	1.16	0.106												
MBMG	2004Q0155	09/18/03	69.9	37.2	9.7	2.5	0.03	0.046	11.7	329	0.0	7.0	40	1.33	<0.05	0.43				
Total Rec	2004Q0156	09/18/03	66.9	36.5	10.0	2.7	1.18	0.100												
MBMG	2004Q0237	10/23/03	78.4	38.9	10.3	2.3	0.03	0.042	11.8	358	0.0	7.1	51	9.98	<0.05	0.58				
Total Rec	2004Q0238	10/23/03	79.3	39.3	10.5	2.4	0.68	0.080												
		Mean	74.6	37.1	10.7	2.5	0.46	0.07	11.6	331	0.0	7.57	49	4.36	0.11	0.46	-17.11	#DIV/0!	20.00	63.0
		Maximum	84.4	40.1	11.9	2.9	1.47	0.20	12.8	358	0.0	8.76	59	9.98	0.11	0.58	-17.11	0.00	20.20	63.6
		Minimum	66.9	34.2	9.7	2.2	0.03	0.02	9.2	287	0.0	6.96	40	1.33	0.11	0.37	-17.11	0.00	19.80	62.4
		Number	11	11	11	11	11	11	6	5	5	5	5	5	5	5	1	0	2	2
Lower Box Elder Creek																				
MBMG	2003Q1087	05/28/03	74.8	37.6	10.4	2.7	0.06	0.065	12.8	355	0.0	6.1	49	1.22	0.07	0.46	-16.74		20.30	63.92
Total Rec	2003Q1088	05/28/03	74.3	38.1	10.0	2.5	0.14	0.061												
MBMG	2003Q1162	06/17/03	75.7	40.9	10.1	2.3	0.04	0.035	16.7	359	0.0	5.5	46	0.99	<0.05	0.46				
		Mean	74.9	38.9	10.2	2.5	0.08	0.054	14.8	357	0.0	5.79	47	1.11	0.07	0.46	-16.7	#DIV/0!	20.3	63.9
		Maximum	75.7	40.9	10.4	2.7	0.14	0.065	16.7	359	0.0	6.07	49	1.22	0.07	0.46	-16.7	0.0	20.3	63.9
		Minimum	74.3	37.6	10.0	2.3	0.04	0.035	12.8	355	0.0	5.50	46	0.99	0.07	0.46	-16.7	0.0	20.3	63.9
		Number	3	3	3	3	3	3	2	2	2	2	2	2	2	2	1	0	1	1

Appendix A
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(All concentrations are dissolved, unless ot

DISSOLVED CONCENTRATION

Analy. Lab	Lab No.	DATE (mm/dd/yy)	Al (ug/l)	Ag (ug/l)	As (ug/l)	B (ug/l)	Cd (ug/l)	Co (ug/l)	Cr (ug/l)	Cu (ug/l)	Li (ug/l)	Mo (ug/l)	Ni (ug/l)	Pb (ug/l)	Se (ug/l)	Sr (ug/l)	Ti (ug/l)	U (ug/l)	Zn (ug/l)
Box Elder Creek, Harris Ranch																			
MBMG	2003Q0844	01/29/03	<30	<1	<1	<30	1.1	<2	<2	<2	19	<10	3.0	<2	1.10	390	1.16	3.52	<2
Total Rec	2003Q0845	01/29/03	64	<1	<1		<1	<2	<2	<2	17	<10	<2	<2	<1	430	2.10	3.24	17.0
MBMG	2003Q0864	03/15/03	<30	<1	1.31	<30	<1	<2	2.0	<2	18	<10	3.1	<2	1.35	379	<5	--	<2
MBMG	2003Q1022	04/22/03	<30	<1	<1	<30	<1	<2	<2	<2	17	<10	<2	<2	<1	412	<1	2.98	<2
Total Rec	2003Q1023	04/22/03	<30	<1	<1		<1	<2	<2	<2	16	<10	2.3	<2	<1	401	1.12	2.92	8.1
		Mean	64	#DIV/0!	1.31	#DIV/0!	1.1	#DIV/0!	2.0	#DIV/0!	17	#DIV/0!	2.8	#DIV/0!	1.23	402	1.46	3.17	12.6
		Maximum	64	0.0	1.31	0.0	1.1	0.0	2.0	0.0	19	0.0	3.1	0.00	1.35	430	2.10	3.52	17.0
		Minimum	64	0.0	1.31	0.0	1.1	0.0	2.0	0.0	16	0.0	2.3	0.00	1.10	379	1.12	2.92	8.1
		Number	5	5	5	3	5	5	5	5	5	5	5	5	5	5	5	5	5
Upper Box Elder Creek, Larson Ranch																			
MBMG	2003Q1085	05/28/03	<30	<1	1.04	<30	<1	<2	2.8	<2	15	<10	2.1	<2	<1	394	<1	2.19	<2
Total Rec	2003Q1086	05/28/03	80	<1	1.22		<1	<2	<2	<2	15	<10	2.1	<2	<1	383	2.20	2.35	7.7
MBMG	2003Q1166	06/17/03	32	<1	1.08	<30	<1	<2	<2	<2	16	<10	<2	<2	<1	453	<1	2.29	<2
MBMG	2004Q0033	07/17/03	<30	<1	<1	<30	<1	<2	<2	<2	17	<10	<2	<2	<1	438	<1	2.62	<2
Total Rec	2004Q0034	07/17/03		<1	1.16		<1	<2	<2	<2	17	<10	2.6	<2	<1	449	8.30	2.63	6.0
MBMG	2004Q0097	08/19/03	<30	<1	<1	40	<1	<2	<2	<2	18	<10	<2	<2	1.14	442	<1	2.71	2.6
Total Rec	2004Q0098	08/19/03		<1	1.08		<1	<2	<2	<2	19	<10	2.5	<2	<1	453	36.80	2.77	16.1
MBMG	2004Q0155	09/18/03	<30	<1	<1	36	<1	<2	<2	<2	18	<10	2.5	<2	1.40	450	<1	3.01	<2
Total Rec	2004Q0156	09/18/03		<1	1.36		<1	<2	<2	<2	19	<10	6.0	<2	1.23	440	19.00	3.17	13.6
MBMG	2004Q0237	10/23/03	35	<1	<1	<30	<1	<2	<2	<2	20	<10	4.7	<2	<1	470	<1	3.84	10.6
Total Rec	2004Q0238	10/23/03		<1	<1		<1	<2	<2	<2	20	<10	2.5	<2	<1	478	6.87	3.84	9.6
		Mean	49	#DIV/0!	1.2	37.8	#DIV/0!	#DIV/0!	2.8	#DIV/0!	18	#DIV/0!	3.1	#DIV/0!	1.26	441	14.63	2.86	9.5
		Maximum	80	0.0	1.4	39.8	0.0	0.0	2.8	0.0	20	0.0	6.0	0.00	1.40	478	36.80	3.84	16.1
		Minimum	32	0.0	1.0	35.7	0.0	0.0	2.8	0.0	15	0.0	2.1	0.00	1.14	383	2.20	2.19	2.6
		Number	7	11	11	6	11	11	11	11	11	11	11	11	11	11	11	11	11
Lower Box Elder Creek																			
MBMG	2003Q1087	05/28/03	40	<1	1.86	<30	<1	<2	3.2	3.3	17	<10	2.1	<2	<1	436	<1	2.56	12.0
Total Rec	2003Q1088	05/28/03	35	<1	1.81		<1	<2	<2	<2	17	<10	2.5	<2	<1	410	1.19	2.55	11.7
MBMG	2003Q1162	06/17/03	39	<1	2.07	38	<1	<2	<2	<2	18	<10	2.0	<2	<1	444	<1	2.74	2.1
		Mean	38	#DIV/0!	1.91	37.7	#DIV/0!	#DIV/0!	3.2	3.3	17.0	#DIV/0!	2.2	#DIV/0!	#DIV/0!	430	1.19	2.62	8.6
		Maximum	40	0.0	2.07	37.7	0.0	0.0	3.2	3.3	17.7	0.0	2.5	0.00	0.0	444	1.19	2.74	12.0
		Minimum	35	0.0	1.81	37.7	0.0	0.0	3.2	3.3	16.6	0.0	2.0	0.00	0.0	410	1.19	2.55	2.1
		Number	3	3	3	2	3	3	3	3	3	3	3	3	3	3	3	3	3

Appendix A
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Belt, MT Project
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(All concentrations are dissolved, unless otherwise noted)

Analy. Lab	Lab No.	DATE (mm/dd/yy)	TIME (HRS)	Flow (gpm)	PHYSICAL PARAMETERS FIELD SC (uMHOS)	pH	ORP (MV)	DO (mg/l)	Temp (C)	LAB SC (uMHOS)	pH	Hardness (mg/l)	Alkalinity (mg/l)	Water Type PERCENT MEQ/L Ca	Mg	Na	Fe	HCO3	SO4
Belt Well #1, Creek Well		**M:2316**																	
MBMG	2003Q1129	06/05/03	15:15		600	7.06	258	5.80	12.2	585	7.78	318	171	65.6	30.9	2.5	0.0	52.2	47.8
Total Rec	2003Q1130	06/05/03	15:15									300		64.9	31.4	2.6	0.0		
		Mean		#DIV/0!	600	7.06	258	5.80	12.2	585	7.78	309	171	65.2	31.2	2.5	0.0	52.2	47.8
		Maximum		0	600	7.06	258	5.80	12.2	585	7.78	318	171	65.6	31.4	2.6	0.0	52.2	47.8
		Minimum		0	600	7.06	258	5.80	12.2	585	7.78	300	171	64.9	30.9	2.5	0.0	52.2	47.8
		Number		0	1	1	1	1	1	1	1	2	1	2	2	2	2	1	1
Jim Larson Well		**M:32015**																	
MBMG	2003Q1131	06/05/03	13:40		645	7.27	222	5.81	10.2	622	7.67	331	287	51.2	40.2	7.6	0.0	78.6	18.5
Total Rec	2003Q1132	06/05/03	13:40									303		50.4	40.8	7.8	0.0		
MBMG	2004Q0159	09/24/03	15:00		525	7.46	--	--	11.3	505	7.80	248	222	55.3	40.1	3.9	0.0	92.7	6.4
MBMG	2004Q0239	10/23/03	12:20		630	7.34	68	5.59	10.5	655	7.68	329	301	52.0	39.6	7.2	0.0	80.7	16.5
Total Rec	2004Q0240	10/23/03	12:20									337		51.7	39.9	7.3	0.0		
		Mean		#DIV/0!	600	7.36	145	5.70	10.7	594	7.72	310	270	52.1	40.1	6.8	0.0	84.0	13.8
		Maximum		0	645	7.46	222	5.81	11.3	655	7.80	337	301	55.3	40.8	7.8	0.0	92.7	18.5
		Minimum		0	525	7.27	68	5.59	10.2	505	7.67	248	222	50.4	39.6	3.9	0.0	78.6	6.4
		Number		0	3	3	3	3	3	3	3	5	3	5	5	5	5	3	3
John Harris Well		**M:84937**																	
MBMG	2004Q0093	08/19/03	13:20		740	6.86	186	4.24	9.9	730	7.28	406	287	53.3	38.4	5.9	0.8	70.6	27.4
Total Rec.	2004Q0094	08/19/03	13:20									381		52.3	39.0	6.3	0.8		
MBMG	2004Q0231	10/23/03	13:20		730	7.10	36	3.30	9.0	735	7.54	402	338	55.3	36.5	5.9	0.7	74.9	23.4
Total Rec.	2004Q0232	10/23/03	13:20									400		55.3	36.4	6.1	0.7		
		Mean		#DIV/0!	735	6.98	111	3.77	9.5	733	7.41	397	312	54.0	37.6	6.0	0.8	72.8	25.4
		Maximum		0	740	7.10	186	4.24	9.9	735	7.54	406	338	55.3	39.0	6.3	0.8	74.9	27.4
		Minimum		0	730	6.86	36	3.30	9.0	730	7.28	381	287	52.3	36.4	5.9	0.7	70.6	23.4
		Number		0	2	2	2	2	2	2	2	4	2	4	4	4	4	2	2
John Harris Spring		**M:205653**																	
MBMG	2004Q0101	08/19/03	14:10		560	7.02	234	4.29	10.0	575	7.54	308	258	43.0	50.6	5.3	0.0	81.8	11.9
Total Rec.	2004Q0102	08/19/03	14:10									294		42.3	51.8	5.0	0.0		
MBMG	2004Q0233	10/23/03	13:50		560	7.42	62	3.90	9.5	610	7.74	324	260	43.5	51.6	4.1	0.0	76.4	12.2
Total Rec.	2004Q0234	10/23/03	13:50									311		44.0	50.5	4.7	0.0		
		Mean		#DIV/0!	560	7.22	148	4.10	9.8	593	7.64	309	259	43.2	51.1	4.8	0.0	79.1	12.1
		Maximum		0	560	7.42	234	4.29	10.0	610	7.74	324	260	44.0	51.8	5.3	0.0	81.8	12.2
		Minimum		0	560	7.02	62	3.90	9.5	575	7.54	294	258	42.3	50.5	4.1	0.0	76.4	11.9
		Number		0	2	2	2	2	2	2	2	4	2	4	4	4	4	2	2
John Harris Pond		**M:207767**																	
MBMG	2004Q0157	09/19/03	12:15		500	7.34	192	7.73	9.9	525	7.97	288	228	42.0	51.4	5.4	0.0	80.4	14.3
Total Rec	2004Q0158	09/19/03	12:15									280		42.0	50.4	5.8	0.4		
		Mean		#DIV/0!	500	7.34	192	7.73	9.9	525	7.97	284	228	42.0	50.9	5.6	0.2	80.4	14.3
		Maximum		0	500	7.34	192	7.73	9.9	525	7.97	288	228	42.0	51.4	5.8	0.4	80.4	14.3
		Minimum		0	500	7.34	192	7.73	9.9	525	7.97	280	228	42.0	50.4	5.4	0.0	80.4	14.3

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Analy. Lab	Lab No.	DATE (mm/dd/yy)	Ca (mg/l)	Mg (mg/l)	Na (mg/l)	K (mg/l)	Fe (mg/l)	Mn (mg/l)	SiO2 (mg/l)	HCO3 (mg/l)	CO3 (mg/l)	Cl (mg/l)	SO4 (mg/l)	NO3-N (mg/l)	NO2-N (mg/l)	F (mg/l)	Oxygen 18O	Deuterium 2H	Tritium TU	Tritium Pico curies/L
Belt Well #1, Creek Well		**M:2316**																		
MBMG	2003Q1129	06/05/03	86.6	24.7	3.8	1.4	0.014	<0.001	7.9	208	0.0	<5	150	<0.5	<0.5	<0.5	-18.67		13.10	41.25
Total Rec	2003Q1130	06/05/03	81.0	23.8	3.7	1.2	0.043	<0.001												
		Mean	83.8	24.3	3.7	1.3	0.03	#DIV/0!	7.9	208	0.0	#DIV/0!	150	#DIV/0!	#DIV/0!	#DIV/0!	-18.67	#DIV/0!	13.10	41.3
		Maximum	86.6	24.7	3.8	1.4	0.04	0.00	7.9	208	0.0	0.00	150	0.00	0.00	0.00	-18.67	0.00	13.10	41.3
		Minimum	81.0	23.8	3.7	1.2	0.01	0.00	7.9	208	0.0	0.00	150	0.00	0.00	0.00	-18.67	0.00	13.10	41.3
		Number	2	2	2	2	2	2	1	1	1	1	1	1	1	1	1	0	1	1
Jim Larson Well		**M:32015**																		
MBMG	2003Q1131	06/05/03	74.3	35.4	12.6	2.5	0.02	<0.001	9.7	350	0.0	4.4	65	1.05	<0.5	0.38	-16.99			
Total Rec	2003Q1132	06/05/03	67.1	33.0	11.9	2.2	0.03	<0.001												
MBMG	2004Q0159	09/24/03	57.5	25.3	4.7	0.8	0.01	<0.001	10.7	270	0.0	0.9	15	<0.5	--	0.39				
MBMG	2004Q0239	10/23/03	74.9	34.6	11.9	2.5	0.01	<0.001	11.0	367	0.0	4.1	59	1.04	<0.05	0.36				
Total Rec	2004Q0240	10/23/03	76.1	35.6	12.4	2.6	0.02	<0.001												
		Mean	70.0	32.8	10.7	2.1	0.02	#DIV/0!	10.5	329	0.0	3.1	46	1.05	#DIV/0!	0.38	-16.99	#DIV/0!	#DIV/0!	#DIV/0!
		Maximum	76.1	35.6	12.6	2.6	0.03	0.000	11.0	367	0.0	4.4	65	1.05	0.00	0.39	-16.99	0.00	0.00	0.0
		Minimum	57.5	25.3	4.7	0.8	0.01	0.000	9.7	270	0.0	0.9	15	1.04	0.00	0.36	-16.99	0.00	0.00	0.0
		Number	5	5	5	5	5	5	3	3	3	3	3	3	3	3	1	0	0	0
John Harris Well		**M:84937**																		
MBMG	2004Q0093	08/19/03	94.5	41.3	11.9	4.1	1.31	0.090	6.4	350	0.0	3.1	107	<0.05		1.41	-18.59	-146.11	8.90	28.03
Total Rec.	2004Q0094	08/19/03	87.3	39.5	12.1	4.0	1.21	0.085												
MBMG	2004Q0231	10/23/03	97	38.9	11.9	4.1	1.16	0.081	6.2	412	0.0	2.8	101	<0.05	<0.05	1.49				
Total Rec.	2004Q0232	10/23/03	96.6	38.6	12.2	4.2	1.2	0.080												
		Mean	93.9	39.6	12.0	4.1	1.22	0.08	6.3	381	0.0	2.92	104	#DIV/0!	#DIV/0!	1.45	-18.59	-146.11	8.90	28.0
		Maximum	97.0	41.3	12.2	4.2	1.31	0.09	6.4	412	0.0	3.08	107	0.00	0.00	1.49	-18.59	-146.11	8.90	28.0
		Minimum	87.3	38.6	11.9	4.0	1.16	0.08	6.2	350	0.0	2.75	101	0.00	0.00	1.41	-18.59	-146.11	8.90	28.0
		Number	4	4	4	4	4	4	2	2	2	2	2	2	1	2	1	1	1	1
John Harris Spring		**M:205653**																		
MBMG	2004Q0101	08/19/03	56.7	40.4	8.0	2.3	0.02	<0.001	8.4	315	0.0	3.5	36	3.72	<0.05	0.62	-17.81	-141.67	14.20	44.72
Total Rec.	2004Q0102	08/19/03	53.0	39.3	7.2	1.8	0.01	<0.001												
MBMG	2004Q0233	10/23/03	59.4	42.7	6.4	1.6	0.02	0.001	7.6	317	0.0	1.8	37	4.40	<0.05	6.72				
Total Rec.	2004Q0234	10/23/03	58.0	40.4	7.1	1.8	0.02	<0.001												
		Mean	56.8	40.7	7.2	1.8	0.02	0.001	8.0	316	0.0	2.7	37	4.06	#DIV/0!	3.67	-17.81	-141.67	14.20	44.7
		Maximum	59.4	42.7	8.0	2.3	0.02	0.001	8.4	317	0.0	3.5	37	4.40	0.00	6.72	-17.81	-141.67	14.20	44.7
		Minimum	53.0	39.3	6.4	1.6	0.01	0.001	7.6	315	0.0	1.8	36	3.72	0.00	0.62	-17.81	-141.67	14.20	44.7
		Number	4	4	4	4	4	4	2	2	2	2	2	2	2	2	1	1	1	1
John Harris Pond		**M:207767**																		
MBMG	2004Q0157	09/19/03	51.9	38.5	7.7	2.4	0.06	0.010	11.7	279	0.0	2.3	39	2.92	0.06	0.50				
Total Rec	2004Q0158	09/19/03	50.9	37.1	8.1	2.6	0.51	0.091												
		Mean	51.4	37.8	7.9	2.5	0.28	0.051	11.7	279	0.0	2.28	39	2.92	0.06	0.50	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
		Maximum	51.9	38.5	8.1	2.6	0.51	0.091	11.7	279	0.0	2.28	39	2.92	0.06	0.50	0.00	0.00	0.00	0.0
		Minimum	50.9	37.1	7.7	2.4	0.06	0.010	11.7	279	0.0	2.28	39	2.92	0.06	0.50	0.00	0.00	0.00	0.0

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DISSOLVED CONCENTRATION

Analy. Lab	Lab No.	DATE (mm/dd/yy)	Al (ug/l)	Ag (ug/l)	As (ug/l)	B (ug/l)	Cd (ug/l)	Co (ug/l)	Cr (ug/l)	Cu (ug/l)	Li (ug/l)	Mo (ug/l)	Ni (ug/l)	Pb (ug/l)	Se (ug/l)	Sr (ug/l)	Ti (ug/l)	U (ug/l)	Zn (ug/l)
Belt Well #1, Creek Well		**M:2316**																	
MBMG	2003Q1129	06/05/03	<30	<1	<1	<30	<1	<2	<2	2.3	8.4	<10	<2	<2	<1	1,465	<1	1.71	4.8
Total Rec	2003Q1130	06/05/03	<30	<1	<1		<1	<2	<2	18.8	7.6	<10	<2	<2	<1	1,443	<1	1.86	18.8
		Mean	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	10.6	8.0	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	1454	#DIV/0!	1.79	11.8
		Maximum	0.0	0.00	0.00	0.0	0.0	0.0	0.0	18.8	8.4	0.0	0	0.0	0.00	1465	0.00	1.86	18.8
		Minimum	0.0	0.00	0.00	0.0	0.0	0.0	0.0	2.3	7.6	0.0	0	0.0	0.00	1443	0.00	1.71	4.8
		Number	2	2	2	1	2	2	2	2	2	2	2	2	2	2	2	2	2
Jim Larson Well		**M:32015**																	
MBMG	2003Q1131	06/05/03	<30	<1	<1	<30	<1	<2	<2	<2	15.7	<10	<2	<2	<1	356	<1	<2	<5
Total Rec	2003Q1132	06/05/03	<30	<1	<1		<1	<2	<2	<2	13.6	<10	<2	<2	<1	339	3.15	2.51	45.7
MBMG	2004Q0159	09/24/03	<30	<1	<1	<30	<1	<2	<2	<2	15.8	<10	<2	<2	1.35	425	<1	2.81	3.8
MBMG	2004Q0239	10/23/03	<30	<1	<1	36	<1	<2	<2	4.0	16.0	<10	<2	<2	<1	351	<1	2.72	128.0
Total Rec	2004Q0240	10/23/03		<1	<1		<1	<2	<10	4.6	16.7	<10	<2	<2	<1	360	<1	2.80	130.0
		Mean	#DIV/0!	#DIV/0!	#DIV/0!	36.2	#DIV/0!	#DIV/0!	#DIV/0!	4.3	15.6	#DIV/0!	#DIV/0!	#DIV/0!	1.35	366	3.15	2.71	76.9
		Maximum	0.0	0.00	0.00	36.2	0.0	0.0	0.0	4.6	16.7	0.0	0	0.0	1.35	425	3.15	2.81	130.0
		Minimum	0.0	0.00	0.00	36.2	0.0	0.0	0.0	4.0	13.6	0.0	0	0.0	1.35	339	3.15	2.51	3.8
		Number	4	5	5	3	5	5	5	5	5	5	5	5	5	5	5	5	5
John Harris Well		**M:84937**																	
MBMG	2004Q0093	08/19/03	<30	<1	<1	114	<1	<2	<2	<2	52.4	<10	4	<2	<1	889	<1	1.13	19
Total Rec.	2004Q0094	08/19/03		<1	<1		<1	<2	<2	<2	54.4	<10	4	<2	<1	823	<1	1.15	17
MBMG	2004Q0231	10/23/03	<30	<1	<1	107	<1	<2	2.6	<2	54.3	<10	8	<2	<1	914	<1	1.41	20
Total Rec.	2004Q0232	10/23/03		<1	<1		<1	<2	<2	<2	54.2	<10	8	<2	<1	905	<1	1.47	24
		Mean	#DIV/0!	#DIV/0!	#DIV/0!	110.5	#DIV/0!	#DIV/0!	2.6	#DIV/0!	53.8	#DIV/0!	6.1	#DIV/0!	#DIV/0!	883	#DIV/0!	1.29	20.0
		Maximum	0.0	0.00	0.00	114.0	0.0	0.0	2.6	0.0	54.4	0.0	8.1	0.0	0.00	914	0.00	1.47	24.0
		Minimum	0.0	0.00	0.00	107.0	0.0	0.0	2.6	0.0	52.4	0.0	4.3	0.0	0.00	823	0.00	1.13	17.0
		Number	2	4	4	2	4	4	4	4	4	4	4	4	4	4	4	4	4
John Harris Spring		**M:205653**																	
MBMG	2004Q0101	08/19/03	<30	<1	<1	45	<1	<2	<2	<2	19.1	<10	<2	<2	1.89	446	<1	2.40	<2
Total Rec.	2004Q0102	08/19/03		<1	<1		<1	<2	<2	<2	21.2	<10	<2	<2	1.45	420	<1	2.41	8
MBMG	2004Q0233	10/23/03	<30	<1	<1	40	<1	<2	<2	<2	18.3	<10	4	<2	1.77	443	<1	2.71	4
Total Rec.	2004Q0234	10/23/03		<1	<1		<1	<2	<2	<2	20.4	<10	<2	<2	1.69	443	<1	2.65	8
		Mean	#DIV/0!	#DIV/0!	#DIV/0!	42.6	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	19.8	#DIV/0!	3.7	#DIV/0!	1.70	438	#DIV/0!	2.54	6.9
		Maximum	0.0	0.00	0.00	45.1	0.0	0.0	0.0	0.0	21.2	0.0	3.7	0.0	1.89	446	0.00	2.71	8.2
		Minimum	0.0	0.00	0.00	40.1	0.0	0.0	0.0	0.0	18.3	0.0	3.7	0.0	1.45	420	0.00	2.40	4.4
		Number	2	4	4	2	4	4	4	4	4	4	4	4	4	4	4	4	4
John Harris Pond		**M:207767**																	
MBMG	2004Q0157	09/19/03	<30	<1	1.92	40	<1	<2	<2	<2	20	<10	<2	<2	1.28	385	<1	<1	<2
Total Rec	2004Q0158	09/19/03		<1	2.52		<1	<2	<2	<2	21	<10	4	<2	1.22	382	<1	2.26	18
		Mean	#DIV/0!	#DIV/0!	2.22	39.7	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	20.0	#DIV/0!	4.1	#DIV/0!	1.25	384	#DIV/0!	2.26	18.0
		Maximum	0.0	0.00	2.52	39.7	0.00	0.00	0.00	0.00	20.5	0.0	4.1	0.0	1.28	385	0.00	2.26	18.0
		Minimum	0.0	0.00	1.92	39.7	0.00	0.00	0.00	0.00	19.5	0.0	4.1	0.0	1.22	382	0.00	2.26	18.0

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					PHYSICAL PARAMETERS									Water Type PERCENT MEQ/L					
Analy. Lab	Lab No.	DATE (mm/dd/yy)	TIME (HRS)	Flow (gpm)	FIELD SC (uMHOS)	pH	ORP (MV)	DO (mg/l)	Temp (C)	LAB SC (uMHOS)	pH	Hardness (mg/l)	Alkalinity (mg/l)	Ca	Mg	Na	Fe	HCO3	SO4
		Number		0	1	1	1	1	1	1	1	2	1	2	2	2	2	1	1

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Analy. Lab	Lab No.	DATE (mm/dd/yy)	Ca (mg/l)	Mg (mg/l)	Na (mg/l)	K (mg/l)	Fe (mg/l)	Mn (mg/l)	SiO2 (mg/l)	HCO3 (mg/l)	CO3 (mg/l)	Cl (mg/l)	SO4 (mg/l)	NO3-N (mg/l)	NO2-N (mg/l)	F (mg/l)	Oxygen 18O	Deuterium 2H	Tritium TU	Tritium Pico curies/L
		Number	2	2	2	2	2	2	1	1	1	1	1	1	1	1	0	0	0	0

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DISSOLVED CONCENTRATION

Analy. Lab	Lab No.	DATE (mm/dd/yy)	Al (ug/l)	Ag (ug/l)	As (ug/l)	B (ug/l)	Cd (ug/l)	Co (ug/l)	Cr (ug/l)	Cu (ug/l)	Li (ug/l)	Mo (ug/l)	Ni (ug/l)	Pb (ug/l)	Se (ug/l)	Sr (ug/l)	Ti (ug/l)	U (ug/l)	Zn (ug/l)
		Number	1	2	2	1	2	2	2	2	2	2	2	2	2	2	2	2	2

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					PHYSICAL PARAMETERS									Water Type PERCENT MEQ/L					
Analy. Lab	Lab No.	DATE (mm/dd/yy)	TIME (HRS)	Flow (gpm)	FIELD SC (uMHOS)	pH	ORP (MV)	DO (mg/l)	Temp (C)	LAB SC (uMHOS)	pH	Hardness (mg/l)	Alkalinity (mg/l)	Ca	Mg	Na	Fe	HCO3	SO4
Belt Creek#2, above AMD			**M:205508**																
MBMG		07/17/03	18:45	isotopes only															
MBMG	2004Q0091	08/20/03	12:30		460	7.48	253	8.28	20.9	550	7.83	243	186	67.0	27.4	4.4	0.0	72.4	26.3
Total Rec.	2004Q0092	08/20/03	12:30									230		65.3	28.7	4.7	0.0		
		Mean		#DIV/0!	460	7.48	253	8.28	20.9	550	7.83	237	186	66.2	28.0	4.5	0.0	72.4	26.3
		Maximum		0	460	7.48	253	8.28	20.9	550	7.83	243	186	67.0	28.7	4.7	0.0	72.4	26.3
		Minimum		0	460	7.48	253	8.28	20.9	550	7.83	230	186	65.3	27.4	4.4	0.0	72.4	26.3
		Number		1	1	1	1	1	1	1	1	2	1	2	2	2	2	1	1
BC01		**M:205836**																	
MBMG	2004Q0110	08/27/03	10:50	80.64	300	7.79	510	5.61	17.9	430	7.83	189	129	63.9	29.9	4.7	0.0	68.7	30.3
Total Rec	2004Q0111	08/27/03	10:50									167		62.0	32.0	4.5	0.1		
		Mean		81	300	7.79	510	5.61	17.9	430	7.83	178	129	63.0	31.0	4.6	0.1	68.7	30.3
		Maximum		81	300	7.79	510	5.61	17.9	430	7.83	189	129	63.9	32.0	4.7	0.1	68.7	30.3
		Minimum		81	300	7.79	510	5.61	17.9	430	7.83	167	129	62.0	29.9	4.5	0.0	68.7	30.3
		Number		1	1	1	1	1	1	1	1	2	1	2	2	2	2	1	1
BC02		**M:205838**																	
MBMG	2004Q0112	08/27/03	13:35		370	7.22	512	4.61	18.41	415	7.67	202	179	64.7	28.4	5.3	0.0	77.8	21.1
Total Rec	2004Q0113	08/27/03	13:35									216		65.0	28.5	5.1	0.0		
		Mean		#DIV/0!	370	7.22	512	4.61	18.4	415	7.67	209	179	64.9	28.4	5.2	0.0	77.8	21.1
		Maximum		0	370	7.22	512	4.61	18.4	415	7.67	216	179	65.0	28.5	5.3	0.0	77.8	21.1
		Minimum		0	370	7.22	512	4.61	18.4	415	7.67	202	179	64.7	28.4	5.1	0.0	77.8	21.1
		Number		0	1	1	1	1	1	1	1	2	1	2	2	2	2	1	1
BC03		**M:205839**																	
MBMG	2004Q0114	08/27/03	15:15	215.04	370	7.48	513	5.99	19.2	405	7.82	213	174	66.4	27.3	4.8	0.0	76.2	22.7
Total Rec	2004Q0115	08/27/03	15:15									213		66.4	27.4	4.9	0.0		
		Mean		215	370	7.48	513	5.99	19.2	405	7.82	213	174	66.4	27.4	4.8	0.0	76.2	22.7
		Maximum		215	370	7.48	513	5.99	19.2	405	7.82	213	174	66.4	27.4	4.9	0.0	76.2	22.7
		Minimum		215	370	7.48	513	5.99	19.2	405	7.82	213	174	66.4	27.3	4.8	0.0	76.2	22.7
		Number		1	1	1	1	1	1	1	1	2	1	2	2	2	2	1	1
Belt Cr @ Bank Seepage			**M:186802**																
Total Rec	2001Q1360	03/29/01	10:30			4.89						449	0.0	19.9	11.5	1.1	0.5		
Total Rec	2004Q0089	08/20/03	12:50		1,250	3.73	477	5.74	23.2	1,570	4.01	518	0.0	9.5	5.6	0.4	7.8		
		Mean		#DIV/0!	1,250	4.31	477	5.74	23.2	1,570	4.01	483	0.0	14.7	8.6	0.8	4.1	#DIV/0!	#DIV/0!
		Maximum		0	1,250	4.89	477	5.74	23.2	1,570	4.01	518	0.0	19.9	11.5	1.1	7.8	0.0	0.0
		Minimum		0	1,250	3.73	477	5.74	23.2	1,570	4.01	449	0.0	9.5	5.6	0.4	0.5	0.0	0.0
		Number		0	1	2	1	1	1	1	1	2	2	2	2	2	2	0	0

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Analy. Lab	Lab No.	DATE (mm/dd/yy)	Ca (mg/l)	Mg (mg/l)	Na (mg/l)	K (mg/l)	Fe (mg/l)	Mn (mg/l)	SiO2 (mg/l)	HCO3 (mg/l)	CO3 (mg/l)	Cl (mg/l)	SO4 (mg/l)	NO3-N (mg/l)	NO2-N (mg/l)	F (mg/l)	Oxygen 18O	Deuterium 2H	Tritium TU	Tritium Pico curies/L
Belt Creek#2, above AMD																				
MBMG		07/17/03															-17.94		13.20	41.57
MBMG	2004Q0091	08/20/03	69.1	17.1	5.2	1.8	0.04	0.005	9.3	227	0.0	1.9	65	0.11	<0.05	0.16	-17.89	-136.32	13.00	40.94
Total Rec.	2004Q0092	08/20/03	64.1	17.1	5.3	1.8	0.03	0.007												
		Mean	66.6	17.1	5.2	1.8	0.03	0.006	9.3	227	0.0	1.85	65	0.11	#DIV/0!	0.16	-17.92	-136.32	13.10	41.3
		Maximum	69.1	17.1	5.3	1.8	0.04	0.007	9.3	227	0.0	1.85	65	0.11	0.00	0.16	-17.89	-136.32	13.20	41.6
		Minimum	64.1	17.1	5.2	1.8	0.03	0.005	9.3	227	0.0	1.85	65	0.11	0.00	0.16	-17.94	-136.32	13.00	40.9
		Number	2	2	2	2	2	2	1	1	1	1	1	1	1	1	2	1	2	2
BC01		**M:205836**																		
MBMG	2004Q0110	08/27/03	51.8	14.6	4.4	1.6	0.03	0.095	7.1	157	0.0	0.8	55	0.09	<0.05	0.08	-17.46	-135.56	12.40	39.05
Total Rec	2004Q0111	08/27/03	44.1	13.8	3.7	1.3	0.05	0.015												
		Mean	48.0	14.2	4.1	1.5	0.04	0.055	7.1	157	0.0	0.82	55	0.09	#DIV/0!	0.08	-17.46	-135.56	12.40	39.0
		Maximum	51.8	14.6	4.4	1.6	0.05	0.095	7.1	157	0.0	0.82	55	0.09	0.00	0.08	-17.46	-135.56	12.40	39.0
		Minimum	44.1	13.8	3.7	1.3	0.03	0.015	7.1	157	0.0	0.82	55	0.09	0.00	0.08	-17.46	-135.56	12.40	39.0
		Number	2	2	2	2	2	2	1	1	1	1	1	1	1	1	1	1	1	1
BC02		**M:205838**																		
MBMG	2004Q0112	08/27/03	56.3	15.0	5.3	1.9	0.04	0.003	8.4	218	0.0	1.5	47	<0.05	<0.05	0.16	-18.02	138.19	11.60	36.53
Total Rec	2004Q0113	08/27/03	60.3	16.0	5.4	1.8	0.02	0.006												
		Mean	58.3	15.5	5.4	1.8	0.03	0.005	8.4	218	0.0	1.45	47	#DIV/0!	#DIV/0!	0.16	-18.02	138.19	11.60	36.5
		Maximum	60.3	16.0	5.4	1.9	0.04	0.006	8.4	218	0.0	1.45	47	0.00	0.00	0.16	-18.02	138.19	11.60	36.5
		Minimum	56.3	15.0	5.3	1.8	0.02	0.003	8.4	218	0.0	1.45	47	0.00	0.00	0.16	-18.02	138.19	11.60	36.5
		Number	2	2	2	2	2	2	1	1	1	1	1	1	1	1	1	1	1	1
BC03		**M:205839**																		
MBMG	2004Q0114	08/27/03	60.5	15.1	5.0	1.7	0.03	0.006	9.5	213	0.0	1.5	50	0.08	<0.05	0.07	-17.83	-136.77	14.50	45.66
Total Rec	2004Q0115	08/27/03	60.3	15.1	5.1	1.7	0.05	0.009												
		Mean	60.4	15.1	5.0	1.7	0.04	0.008	9.5	213	0.0	1.46	50	0.08	#DIV/0!	0.07	-17.83	-136.77	14.50	45.7
		Maximum	60.5	15.1	5.1	1.7	0.05	0.009	9.5	213	0.0	1.46	50	0.08	0.00	0.07	-17.83	-136.77	14.50	45.7
		Minimum	60.3	15.1	5.0	1.7	0.03	0.006	9.5	213	0.0	1.46	50	0.08	0.00	0.07	-17.83	-136.77	14.50	45.7
		Number	2	2	2	2	2	2	1	1	1	1	1	1	1	1	1	1	1	1
Belt Cr @ Bank Seepage																				
Total Rec	2001Q1360	03/29/01	114	40.0	7.3	2.5	2.54	0.417												
Total Rec	2004Q0089	08/20/03	130	46.9	6.7	2.5	98.90	0.773												
		Mean	122	43.5	7.0	2.5	50.72	0.595	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
		Maximum	130	46.9	7.3	2.5	98.90	0.773	0	0	0	0	0	0	0	0	0	0	0	0
		Minimum	114	40.0	6.7	2.5	2.54	0.417	0	0	0	0	0	0	0	0	0	0	0	0
		Number	2	2	2	2	2	2	0	0	0	0	0	0	0	0	0	0	0	0

Appendix A
Inorganic Water Quality Data

Belt, MT Project
Water Quality Results
(All concentrations are dissolved, unless ot

DISSOLVED CONCENTRATION

Analy. Lab	Lab No.	DATE (mm/dd/yy)	Al (ug/l)	Ag (ug/l)	As (ug/l)	B (ug/l)	Cd (ug/l)	Co (ug/l)	Cr (ug/l)	Cu (ug/l)	Li (ug/l)	Mo (ug/l)	Ni (ug/l)	Pb (ug/l)	Se (ug/l)	Sr (ug/l)	Ti (ug/l)	U (ug/l)	Zn (ug/l)
Belt Creek#2, above AMD																			
MBMG		07/17/03																	
MBMG	2004Q0091	08/20/03	<30	<1	<1	<30	<1	<2	<2	<2	11.0	<10	<2	<2	<1	714	<1	1.17	7.8
Total Rec.	2004Q0092	08/20/03		<1	<1		<1	<2	<2	<2	12.2	<10	<2	<2	<1	628	<1	1.21	8.2
		Mean	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	11.6	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	671	#DIV/0!	1.19	8.0
		Maximum	0.0	0.00	0.00	0.0	0.0	0.0	0.0	0.0	12.2	0.0	0	0.0	0.00	714	0.00	1.21	8.2
		Minimum	0.0	0.00	0.00	0.0	0.0	0.0	0.0	0.0	11.0	0.0	0	0.0	0.00	628	0.00	1.17	7.8
		Number	1	2	2	1	2	2	2	2	2	2	2	2	2	2	2	2	2
BC01		**M:205836**																	
MBMG	2004Q0110	08/27/03	41	<1	<1	<30	1.5	<2	<2	6.3	8.1	17.4	<2	<2	<1	639	<1	3.05	29.0
Total Rec	2004Q0111	08/27/03		<1	<1		1.2	<2	<2	9.1	6.5	<10	3	<2	<1	624	1.07	1.13	40.4
		Mean	40.7	#DIV/0!	#DIV/0!	#DIV/0!	1.3	#DIV/0!	#DIV/0!	7.7	7.3	17.4	3	#DIV/0!	#DIV/0!	632	1.07	2.09	34.7
		Maximum	40.7	0.00	0.00	0.0	1.5	0.0	0.0	9.1	8.1	17.4	3	0.0	0.00	639	1.07	3.05	40.4
		Minimum	40.7	0.00	0.00	0.0	1.2	0.0	0.0	6.3	6.5	17.4	3	0.0	0.00	624	1.07	1.13	29.0
		Number	1	2	2	1	2	2	2	2	2	2	2	2	2	2	2	2	2
BC02		**M:205838**																	
MBMG	2004Q0112	08/27/03	37	<1	<1	<30	<1	<2	<2	<2	11	<10	<2	<2	<1	644	<1	1.13	10.3
Total Rec	2004Q0113	08/27/03		<1	<1		<1	<2	<2	<2	10	<10	3	<2	<1	676	<1	1.24	13.0
		Mean	36.5	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	10.3	#DIV/0!	3	#DIV/0!	#DIV/0!	660	#DIV/0!	1.19	11.6
		Maximum	36.5	0.00	0.00	0.0	0.00	0.00	0.00	0.00	10.7	0.0	3	0.0	0.00	676	0.00	1.24	13.0
		Minimum	36.5	0.00	0.00	0.0	0.00	0.00	0.00	0.00	9.9	0.0	3	0.0	0.00	644	0.00	1.13	10.3
		Number	1	2	2	1	2	2	2	2	2	2	2	2	2	2	2	2	2
BC03		**M:205839**																	
MBMG	2004Q0114	08/27/03	71	<1	<1	<30	<1	<2	<2	<2	10.4	<10	<2	<2	<1	673	<1	1.07	10.4
Total Rec	2004Q0115	08/27/03		<1	<1		<1	<2	<2	<2	10.8	<10	3	<2	<1	667	<1	<1	19.3
		Mean	71.2	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	10.6	#DIV/0!	3	#DIV/0!	#DIV/0!	670	#DIV/0!	1.07	14.9
		Maximum	71.2	0.00	0.00	0.0	0.00	0.00	0.00	0.00	10.8	0.0	3	0.0	0.00	673	0.00	1.07	19.3
		Minimum	71.2	0.00	0.00	0.0	0.00	0.00	0.00	0.00	10.4	0.0	3	0.0	0.00	667	0.00	1.07	10.4
		Number	1	2	2	1	2	2	2	2	2	2	2	2	2	2	2	2	2
Belt Cr @ Bank Seepage																			
Total Rec	2001Q1360	03/29/01	171,000	<10	<10		<20	40.4	<20	<20	82	<100	41	20.7	<10	829	8.0		124
Total Rec	2004Q0089	08/20/03	471,017		8.72		14.0	49.0	<10	17.9	248	<50	62	56.4	<5	845	31.3	22.80	589
		Mean	321,009	#DIV/0!	8.7	#DIV/0!	14.0	44.7	#DIV/0!	17.9	165	#DIV/0!	51	38.6	#DIV/0!	837	19.7	22.80	357
		Maximum	471,017	0	8.7	0	14.0	49.0	0	17.9	248	0	62	56.4	0	845	31.3	22.80	589
		Minimum	171,000	0	8.7	0	14.0	40.4	0	17.9	82	0	41	20.7	0	829	8.0	22.80	124
		Number	2	1	2	0	2	2	2	2	2	2	2	2	2	2	2	2	2

APPENDIX B

Isotope Data

Appendix B
Isotope Data

Belt, MT Project
Water Quality Results

	DATE (mm/dd/yy)	TIME (HRS)	Lab No.	Oxygen 18O	Deuterium 2H	Tritium TU E3H	Tritium Pico curies/L
Anaconda Mine Drain							
	01/30/03	11:30	57350	--	--	14.2	44.7
	05/28/03	18:30	67115	-18.04	--	16.0	50.4
	07/17/03	17:45	67123	-18.22	--	16.0	50.4
	10/23/03	16:20	72794	-18.46	-146.49	12.9	40.6
Mean				-18.2		14.8	46.5
Maximum				-18.0		16.0	50.4
Minimum				-18.5		12.9	40.6
Number				4		4	4
French Coulee Drain							
	01/29/03	14:00	57351	--	--	15.3	48.2
	05/28/03	18:00	67116	-17.98	--	19.5	61.4
	07/17/03	17:10	67124	-18.04	--	17.2	54.2
	10/23/03	15:50	72793	-18.28	-143.92	16.0	50.4
Mean				-18.1		17.0	53.5
Maximum				-18.0		19.5	61.4
Minimum				-18.3		15.3	48.2
Number				4		4	4
Highway Drain							
	01/30/03	14:10	57352	--	--	26.0	81.9
	05/28/03	17:25	67117	-16.52	--	23.6	74.3
Mean				-16.5		24.8	78.1
Maximum				-16.5		26.0	81.9
Minimum				-16.5		23.6	74.3
Number				2		2	2
HWD-Seep							
	07/17/03	14:15	67125	-17.36	--	31.9	100.5
Mean				-17.4		31.9	100.5
Maximum				-17.4		31.9	100.5
Minimum				-17.4		31.9	100.5
Number				1		1	1

Appendix B
Isotope Data

Belt, MT Project
Water Quality Results

DATE (mm/dd/yy)		TIME (HRS)	Lab No.	Oxygen 18O	Deuterium 2H	Tritium TU E3H	Tritium Pico curies/L
Box Elder Creek, Harris Ranch							
	01/29/03	16:15	57353	--	--	18.6	58.6
Mean				#DIV/0!		18.6	58.6
Maximum				0.00		18.6	58.6
Minimum				0.00		18.6	58.6
Number				1		1	1
Upper Box Elder Creek, Larson Ranch							
	05/28/03	15:50	67119	-17.11	--	20.2	63.6
	07/17/03	11:20	67126	--	--	19.8	62.4
	10/23/03	11:15	72792	-16.88	-135.16	23.2	73.1
Mean				-17.0	-135.2	21.1	66.3
Maximum				-16.9	-135.2	23.2	73.1
Minimum				-17.1	-135.2	19.8	62.4
Number				2	1	3	3
Lower Box Elder Creek							
	05/28/03	16:45	67118	-16.74	--	20.3	63.9
Mean				-16.7		20.3	63.9
Maximum				-16.7		20.3	63.9
Minimum				-16.7		20.3	63.9
Number				1		1	1
Belt Well #1, Creek Well							
	06/05/03	15:15	67121	-18.67	--	13.1	41.3
	11/23/03	15:30	72795	-18.99	-145.62	12.2	38.4
Mean				-18.8		12.7	39.8
Maximum				-18.7		13.1	41.3
Minimum				-19.0		12.2	38.4
Number				2		2	2
Belt Well #2, Park Well							
	11/23/03	15:45	72796	-19.04	-145.04	13.6	42.8
Mean				-19.0	-145.0	13.6	42.8
Maximum				-19.0	-145.0	13.6	42.8
Minimum				-19.0	-145.0	13.6	42.8
Number				1	1	1	1

Appendix B
Isotope Data

Belt, MT Project
Water Quality Results

DATE (mm/dd/yy)	TIME (HRS)	Lab No.	Oxygen 18O	Deuterium 2H	Tritium TU E3H	Tritium Pico curies/L

Appendix B
Isotope Data

Belt, MT Project
Water Quality Results

	DATE (mm/dd/yy)	TIME (HRS)	Lab No.	Oxygen 18O	Deuterium 2H	Tritium TU E3H	Tritium Pico curies/L
Jim Larson Well							
	06/05/03	13:40	67120	-16.99	--	18.1	57.0
	10/23/03	12:20	72791	-17.08	-136.06	16.8	52.9
Mean				-17.04		17.45	55.0
Maximum				-16.99		18.10	57.0
Minimum				-17.08		16.80	52.9
Number				2		2	2
John Harris Well							
	08/19/03	13:20	68103	-18.59	-146.11	8.9	28.0
	10/23/03	13:20	72789	-18.60	-143.91	8.6	27.1
Mean				-18.60	-145.01	8.8	27.6
Maximum				-18.59	-143.91	8.9	28.0
Minimum				-18.60	-146.11	8.6	27.1
Number				2	2	2	2
John Harris Spring							
	08/19/03	14:10	68104	-17.81	-141.67	14.2	44.72
	10/23/03	13:50	72790	-17.91	-142.48	13.6	42.83
Mean				-17.86	-142.08	13.90	43.8
Maximum				-17.81	-141.67	14.20	44.7
Minimum				-17.91	-142.48	13.60	42.8
Number				2	2	2	2
John Harris Pond							
Mean						#DIV/0!	#DIV/0!
Maximum						0.00	0.0
Minimum						0.00	0.0
Number						0	0

Appendix B
Isotope Data

Belt, MT Project
Water Quality Results

	DATE (mm/dd/yy)	TIME (HRS)	Lab No.	Oxygen 18O	Deuterium 2H	Tritium TU E3H	Tritium Pico curies/L
Belt Creek#2, above AMD							
	07/17/03	18:45	67122	-17.94	--	13.2	41.6
	08/20/03	12:30	68105	-17.89	-136.32	13.0	40.9
Mean				-17.9	-136.3	13.1	41.3
Maximum				-17.9	-136.3	13.2	41.6
Minimum				-17.9	-136.3	13.0	40.9
Number				2	2	2	2
BC01							
	08/27/03	10:50	68106	-17.46	-135.56	12.4	39.0
Mean				-17.5	-135.6	12.4	39.0
Maximum				-17.5	-135.6	12.4	39.0
Minimum				-17.5	-135.6	12.4	39.0
Number				1	1	1	1
BC02							
	08/27/03	13:35	68107	-18.02	-138.19	11.60	36.53
Mean				-18.02	-138.19	11.60	36.53
Maximum				-18.02	-138.19	11.60	36.53
Minimum				-18.02	-138.19	11.60	36.53
Number				1	1	1	1
BC03							
	08/27/03	19:35	68108	-17.83	-136.77	14.5	45.7
Mean				-17.83	-136.77	14.50	45.66
Maximum				-17.83	-136.77	14.50	45.66
Minimum				-17.83	-136.77	14.50	45.66
Number				1	1	1	1

APPENDIX C

Abstract

Use of Airborne Thermal Infrared Imaging, EM Conductivity,
and Total Field Magnetics to Identify Faults, Acid Mine Drainage Plumes
and Groundwater Discharge Zones

by

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The National Energy Technology Laboratory (NETL) has conducted airborne reconnaissance of large mined areas in California, West Virginia, Pennsylvania, Maryland, and Ohio using thermal infrared imaging, electromagnetic conductivity, and total field magnetics. The purpose of these surveys was to locate sites of groundwater discharge and to identify hydrologic features that affect the flow of contaminated groundwater. This information was then used to target selected areas for more detailed investigations. Although airborne surveys cost about $100/line-km, they are more cost effective than comparable ground-based surveys because data can be acquired from large areas in a minimum amount of time. Moreover, airborne surveys avoid land access issues that are problematic to ground-based surveys. A field study will be presented where airborne geophysics identified groundwater flow paths that were missed by a multimillion dollar network of groundwater monitoring wells.

Thermal Infrared Imaging

- » Locates springs, seeps, and mine discharges
- » Acquired from aircraft platform
- » Night-time data collection during winter months

Maximizes thermal contrast between surface and groundwater

Temperature resolution - 0.1 degrees centigrade

- » Correction of imagery
  - Aircraft attitude
  - Topographic
  - Polynomial stretching using ground control points

- » Examples
  - Mine discharges
  - Seeps and springs
  - Cultural anomalies

EM Conductivity

- » Locate plumes of contaminated (conductive) groundwater
- » Locate alteration envelopes along fault zones
- » Acquired from helicopter platform (sling load)
- » Data processing

Contoured data overlain on DOQQ or draped from a DEM

Cross-sections using inverted conductivity data

- » Examples
- » Plume of contaminated groundwater
- » Faults
- » Sources of acidic groundwater

Total Field Magnetics

- » Locates geologic contacts and faults
- » Acquired from aircraft platform
- » Detects differences in the abundance of magnetic minerals
- » Data processing

Contoured data overlain on DOQQ or draped from a DEM

- » Examples
- » Lava flow
- » Faults

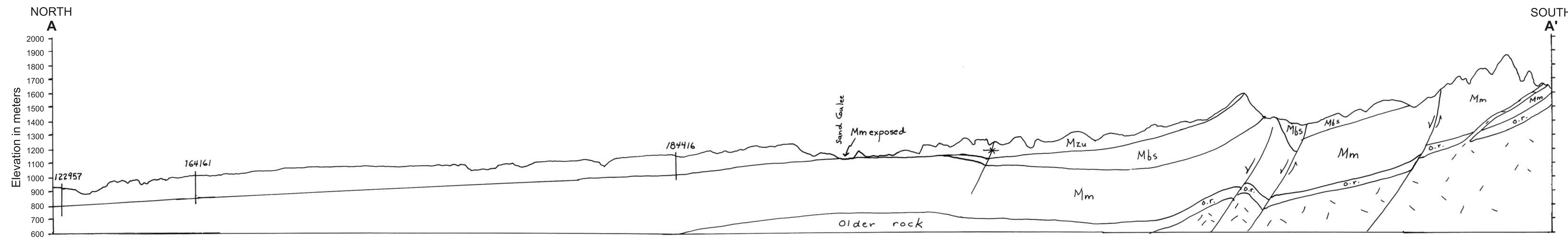
Resistivity

1. Locate mine subsidence "chimneys"
2. Vertical grout distribution
3. Ground
4. Example

I77 Guernsey County, Ohio

Using the techniques mentioned above, new areas of springs or AMD were not seen at the resolutions available.

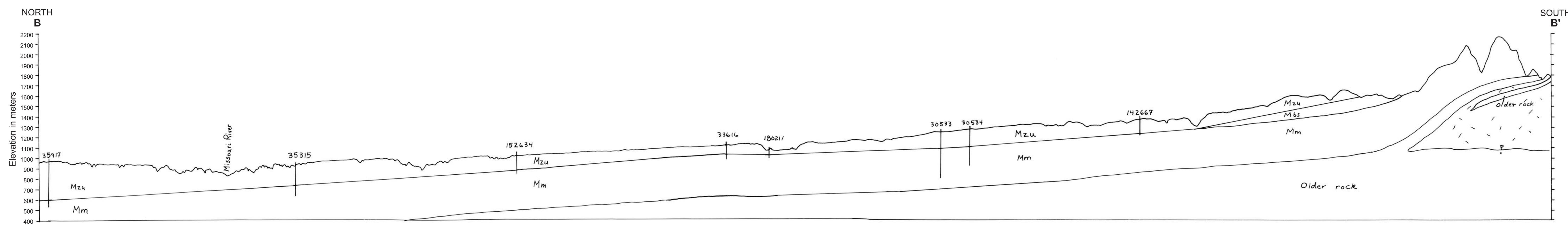
The infiltration of surface water into the mine and contributing to the AMD is inconclusive. The areas that were found using the thermal images don't seem to hold much water and are virtually nonexistent in the dry season.

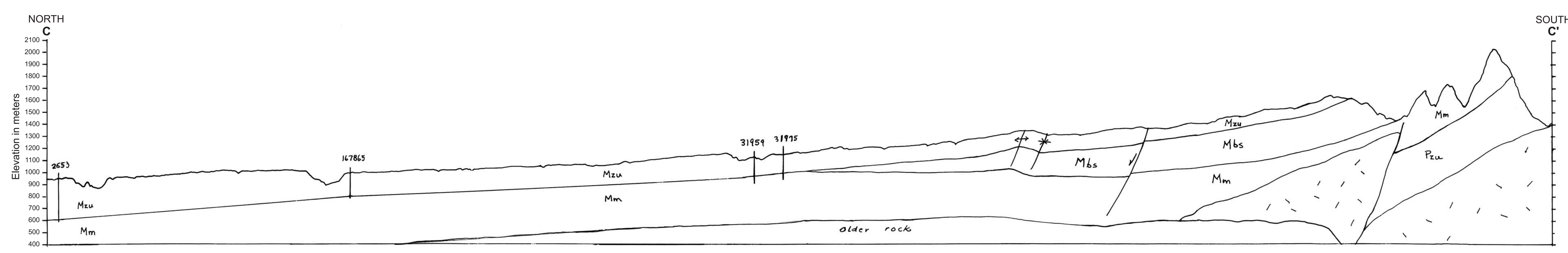


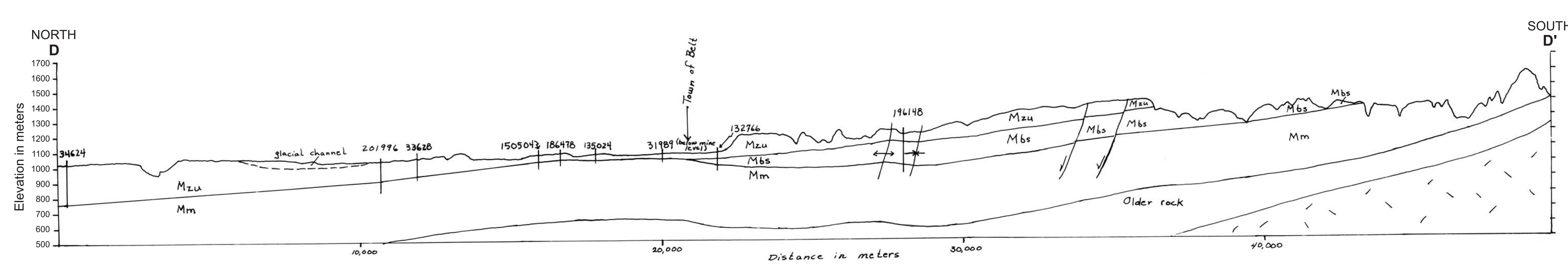
Vertical exaggeration: 5x
Datum: Mean sea level
Thin surficial deposits not shown

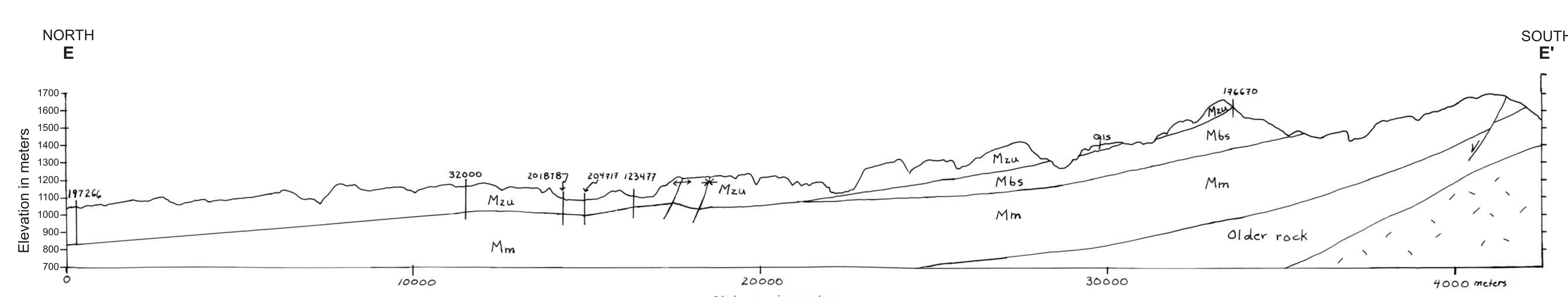
KEY
Mzu Mesozoic rocks, undivided (includes Swift, Morrison and Kootenai Fms., undivided
Mbs Big Snowy Group
Mm Madison Group
Igneous rock

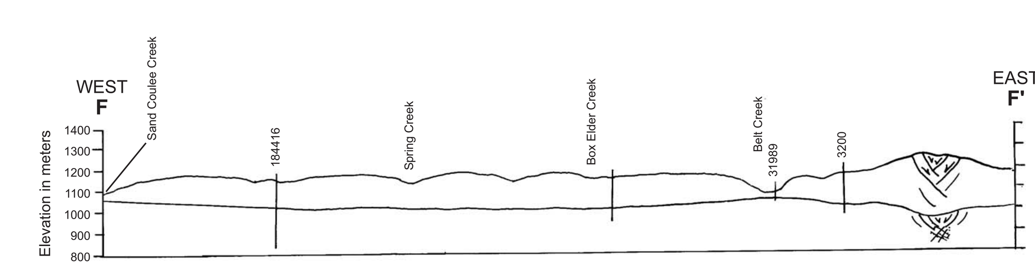
3200 GWIC well

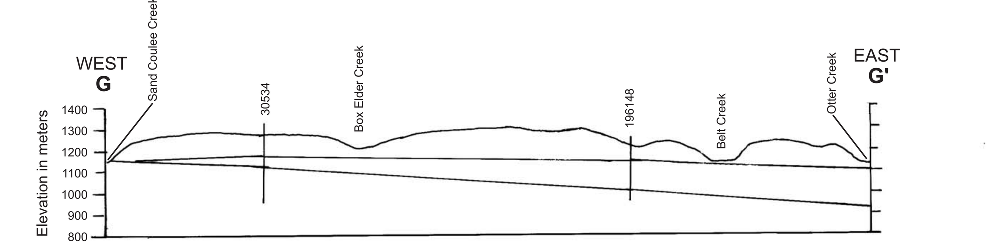












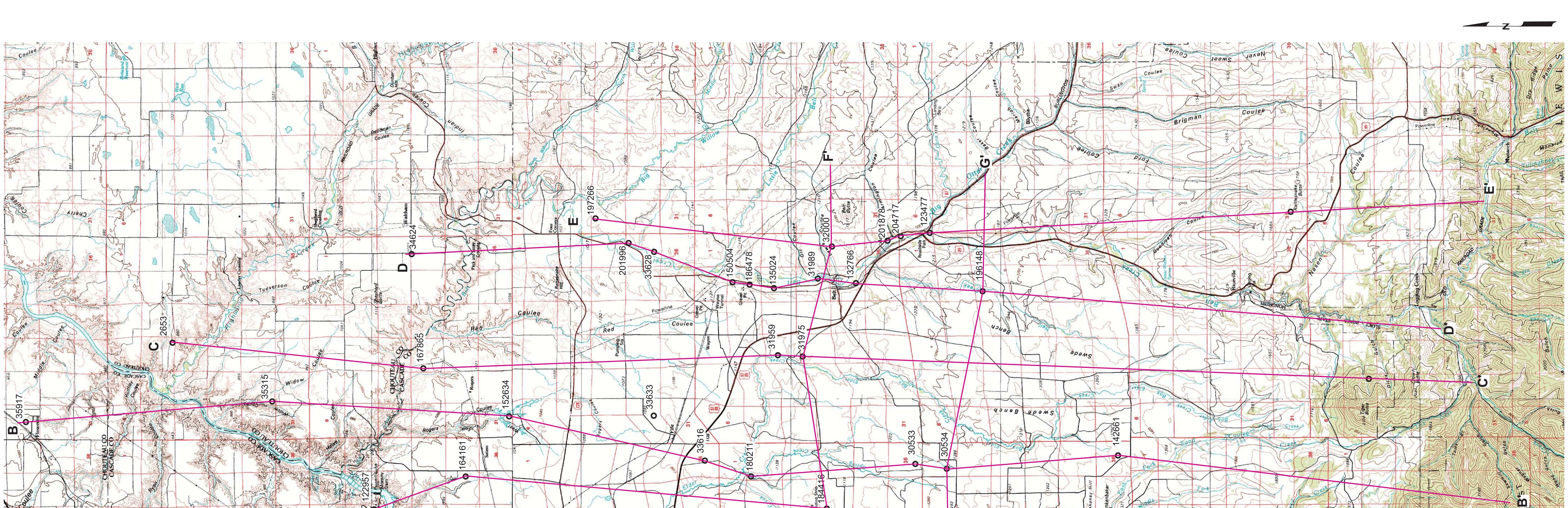


Plate 1. Cross Sections A–E

MBMG Open File 504

Reevaluation of the Hydrological System in the Vicinity of the Anaconda Mine at Belt, Cascade County, Montana

by
Ted Duaime, Ken Sandau, Susan Vuke, Jay Hanson,
Shawn Reddish, and Jon Reiten
2004

Maps may be obtained from
Publications Office
Montana Bureau of Mines and Geology
1300 West Park Street, Butte, Montana 59701-8997
Phone: (406) 496-4167 Fax: (406) 496-4451
http://www.mbmg.mtech.edu