# Ground Water and Surface Water in a Study Area within the Upper Big Hole River Basin


Project Completion Report to the
U.S. Bureau of Reclamation
Big Hole River Watershed Committee

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by

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## ABSTRACT

A hydrologic investigation was performed in a study area in the upper Big Hole River Basin to assess the dynamics between the surface water, ground water, evapotranspiration and precipitation. The study area encompassed about 10 $mi^2$ and included a 3-mile segment of the Big Hole River just north of Jackson, Montana. During 2005 and 2006, ground water was monitored monthly and every two weeks during the growing season. Big Hole River stream flows were monitored continuously from April – October as they entered and exited the study area. Monthly synoptic measurements of ground water and surface water provided information used to estimate a water budget within the study area.

After accounting for all surface water entering and exiting the study area, more water was leaving the system than entering during May and June indicating a gain in stream flow. Ground water was rapidly released from aquifer storage once irrigation ended in July and by mid-August ground water had returned to within 90 percent of pre-irrigation levels in over 50 percent of the wells monitored. From July through October the surface water showed a slight loss or was essentially balanced with no significant gains or losses after irrigation ended. These results were consistent for both 2005 and 2006.

A water budget was approximated during the synoptic run dates within the study area to examine the components that contribute water (sources) and losses (sinks) to the hydrogeologic system. Although the budget was only estimated during the synoptic run dates, the analyses provided information on how the system responds during periods of pre-irrigation, at the height of irrigation and later on in the summer/fall. The water budget revealed that water lost to evapotranspiration was equivalent or exceeded the amount of ground water released from storage. This does not mean that ground water discharged from storage was not returning to the river during this time, but the gains from storage were matched or exceeded by losses due to evapotranspiration. Although no surface-water flows were monitored throughout the winter months when evapotransipration losses were minimal, it was estimated that about 3 to 5 cfs was released from ground-water storage within the study area and most likely helped sustain river flows during this time.

Data indicates that augmentation of surface flow by irrigation return flow is potentially most significant during June, July and August when the highest quantity of ground water is released from storage. However, evapotranspiration demands during these months roughly equals or exceeds ground-water contributions and in fact, surface flows through the study area either slightly increased (June) or were at a net loss (July and August).

Due to the variable nature of flood irrigation in the upper Big Hole basin, it was difficult to quantify the impacts of a reduction in the amount of water used to flood irrigate, even at a study-area scale. However, many of the operators flood irrigate to the point of field saturation thus promoting surface ponding and tailwater runoff of excess diverted waters. In these cases, ground-water recharge has been satisfied and a reduction in the amount of water diverted would not likely impact ground-water storage and in effect could enhance instream flows by reducing the amount of diverted water. In addition, with more efficient irrigation management, which may include a reduction in the amount of water diverted, evapotranspiration in some areas would decrease due to the conversion of more consumptive plants, such as sedges, to grass hay.

These results are consistent with a previous investigation performed during 1997 and 1998 on a drainage on the east side of the Big Hole River. Therefore, despite variability within the upper basin, both studies reached similar conclusions.

# INTRODUCTION

The Big Hole River watershed lies within the Missouri River Basin. The river is about 130 miles long and drains about 2,800-square miles of an intermontane basin in southwestern Montana. The headwaters for the Big Hole River are about 13 miles south of Jackson, Montana in the Beaverhead Mountains (figure 1). The river flows to the north through a broad basin; about 20 miles north of Wisdom, Montana the valley constricts and the river bends to the southeast. Near the town of Divide the river turns south, joining the Beaverhead and Ruby rivers near Twin Bridges to form the headwaters of the Jefferson River.

The upper Big Hole River Basin encompasses an area of 1,267 $mi^2$ within Beaverhead and Deer Lodge Counties and includes the towns of Jackson and Wisdom, Montana (figure 1). The culture and economy of this pristine watershed is dominated by agriculture, particularly cattle and hay production, and recreation. The Big Hole River is a blue ribbon trout stream used by fishing and boating enthusiasts and outfitters. Southwestern Montana has been in a drought these past 10 years and the cumulative effects have impacted ranchers, fisheries, and recreationists who depend on the Big Hole River for their livelihood.

The river also is home to the last wild population of fluvial Arctic grayling, a trout species, in the lower 48 states. Historically, these fish were distributed throughout the entire Missouri River system. Over the past century, dams, habitat loss, competition from introduced trout species, climate change, and over-fishing have reduced the population (Byorth, 1996; Montana River Action, 2008). In recent years, drought has resulted in lower river flows, increasing the challenge of maintaining minimum stream flows for healthy fisheries. Low-river flows also result in higher water temperatures, which provide an additional challenge for the fluvial Artic grayling.

Drought conditions are compounded by the withdrawal of water from the Big Hole River and its tributaries for irrigation. In the upper basin, water from the Big Hole River and its tributaries are diverted to mostly irrigate grass hay and for pasture. Hay irrigation typically begins in May and ends by mid-July while pasture irrigation may continue through September. Because of the short growing season there is only one cutting of hay.

The recreational industry is also impeded by low stream flows, and portions of the river are closed to fishing when critical flow levels and temperatures are reached. Although the fluvial Artic grayling have been removed as a candidate for listing under the Endangered Species Act (April 2007), there is still concern for their survival, and keeping as much flow in the river as possible during critical periods is essential in order to minimize impacts to fisheries and other stakeholder interests.

In addition to natural changes such as climate, the demand for water to meet various stakeholder interests has prompted the need to make informed decisions on how to best manage the limited water resources in the upper Big Hole River Basin. In 2006, the U.S. Fish and Wildlife Service implemented a program known as a Candidate Conservation Agreement with Assurances (CCAA) to provide protection for the grayling by enhancing in-stream habitat and assisting ranchers with irrigation management that may ultimately leave more water in the river.

Although aspects of the water budget have been examined in previous studies, the importance of flood irrigation and how and when it contributes return flows to the river is still not well understood. Return flow is a concept that has been used in recent years to explain the fate of excess ground-water flow

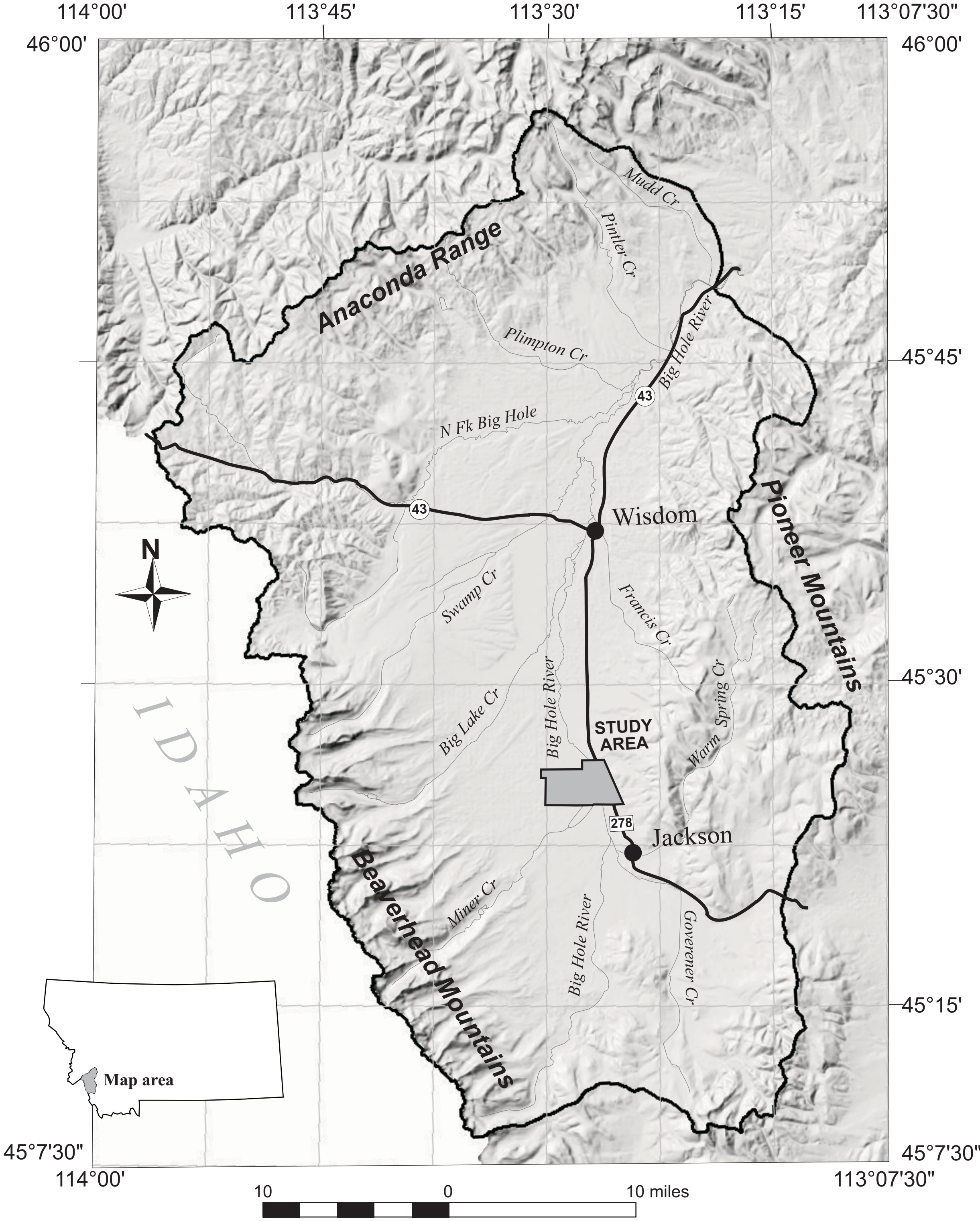



**Figure 1**. Location map for the upper Big Hole River basin. The upper Big Hole River basin encompasses about 1200 mi$^2$ above Mud Creek. The study area is about 2.5 miles north of Jackson, MT.

that results from flood irrigation. In the upper basin, irrigation usually starts in May and ends by early July. Ground-water levels rise at the onset of flood irrigation when water is put into storage in the shallow aquifer beneath irrigated fields. The premise is that excess water from flood irrigation recharges the local shallow aquifer and, after a period of time, returns to the river as ground-water discharge. The present perception is that without irrigation, river flows would be even lower or non-existent in the summer and fall.

The process of recharge to the shallow aquifers from flood irrigation is generally well defined but the fate of the ground water discharged from storage once flood irrigation ends is less understood. A water budget was approximated to help account for the water entering and exiting a study area north of Jackson, Montana. Further understanding of the ground-water – surface-water relationship can help ranchers, the Big Hole River Watershed Committee (BHWC), Big Hole River Foundation, fisheries biologists and recreationists make informed decisions on how to best manage the land and water resources.

**Purpose**

The purpose of this project was to investigate how ground water and surface water interact in order to provide a better understanding of the timing and magnitude of irrigation return flows to the Big Hole River. A study area was chosen to reflect conditions on the west side of the river as a complement to previous investigations that examined the interrelationship between ground water and surface water on the east side of the river.

A field area was selected based on the number of pre-existing wells and the ability to access surface water sites for measuring inflows and outflows to the study area. An important consideration was including the Big Hole River itself into the study area, which was lacking in previous investigations. Surface and ground-water data were collected during 2005 and 2006.

**Location and Physiography**

The upper Big Hole River Basin extends downstream to the Highway 43 bridge that crosses the Big Hole River below Mudd Creek (figure 1). In its upper reaches near Jackson, the river is a single thread and begins to divide into several channels about 4 miles downstream of Jackson. These channels braid but form a single channel again about 0.5 miles above the Wisdom Bridge, near Wisdom.

The upper basin is surrounded by three mountain ranges administered by the Beaverhead National Forest (figure 1). The Pioneer Mountains to the east reach altitudes of 9,000 feet. The crest of the Anaconda Range to the northwest forms a portion of the continental divide. The divide continues south into the Beaverhead Mountains which border the upper basin on the southwest. Altitudes in these ranges reach over 10,000 feet.

Along its length, the valley floor in the upper basin decreases in elevation from about 7,000 feet near Jackson to about 6,000 feet at the lower end of the upper basin in the vicinity of Mudd Creek. The valley is relatively broad and flat on the west side of the river with a width of up to 8 miles. The valley to the east of the river is narrower, averaging no more than three to four miles. The surface-water drainage is more extensive on the west side of the valley because of higher mountainous elevations. Perry (1934) noted that three times as many tributaries enter the basin from the west side than the east side. Major tributaries in the upper basin between Jackson and Wisdom include Miner Creek, Big Swamp Creek, Little Lake Creek, and Big Lake Creek which flow into the Big Hole River on its west side. Warm Springs Creek and Governor Creek are the major tributaries which drain into the Big Hole River on the east side.

**Previous Investigations**

Several water-resource investigations have been performed in the upper Big Hole River Basin. Those most relevant to this study are summarized in this section. The earliest documented work is that of Perry (1934). He postulated that the ancient Big Hole River drainage originally flowed south into Idaho during the middle Tertiary and subsequent uplift raised a portion of the valley floor south of Jackson reversing the flow of the river to its present direction. He described a shallow ground-water flow system within the uppermost 100 feet of the valley fill and a deeper system as evidenced by an artesian well in Jackson.

Levings (1986) assessed the upper Big Hole River Basin to provide baseline information on the ground and surface-water resources. Levings determined that surface water and ground-water quality were generally very good except for elevated iron concentrations in a number of wells. She identified three aquifers composed of Tertiary sedimentary rocks, Quaternary glacial outwash and Quaternary alluvium. Levings estimated that about 75 percent of the basin's discharge was lost through evapotranspiration.

Surface water/ground-water interactions were examined by Marvin (1997) to assess the effect of ground-water withdrawals from stock wells on the river flow. He determined that on an average, surface water diversions in the upper basin lost 0.6 cfs/mile to the shallow ground water through infiltration. Based on aquifer characteristics, he concluded that the use of stock wells would not have a significant impact on the basin's surface-water resource and that flood irrigation and surface-water diversions contribute significantly to near-surface aquifer recharge.

Several graduate studies were initiated through Montana Tech of the University of Montana. Phillip (1999) investigated the changes in water quality resulting from irrigation at four study sites, one of which was located in the upper basin. Samples were collected upstream and downstream of irrigated pastures. She concluded that there was no dramatic change in water quality between irrigation and return-flow water. She did note however, a general warming of about 4 degrees between influent and effluent waters but it was unclear if this warming would occur in the absence of irrigation.

Ridenour (2002) examined field parameters and sampled for cations, anions and nutrients at nine locations along the Big Hole River (three were located in the upper basin). Diurnal (24-hour) measurements of pH and dissolved oxygen showed that maximum pH and dissolved oxygen values occurred in the late afternoon and early evening and minimum values occurred in the early morning. This response was attributed to the photosynthesis/respiration processes of stream periphyton. In the upper basin, exceedances of iron and manganese standards in the Big Hole River were attributed to ground-water inflows. Field parameters indicated that the surface water is cold, alkaline, and mildly buffered with fairly low total dissolved solids.

Water-quality characteristics were measured diurnally (hourly for a 24-hour period) at several sites along the main stem Big Hole River. Wenz (2003) was able to discern the effects of photosynthesis by an increase in pH levels during the day and a decrease during the night. pH varied by as much as two log units. Variations in pH were driven by changes in dissolved oxygen and carbon dioxide levels due to photosynthesis. Temperature variations were shown to be dependent on the weather. Diurnal variations were noted for some trace metals such as manganese, strontium, barium, iron, phosphorous and arsenic, in addition to major solutes such as calcium, carbonate and bicarbonate. Diurnal variations were attributed to changes in pH resulting in the sorption and desorption of metals and associated changes to the carbonate-bicarbonate balance

Marvin and Voeller (2000) performed an investigation of the Big Hole River Basin during 1997 and 1998 to document the effects of irrigation on the basin's water budget. In the upper basin, the Francis Creek area located just south of Wisdom, Montana on the east side of the river, was studied intensively. A water balance for this area indicated that irrigation return flows to Francis Creek occurred for only 4 days in June, with evapotranspiration consuming all water accountable to precipitation, surface-water flow loss, and water released from ground-water storage. This implies that ground water released from storage did not directly help increase surface water flow. Since data were only collected through September, Marvin and Voeller (2000) postulated that after the growing season (October) return flows might be available to augment stream flows. Similar results were noted in the lower Big Hole River Basin.

Abdo and Metesh (2005) examined an area which included a portion of the Francis Creek drainage. A computer model based on field data collected during 2003 indicated that the groundwater component of the water budget was too small to be of measurable significance to "return flow". The model was most sensitive to evapotranspiration. The timing of irrigation return flow was not directly addressed by this investigation.

## STUDY AREA

### Description

The study area is about 3 miles north of Jackson and encompasses about 10 $mi^2$ (figure 2). The valley is about 5 miles wide on the west side of the river and only about a mile wide on the east side. The study area is bounded by roads on the north, east and south, which made access for field measurements easier. Highway 278 provided a convenient border for measuring inflows into the floodplain from the east side of the valley. The boundary of the study area on the east was located upgradient of the domestic/stock wells monitored during this project.

The study area includes about 3 miles of the Big Hole River. Within this reach, the channel varies from a single thread to a braided river system. Meander scars, indicating a historically active channel, are evident from aerial photography and from scouting the area on foot. There are no active irrigation diversions on the river in this reach. Water for irrigation is obtained by diverting water from tributaries to the Big Hole River.

In this reach, the South Branch of Big Swamp Creek, Little Lake Creek and Miner Creek are the main tributaries that flow into the river on the west side; along with several smaller seeps. There are no major tributaries on the east side of the river; however, some surface water inflow occurs from seeps, springs, and drainage from the upland area east of the highway. Just up gradient of Petersons Bridge, a larger inflow on the east side of the river is derived from seepage off the upland area east of the highway and from drainage further upstream outside of the study area.

### Climate

Average annual precipitation at Jackson, Montana is 12.1 inches based on a 37-year period of record (Western Regional Climate Center, 2007). Figure 3 shows the departure from the average annual

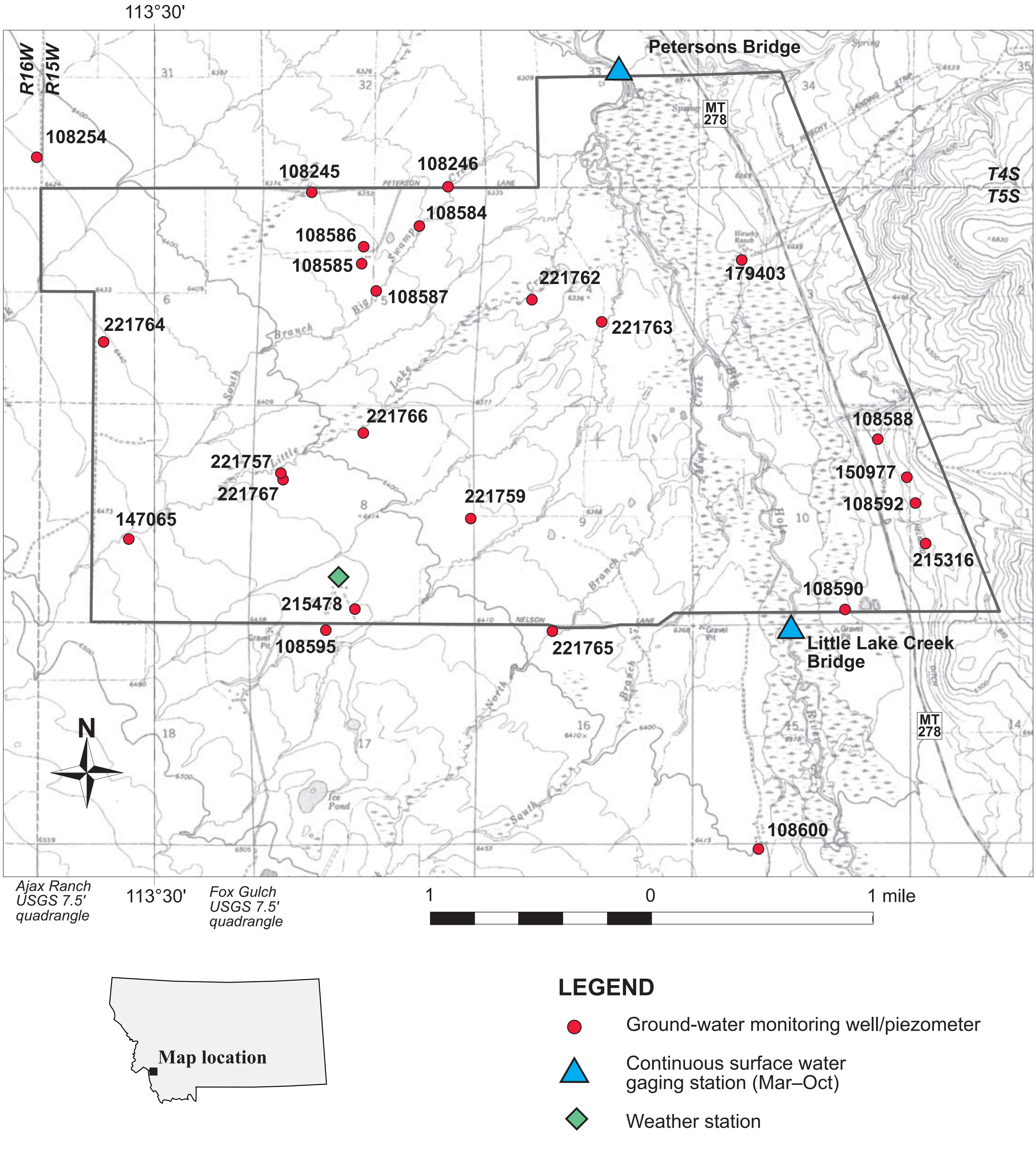
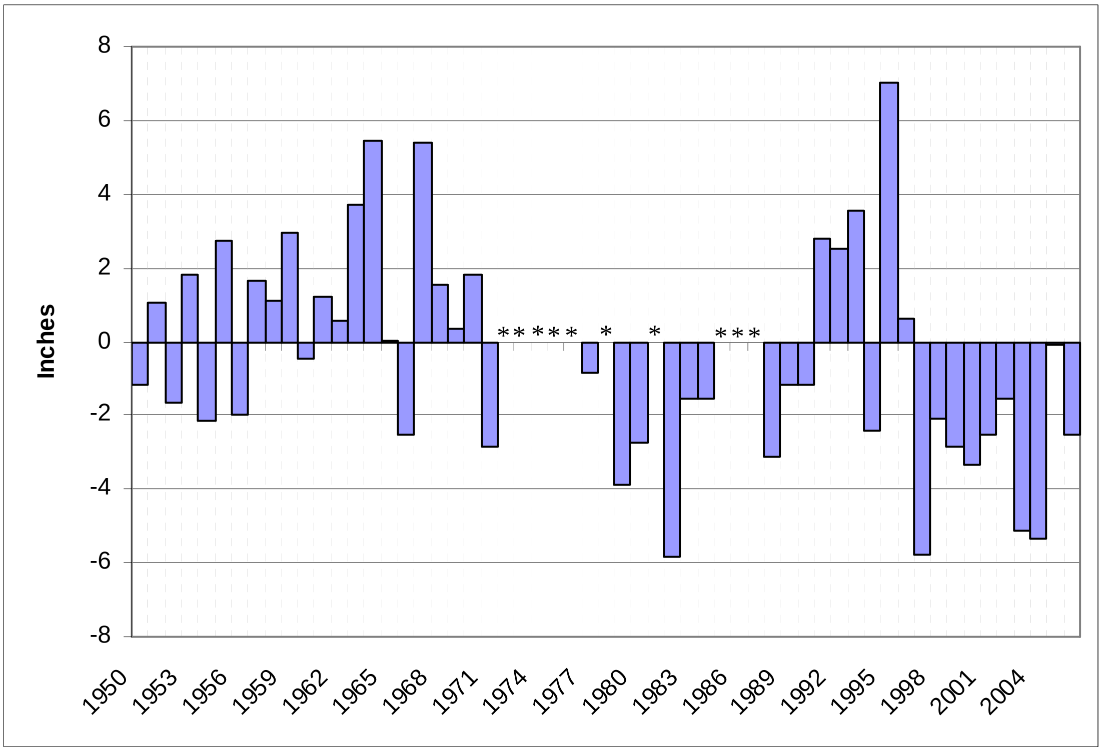



**Figure 2.** There are about 25 wells and 2 surface-water gaging stations in the 10 mi$^2$ area.

precipitation. The graph shows that although there are 10 years of missing data, below average precipitation is prevalent from 1979-1984 and 1997 to present. The latest drought spans a 10-year period. The average maximum temperature over the period of record occurred in August (76.3° F) and the average minimum temperature occurred in January (6.2° F). The average total precipitation during the growing season (April – October) was 8.65 inches. During the fall 2004 and winter 2005 conditions were dry in the Big Hole Valley with precipitation at Jackson about 34 percent of average. Peak snowpack was at 52 percent of average (NRCS, 2007). Precipitation during the growing season (April – October) was near average at 8.73 inches.




Average annual precipitation over a 37 year period was 12.10 inches at Jackson, Montana
* Not enough data to determine the departure from normal

**Figure 3.** A graph of the departure from the average annual precipitation at Jackson, Montana illustrates the below-average annual precipitation during the past 10 years.

Fall 2005 and winter 2006 were wetter with precipitation in the valley at 94 percent of normal precipitation and a snow pack at 103 percent of average. The wetter fall and winter allowed ranchers to start irrigating a couple of weeks later than in 2005. Precipitation during the growing season (April – October) was 7.80 inches or about 90 percent of normal.

**Geology**

The Big Hole Basin lies within the thrust belt of the Northern Rocky Mountain physiographic province, which is characterized by numerous mountain ranges and intermontane valleys. The mountains surrounding the upper Big Hole River Basin are predominantly uplifted Proterozoic (2,500 –543 million years ago (mya)) and Cretaceous (144 – 65 mya) sedimentary and igneous rocks. The Beaverhead Mountains are composed mostly of Middle Proterozoic quartzites and siltites. The geology is similar in the Pioneer Mountains, but the rocks also contain Cretaceous granite and granodiorite of the Pioneer batholith. The batholith was emplaced about 90 to 70 million years ago.

The valley fill in the upper basin consists of thin (<150 ft) deposits of Quaternary glacial till, outwash, and alluvium, which overlie Tertiary sandstone and siltstone. The thickness of the Tertiary fill in the upper basin between Wisdom and Jackson is estimated at more than 16,000 ft (Hanneman and Nichols, 1981).

A geologic map for the study area is shown in figure 4 and presented in cross section in figure 5. Tertiary sediments form the surficial deposits on the east side of the study area. During the Tertiary, Perry (1934) postulated that the ancient Big Hole River flowed south into Idaho. According to Perry, uplift during the later part of the Tertiary raised the floor south of Jackson, resulting in ponding water that formed a lake. Lake sediments consisted of silts and fine sands intermixed with ash deposits. The ash deposits were probably generated about 50 million years ago when widely scattered volcanoes erupted in parts of Montana. Examination of an outcrop in the study area on the east side of Highway 278 indicates that it consists of volcanic tuff (Berg, 2006; figure 6). Perry (1934) used this outcrop as one of the examples of the Tertiary lake deposits. Stream piracy and faulting probably contributed to the rivers' drainage reversal to the north during the later part of the Tertiary (5.3 to 1.8 million years ago) (Ruppel, 1967).

On the west side of the valley, mountain glaciation during the Pleistocene deposited till along the mountain flanks and glacial outwash along the valley center (figure 4). These deposits overlie Tertiary sediments. The glacial outwash consists of gravels, sands, silts and clay interbeds and is about 40 to 100 feet thick in the study area. The cross section (figure 5) shows that the wells are completed in a basal sand and gravel unit which is believed to overlie the Tertiary sediment. The thickness of this basal sand and gravel is unknown.

As the Big Hole River continued aggrading and eroding, it incised the older Tertiary and Pleistocence deposits. More recent Holocene (10,000 years ago to present) silts, sands and gravels are present in the stream banks and vicinity of the Big Hole River and its tributaries.

**Data Collection**

A well inventory was performed to determine the accessibility of pre-existing stock and domestic wells for the ground-water monitoring network. In addition, seven shallow piezometers (deepest piezometer was 15 feet deep) were installed to examine the shallow ground-water flow system and help fill spatial voids in the monitoring network. The ground-water monitoring locations are shown in figure 2. Ground-water measurements were made in 24 wells/piezometers once a month and every two weeks during the growing season (April – October) during 2005 and 2006. Ground-water measurements are included in appendix A.

Two aquarods were installed on the Big Hole River by the Department of Natural Resources and Conservation (DNRC) to provide a continuous record of surface water flow. The locations of the aquarods are shown in figure 2. The Aquarod at the outflow (Petersons Bridge) has been monitored by the DNRC since 2002. For the purposes of this study, a second aquarod at the south end of the study area was installed in 2005 to measure Big Hole River inflow at Little Lake Creek Bridge. These surface-water measuring devices record stage which is then converted to flow. These sites were monitored in the spring through the fall. Winter conditions, which cause the river to freeze in some locations, prevent monitoring stream flow through the winter.

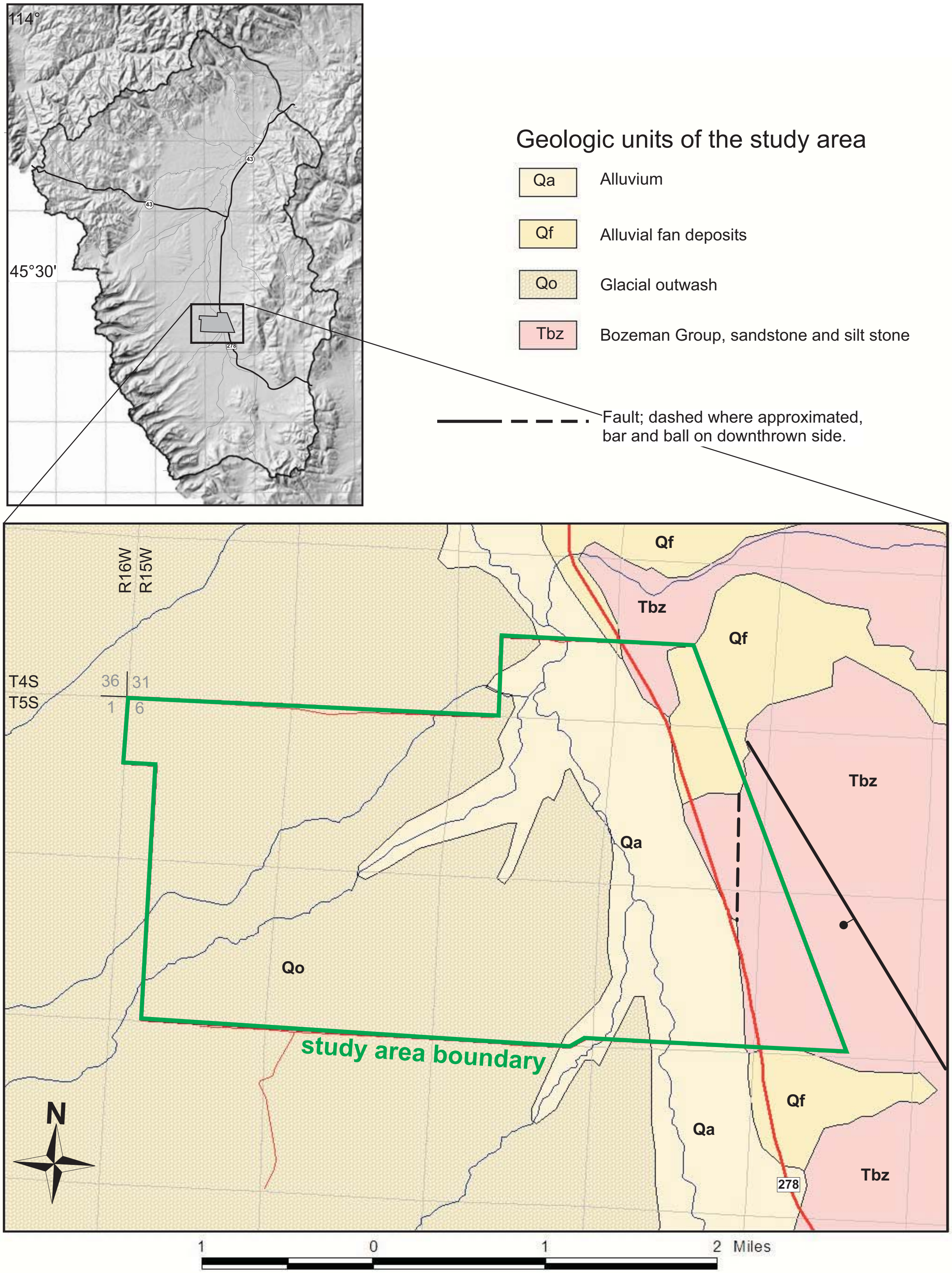



Figure 4. Geologic map of study area (modified from Ruppel and others, 1993). Note glacial outwash forms the surficial deposits on the west side of the river and Tertiary sediments (Tbz) are present in the upland areas east of the river.

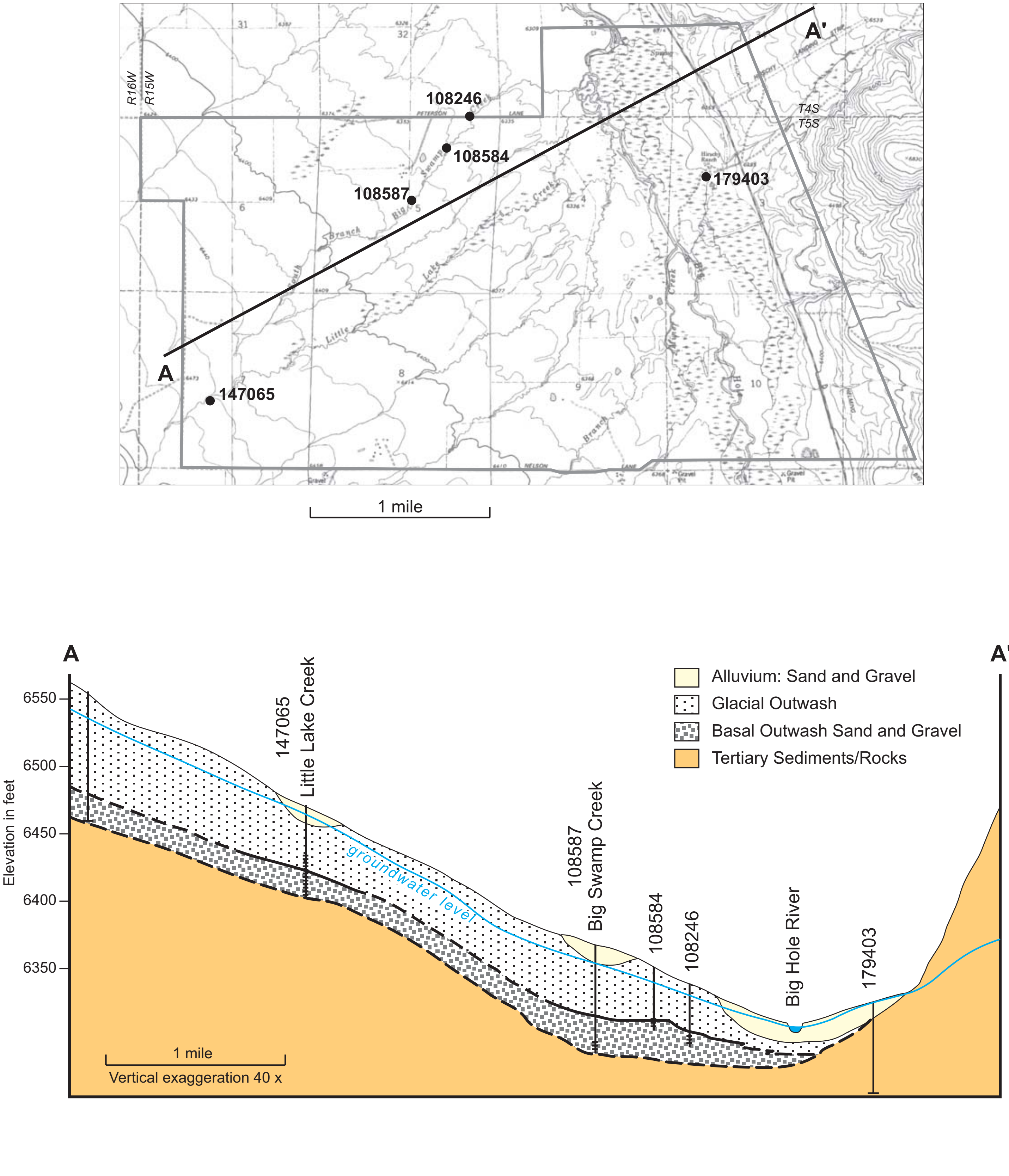



**Figure 5.** This schematic geologic cross section postulates a basal outwash sand and gravel that may overlie the Tertiary sediments.

**Figure 6.** This photograph shows an exposure of Tertiary tuff exposed in a highway cut on the east side of the study area.

Monthly synoptic runs in which ground water and surface water were monitored on the same day were performed from June – October 2005 and May – October 2006. These measurements were made by walking/driving the river floodplain to measure flows in all seeps/springs in addition to the tributaries that drain into and out of the river directly. In addition, surface water inflows and outflows were also measured along the road that bounded the study area – providing good access and reliability to the measurements. During the June synoptic runs, when flood irrigation was at its peak and the mosquitoes were at their worst, this was a daunting task. Wells monitored during this project were denoted by the letter M followed by a six-digit number. Information on these wells can be found in the Montana Bureau of Mines and Geology Ground Water Information Center (GWIC) database and can be accessed on line at http://mbmggwic.mtech.edu/. In October 2006, eight wells were pumped from about 1 to 8 hours to estimate transmissivity of the aquifer. During this time, pH, specific conductance, iron and nitrate concentrations were measured in the field at 14 locations including the Big Hole River at Little Lake Creek and Petersons Bridge. Samples were collected for nitrate in 13 wells and were sent to the Montana Bureau of Mines and Geology analytical laboratory for analyses. One well had a full suite of cations and anions (M: 108595) and three wells (M: 108585, M: 215478, M: 179403) were analyzed in the lab for iron and arsenic.

A Campbell Scientific CR10 weather station was installed on site (figure 2). Parameters measured included air temperature, precipitation, wind speed and direction, shallow soil temperature, solar radiation, barometric pressure, relative humidity, and net radiation. The instrument was programmed to collect readings once a minute and to average the previous 60 readings for each sensor once an hour.

Marsh-McBirney electromagnetic flow meters were used to measure flow in streams, springs and ditches. Measurement accuracy was considered fair to good and therefore within 5 to 8 percent accuracy (Roberts, 2006). A Sokkia Locus survey-grade Global Positioning System Receiver was used to survey the ground water and surface water monitoring locations. This instrument has a horizontal accuracy of 0.039 feet and a vertical accuracy of 0.049 feet (Uthman, 2006).

## RESULTS

### Surface Water

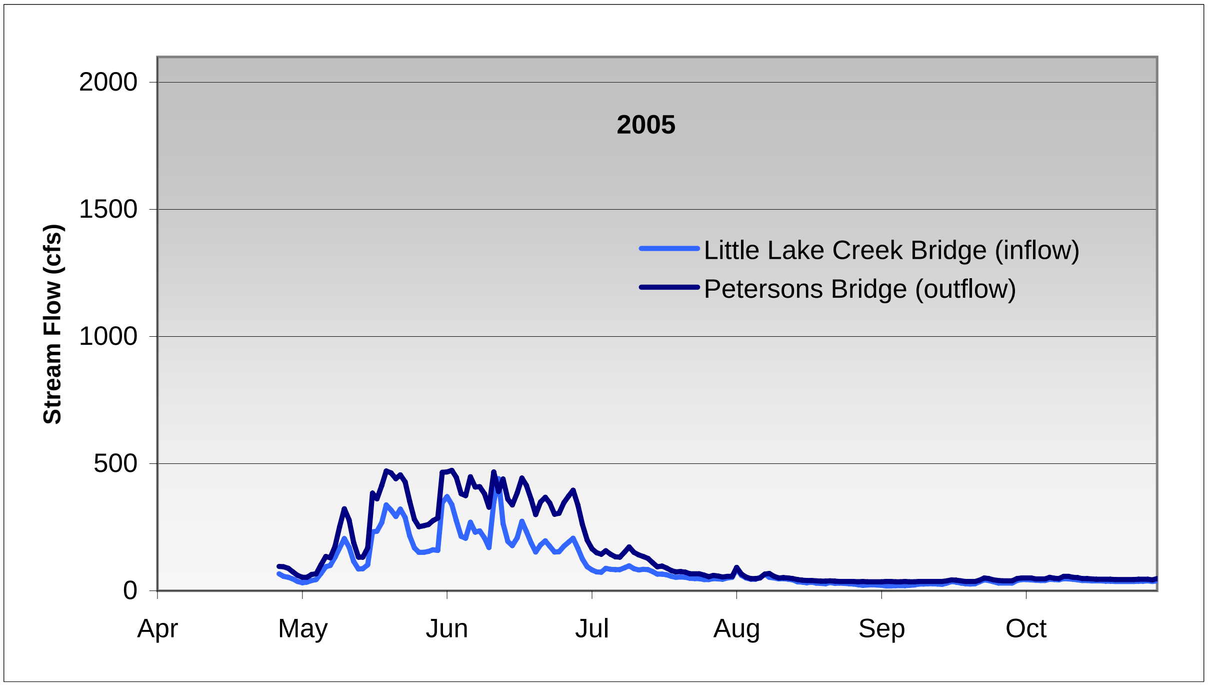
Surface-water flow measured during 2005 and 2006 on the Big Hole River at the inflow and outflow locations in the study area are plotted in figure 7. Flow data are included in appendix B. The hydrograph for 2005 was more subdued than the 2006 hydrograph; no flows exceeded 500 cfs. In 2006, peak flows exceeded 1000 cfs on three occasions. These hydrographs illustrate that outflows exceed inflows in this reach. Based just on the Big Hole River flow at Little Lake Creek Bridge and Petersons Bridge it appears the river is gaining water in this reach. This concept is examined more closely in the water-budget section which considers all the surface-water inflows and outflows to the study area.

Figure 8 shows stream flows during 2005 and 2006 at Petersons Bridge and precipitation data obtained from the Western Regional Climate Center weather station in Jackson. Total precipitation from April – October was 8.73 inches in 2005 and 7.80 inches in 2006. Although precipitation does provide recharge to the surface water, the correlation between precipitation and stream flow is not always easy to discern. Figure 8 shows that precipitation helped sustain stream flows during May and June 2005. In 2006 stream flow peaks do not necessarily correlate with precipitation – in fact there was a lack of precipitation in May, however, the stream flow hydrograph shows a peak that exceeds 1000 cfs around May 21.

A closer look at the snow water equivalent (SWE) data obtained from the Calvert Creek and Darkhorse Lake SNOTEL sites (NRCS, 2007) helps explain the late spring/early summer stream flow patterns. SWE is the amount of water content that would result from melting accumulated snow. The greater the snowpack the higher the SWE. Calvert Creek is located about 18 miles north of Wisdom at an elevation
of 6430 feet and reflects lower elevation snowpack. The Darkhorse Lake SNOTEL site is located 13 miles southwest of Jackson at an elevation of 8600 feet, and is a good indicator of high-elevation snowpack.

SWE was plotted in conjunction with stream flow in figures 8 and 9. Peak snowpack in 2005 was 52 percent of normal; with a maximum SWE of just over 25 inches. The 2005 hydrograph in figure 8 is reflective of steady but low-volume snowmelt. By mid-April 2005 the lower elevation snowpack had already melted off and the higher elevation snowpack (Darkhorse Lake) was gone by the end of June. Because of the below average snowpack, less water was available to the river from snowmelt. Flows in May and June, were sustained above 200 cfs, and most likely were supplemented by the 3.64 inches of precipitation that was recorded over the two-month period at the Jackson weather station.

The 2006 peak snowpack was 102 percent of normal and reached a maximum SWE of about 35 inches at the higher elevations. In 2006, warm spring air temperatures resulted in an early snowpack melt during late May and early June. The stream flow peaks in April and May (figure 9) are mainly associated with snowmelt, while the peak in mid-June is a function of snowmelt and an intense precipitation event. The lower elevation snowpack began melting in mid-April corresponding to the mid-April peaks in stream flow in the river. The higher elevation snowpack began melting in early May and was completely melted off by mid-June. The combination of mid-June snowmelt and the 3.03 inches of precipitation



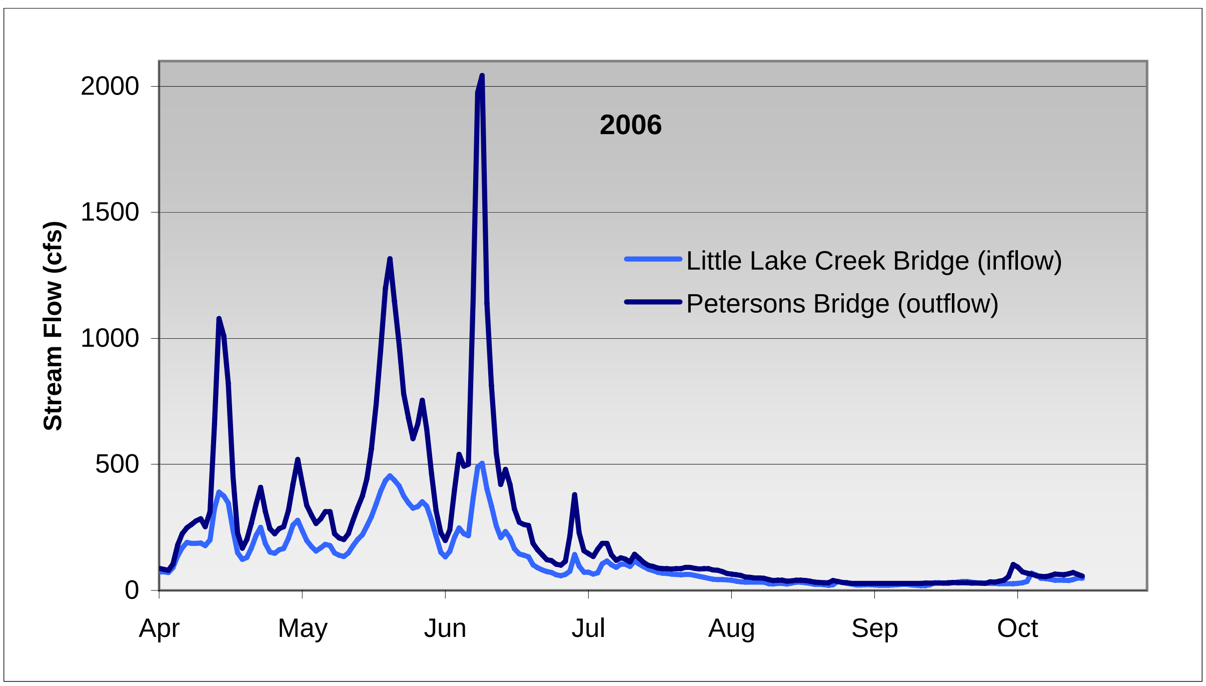
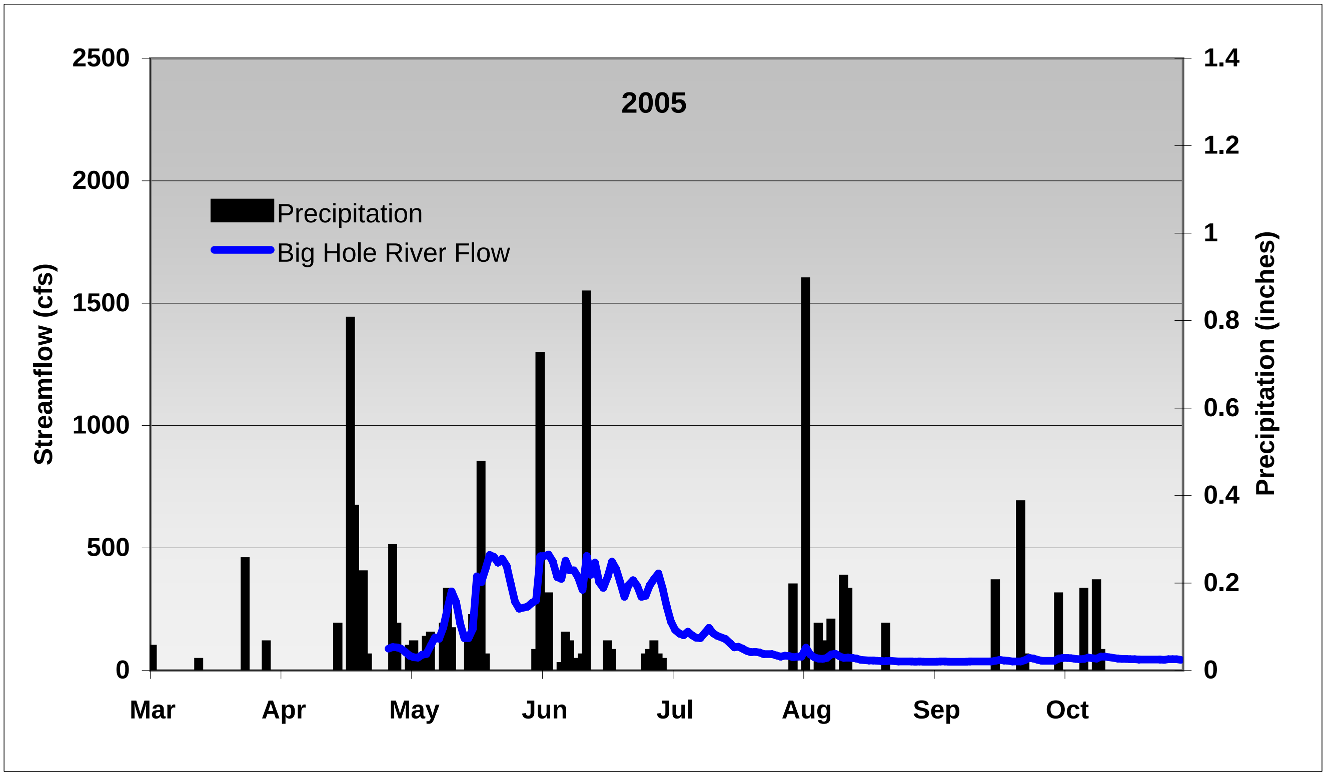




**Figure 7.** Stream flow in the Big Hole River at the inflow and outflow locations in the study area.



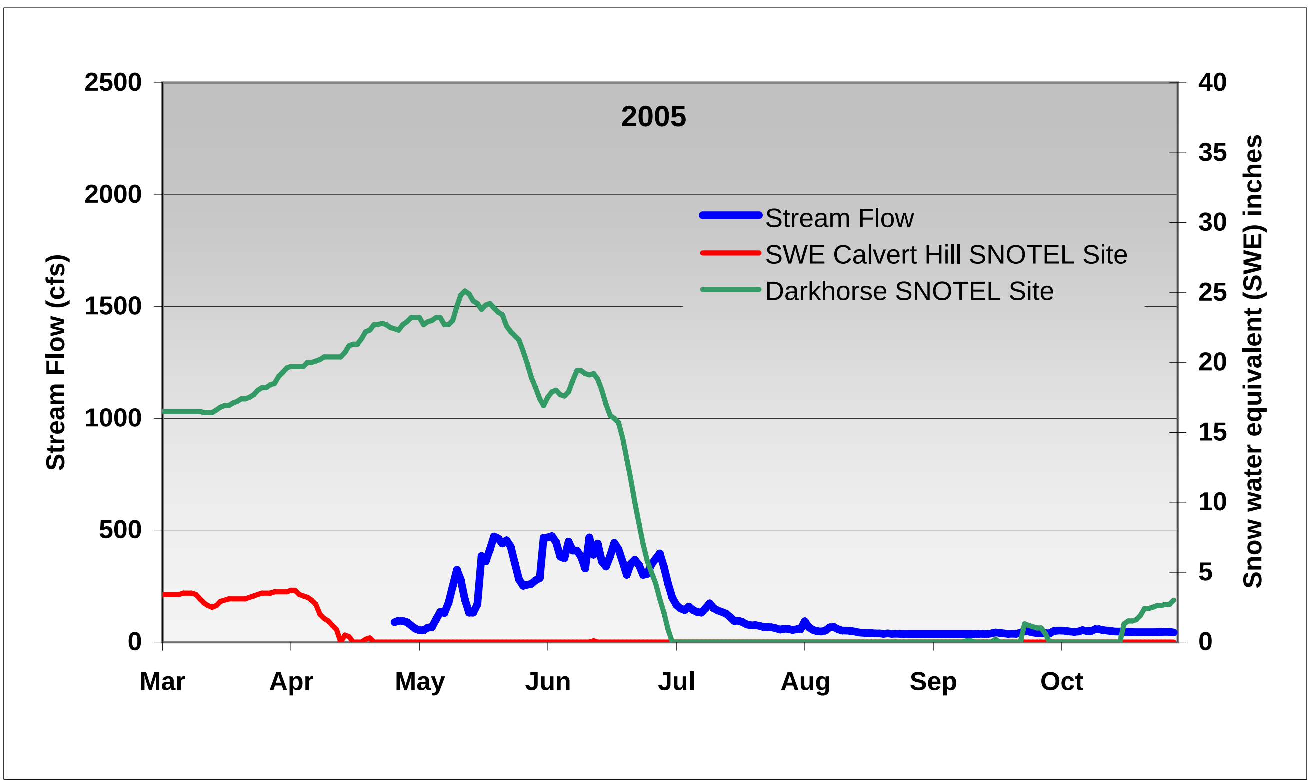
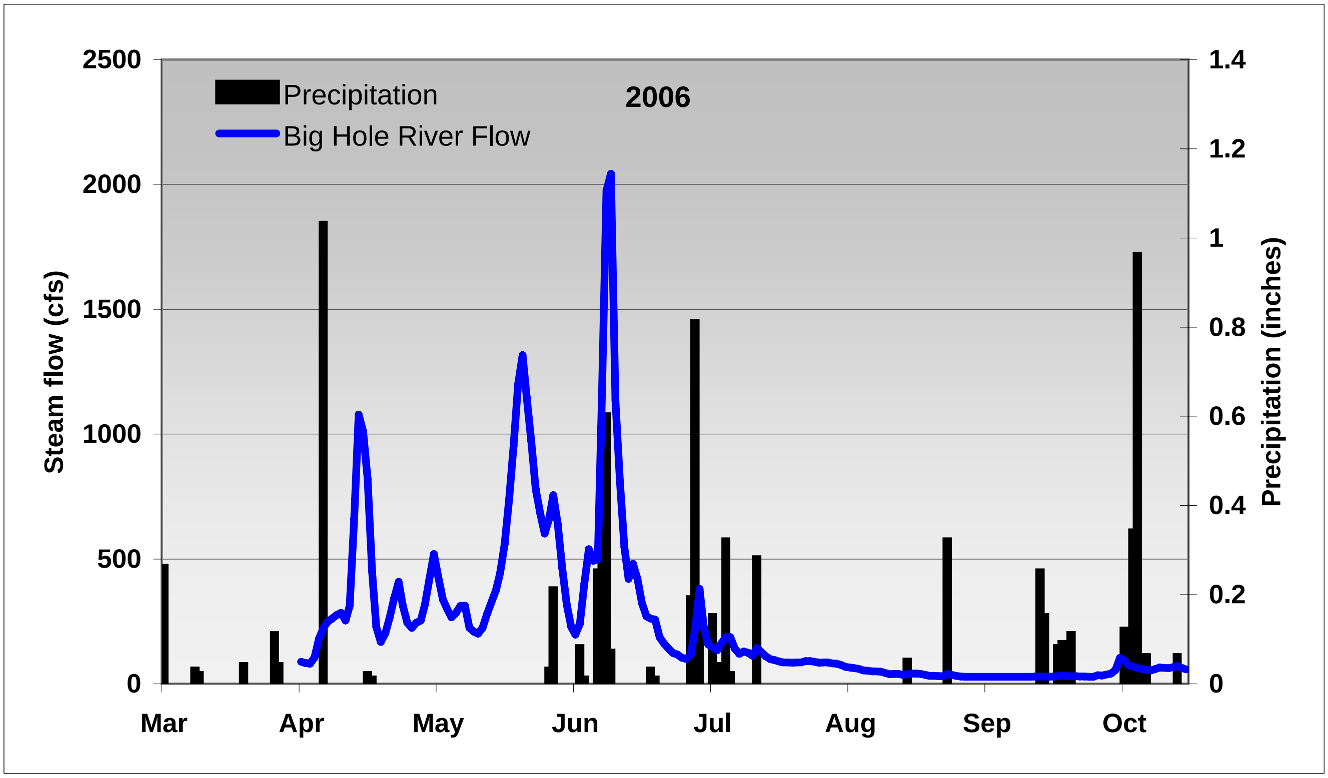




**Figure 8.** These graphs show the relation between stream flow, precipitation and snow water equivalent from SNOTEL sites. Note the final decline in the snowpack and the decrease in stream flow.



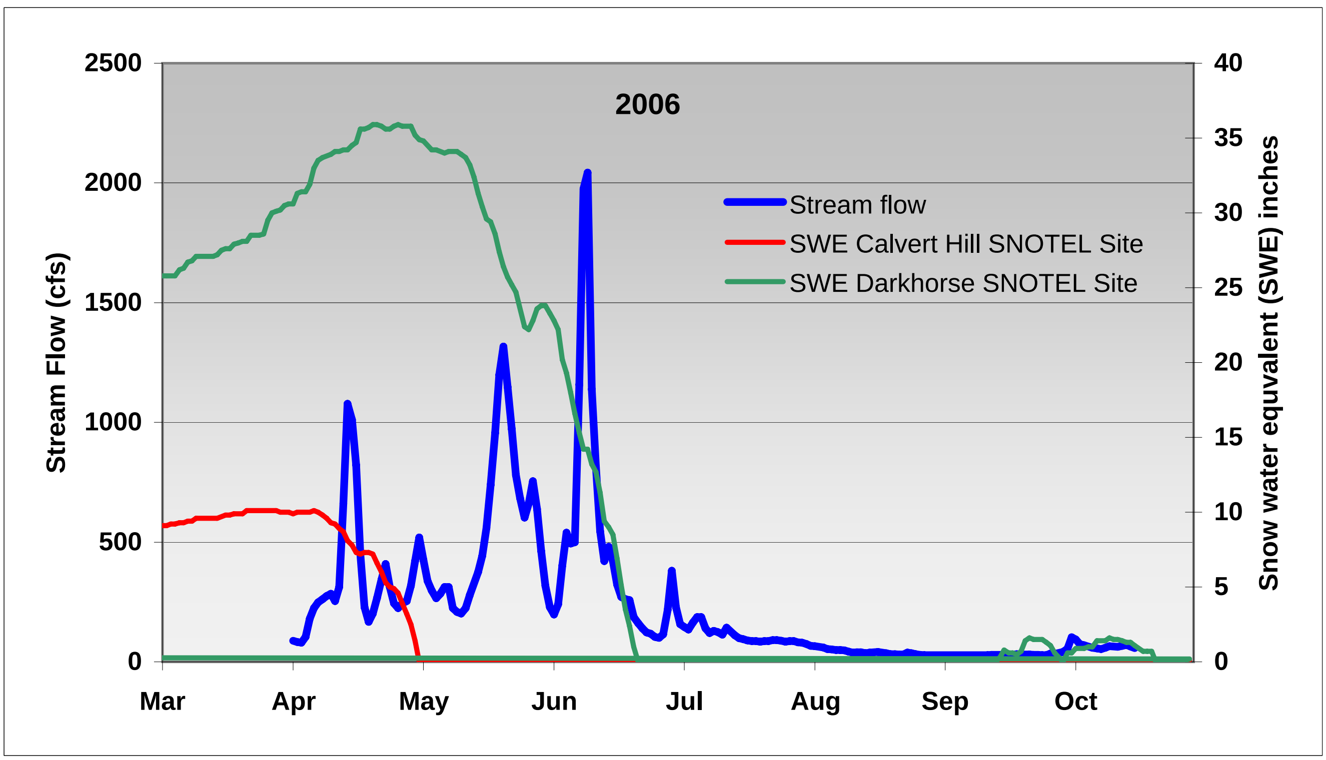




**Figure 9.** These graphs show the relation between stream flow, precipitation and snow water equivalent from SNOTEL sites in 2006. The late spring and early summer hydrographs are reflective of the melting snow pack at higher elevations.

that fell during a two-day period, along with saturated valley bottom conditions resulted in an extremely flashy response in the hydrograph.

During the later part of the summer, when conditions are drier, precipitation is most likely lost to evapotranspiration. The drier soils hold the water making it less available for recharge to the ground water and surface water. This is noted during the late summer/fall 2005 and 2006 surface water hydrographs. Baseflow during this period ranges from 20 to 60 cfs in this section of the river.

**Ground-Water Fluctuations**

Ground-water levels range from above surface (artesian flow) in well M: 179403, located close to the Big Hole River, to 90 feet below the surface in well M: 150977 located on the hillside adjacent to the river. (See figure 2). Table 1 includes the amount ground water fluctuated over the period of record (period varied from May-November 2004 to October-December 2006). Fluctuations ranged from 2.13 to 28.90 feet in 21 wells/piezometers in the study area. The median value was about 6 feet. The greatest fluctuations (greater than 16 feet) occurred in the wells completed in Tertiary sediments, most of which are located in the upland area on the east side of the river. These wells are located within 100 to 200 feet of the Helming Ditch and a second ditch about 0.3 miles further up the mountainside. The greater ground-water fluctuations may be the result of increased recharge coming into this area and/or a function of the hydraulic conductivity (median value of hydraulic conductivity estimated at 5.9 ft/day, Marvin and Voeller, 2000) and lower aquifer storativity.

Two wells located on the west side of the highway, M: 215478 and M: 221757 (figure 2), had fluctuations of 15.90 and 15.10 feet respectively. Both these wells were assumed to be completed in glacial outwash, however, there is no well log for M: 221757 and the driller lumped the geology as gravels and silt from 26 to 80 feet (the depth of the well) in well M: 215478. The smallest fluctuations (two to three feet) occurred in three piezometers located close to streams (M: 221765, M: 221762 and M: 221766). The ground-water levels at these locations are probably controlled by the stream stage. A ten foot fluctuation noted in piezometer M: 221759 was anomalous – this piezometer is about 13 feet deep and water ponded around the well during flood irrigation. Ground-water fluctuations in wells completed in the Quaternary sands and gravels/outwash ranged from 4 to 10 feet.

**Ground-Water Response Over Time**

Ground-water hydrographs, illustrating ground-water levels over time, are included in appendix C. Although in general, the ground-water pattern is often predictable, each hydrograph has its own unique signature. Ground water response depends on climatic conditions, location of the monitoring well within the watershed, type of geologic material in which the well was completed and the hydraulic characteristics of the aquifer. In the upper Big Hole River Basin the ground water response was dominated by flood irrigation. Well M: 221763 is a shallow 15-foot-deep piezometer and its hydrograph (figure 10) is used to illustrate the general response to the ground water.

The lowest ground-water levels occurred during the late fall through early spring (figure 10). In 2005, the bulk of the snowmelt at the lower elevation occurred between March 27 and April 2, recharge from snowmelt is not reflected in the hydrograph during this period. This is most likely due to the low snowpack in 2005, with a SWE of 3.7 inches (compared to 10.1 inches in 2006 at the Calvert Creek SNOTEL site). The snowmelt, therefore, most likely compensated for the soil moisture deficit and did not contribute noticeably to ground water.

Table 1. Fluctuations in ground water over the period of record. (See figure 2 for monitoring well locations.)

| ID No. | Geologic Material | Total Depth (ft) | Fluctuation over period of record (ft) |
|---|---|---|---|
| 221765 | Sand/gravel (Holocene) | 9.40 | 2.13 |
| 221762 | Sand/gravel (Holocene) | 14.00 | 3.02 |
| 221766 | Sand/gravel (Holocene) | 14.50 | 3.34 |
| 108245 | Glacial outwash (Pleistocene) | 105.00 | 4.02 |
| 147065 | Glacial outwash (Pleistocene) | 68.00 | 4.41 |
| 108254 | NA* | 10.00 | 4.66 |
| 221764 | Glacial outwash (Pleistocene) | 15.30 | 4.73 |
| 221767 | Sand/gravel (Holocene) | 15.30 | 4.84 |
| 108246 | Glacial outwash (Pleistocene) | 45.00 | 5.70 |
| 221763 | Glacial outwash (Pleistocene) | 15.40 | 5.84 |
| 108584 | Glacial outwash (Pleistocene) | 48.00 | 6.11 |
| 108587 | Glacial outwash (Pleistocene) | 68.00 | 6.18 |
| 108595 | Glacial outwash (Pleistocene) | 43.00 | 6.78 |
| 108585 | Glacial outwash (Pleistocene) | 112.00 | 6.93 |
| 108586 | NA | 64.00 | 9.99 |
| 221759 | Glacial outwash (Pleistocene) | 13.00 | 10.05 |
| 221757 | Glacial outwash (Pleistocene) | 70.00 | 15.10 |
| 215478 | Glacial outwash (Pleistocene) | 80.00 | 15.90 |
| 108590 | Sediments (Tertiary) | 75.00 | 16.57 |
| 150977 | Sediments (Tertiary) | 115.00 | 19.83 |
| 108588 | Sediments (Tertiary) | 95.00 | 22.59 |
| 108592 | Sediments (Tertiary) | 99.00 | 23.77 |
| 215316 | Sediments (Tertiary) | 100.00 | 28.90 |
| | | **Median** | 6.18 |

NA: Not available

Water levels began to rise the first week of May in response to flood irrigation. Water levels rose about 1 ft in the three week period following the onset of irrigation. Once the ground was saturated and soils reached field capacity, ground-water levels rose about 5 feet in the two week period between May 24 and June 10, 2005. Melting of the higher elevation snow pack occurred around mid-June so the effects of any associated recharge were masked by flood irrigation in the valley.

The ground-water pattern during the 2006 season shows the influence of natural recharge from the lower elevation snow melt. Water levels rose 1.5 feet from March 27 to April 11 corresponding to the snow pack turnover that occurred around the first week in April. The snow pack was greater in 2006 (103 percent of normal) than 2005. Water levels then receded as noted by the measurement made on June 1, 2006. Flood irrigation started during the last week in May – first week in June. During the first three weeks, the water level rose about 4.5 feet, this increase was greater than the first three weeks of irrigation noted in 2005. The natural recharge component and wetter conditions noted in 2006 and not in 2005 were probably enough to saturate the soils prior to flood irrigation resulting in a faster rise in ground-water levels. The effects of recharge from the higher elevation melting snow pack, which occurred around June 4, were masked by flood irrigation.

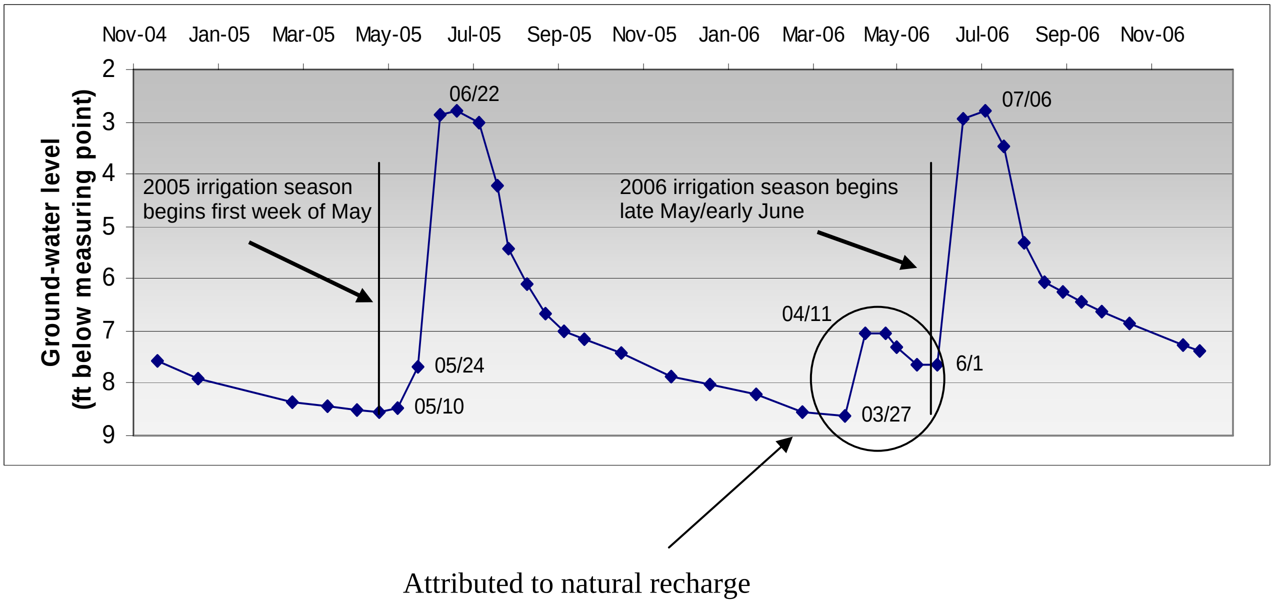


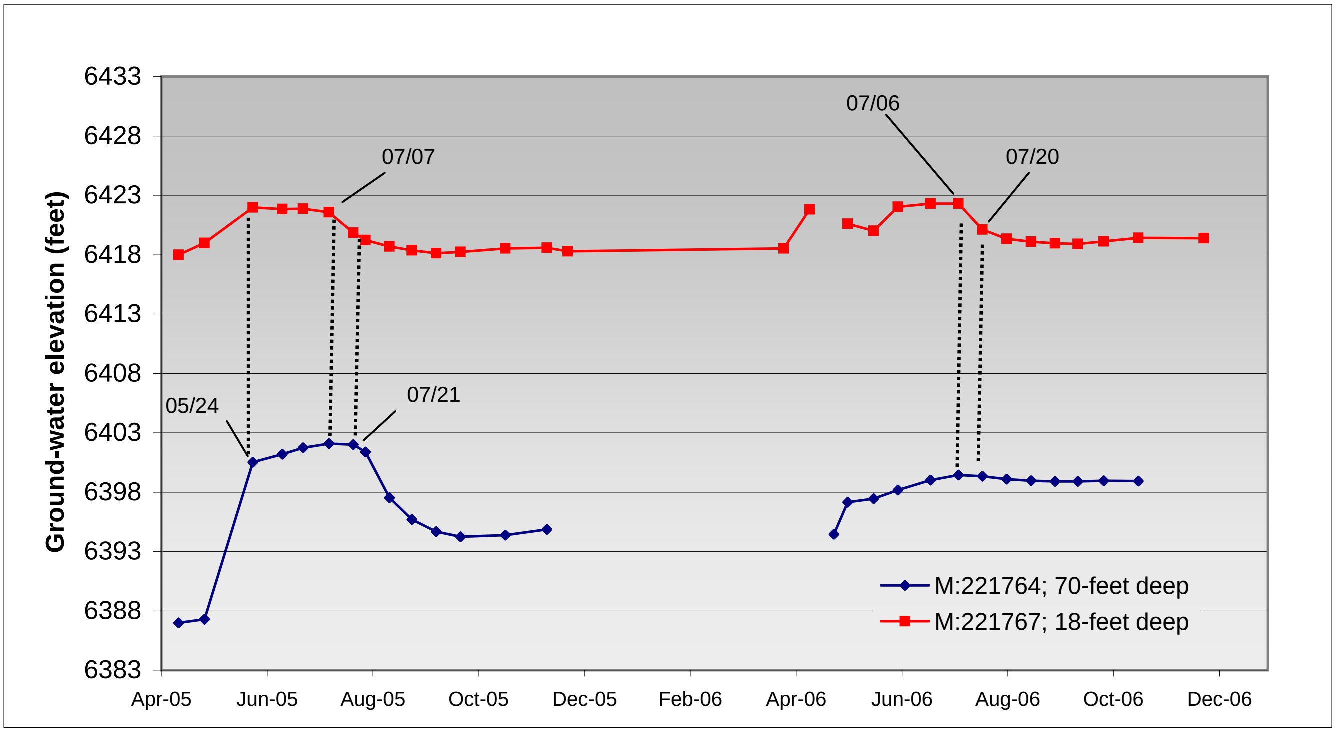

**Figure 10.** Ground-water hydrograph for well M: 221763 illustrating the general response of the ground water to climatic conditions and flood irrigation.

Ground-water levels remained high during irrigation and receded once flood irrigation ends during the first week in July 2005 and 2006. Although water levels did not recede to the 2005 pre-irrigation level until February 2006, the bulk of the ground water in storage (about 90 percent) was released from storage by mid-October.

### Shallow and Deeper Ground-Water Flow Systems

The response of the shallow and deeper ground water was examined in two different well pairs (figure 11). The first pair, piezometer M: 221767 (18 feet deep) and well M: 221757 (70 feet deep), were located less than 200 feet apart (figure 2). During 2005, ground water fluctuated about 15 feet in the deeper ground water compared to about 4 feet in the shallow ground-water flow system. This may be due to the control of Little Lake Creek on shallow ground water, which is located about 200 feet from the wells. The greater rise in ground-water levels in the deeper ground-water flow system could also be due to a lower specific yield in the deeper aquifer.

In 2005, ground-water levels peaked on May 24 and remained elevated throughout the irrigation period. Ground-water levels in the deeper flow system increased by about 13 feet from April 22 to May 24 but did not peak until July 7, 6 to 8 weeks after the onset of irrigation. Water levels began to decrease by the first week in July, once flood irrigation had ceased, and declined to pre-irrigation levels by early September in the shallow ground-water system. Ground-water levels in the deeper well were still about 8 feet higher than the pre-irrigation levels as late as the beginning of November. Unfortunately, well accessibility prevented the collection of data through the winter months at this location. Note the 2-foot decline from July 7 to July 21 in the shallow ground water and only 0.1-foot decline in the deeper



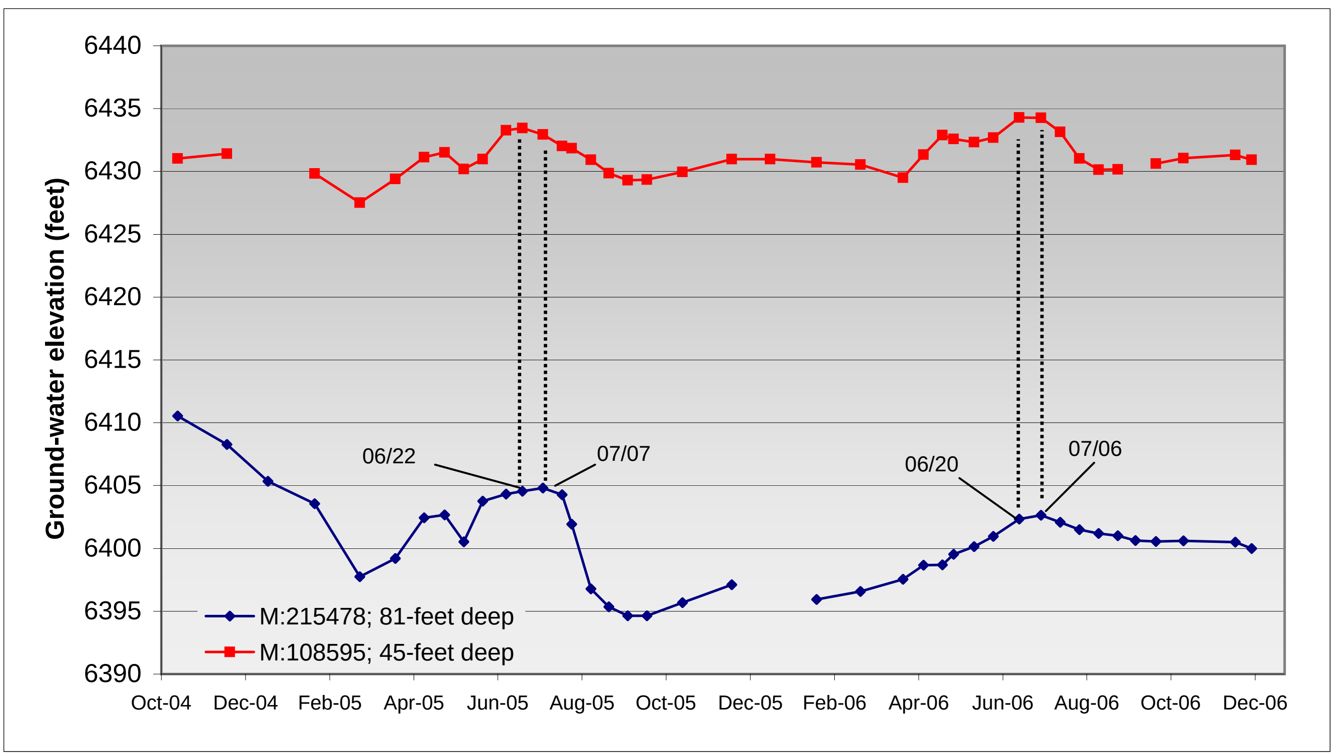




**Figure 11.** These two graphs illustrate the ground-water response in a shallow (M:221757) and deep well (M:221767). The bottom graph illustrates the response in a intermediate depth well (M:108595) and deeper well (M:215478).

flow system during this same time period. Ground-water storage loss from the deeper ground-water system lags behind the shallow system but levels out by mid to late September. During 2006, water levels remained within 0.5 feet of the irrigation peak in the deeper ground-water system as of mid-October, while in 2005 water levels during this same time period decreased about 8.5 feet. This suggests that some additional recharge was replenishing ground water, off setting the decline. Ground-water levels increased by about 3.5 feet in the shallow ground-water system during the irrigation season. A pre-irrigation peak occurred in April in response to natural recharge.

The second well pair, M: 108595 (45-feet deep) and M: 215478 (81-feet deep) were located about 0.2 miles apart. These two wells reflect the response in an intermediate and deeper ground-water flow system. Ground water in M: 108595 reached its peak during the 2005 irrigation season on June 22 while the deeper well, M: 215478 reached its peak two weeks later (July 5). A similar response was shown in 2006 when the shallow ground water peaked two weeks before ground water in the deeper flow system.

Water levels in the 45-foot-deep well did not fully decline to 2005 pre-irrigation levels, but were within less than 2 feet by early-September. By mid-August 2005 water levels already dropped below pre-irrigation levels in the deeper ground-water flow system. By early September 2005 ground water in both the intermediate and deeper systems had reached their peak decline. This decline in the shallow ground water was within 1 foot of pre-irrigation levels and within 4 feet of pre-irrigation levels in the deeper ground-water system.

These examples illustrate that in general, once irrigation commences, the shallow ground-water peaks earlier than deeper ground water and that although some generalizations can be made on how ground water responds, the response is not necessarily consistent from year to year even in the same well. For instance, the hydrograph for M: 215478 (81-feet deep) shows a decline of about 10 feet from the height of irrigation to early September in 2005 and a decline of only 2 feet during the same period in 2006. Given that geologic conditions have not changed, the variables that can affect ground water response include recharge from precipitation, evapotranspiration affects, and differences in amounts of water applied to the fields to flood irrigate.

**Return of Ground Water to Pre-Irrigation Levels**

An estimate was made on how long it took ground water to recede from peak irrigation to within 90 percent of pre-irrigation levels. The ground-water hydrographs vary with some wells receding to pre-irrigation levels quickly while other hydrographs show a slower decline. An example of this is shown in figure 12. The shallow piezometer, M: 221762, located near Little Lake Creek, recedes to pre-irrigation levels by the end of July. Water levels in this well remain fairly stable for most of the year and show a muted response during the irrigation season, reflecting sediments that have a have a high transmissivity. Ground water in well M: 108590 recedes to within 90 percent of pre-irrigation ground-water levels by December 2005. This well was about 75-feet deep and is probably completed in Tertiary sediments. The shape of this hydrograph and delayed ground water decline was a function of sediments with a low transmissivity and storage coefficient.

Figure 13 illustrates an estimate of how long it took ground water to recede to within 90 percent of pre-irrigation levels. Of the 20 wells examined in this analysis, ground water returned to within 90 percent of the pre-irrigation level within 2 months (by mid-August) at 12 locations, and within 4 months (by mid-October) in four wells. Four wells had still not returned to within 90 percent of its pre-irrigation levels by mid-October. Two of these wells were located on the east side of the river in the Tertiary

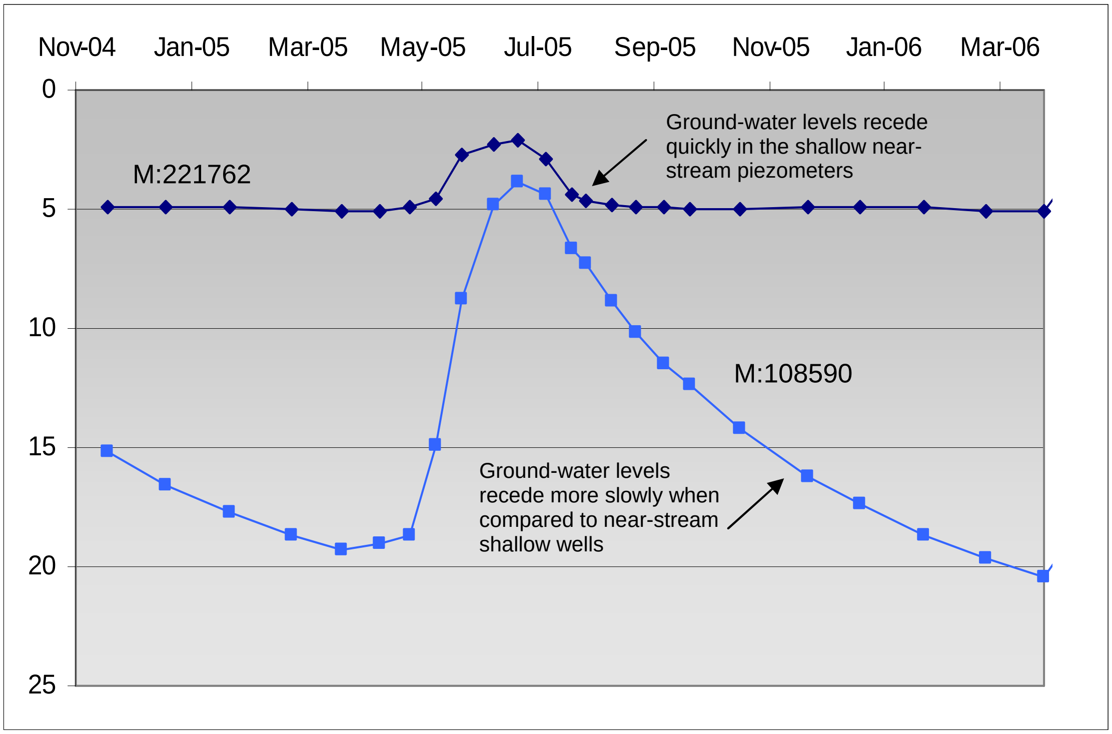



**Figure 12.** This figure presents a hydrograph for a shallow well (M: 221762) in which ground water recedes quickly and well M: 108590 where the ground-water-level decline was more gradual.

sediments which gained the greatest amount of water during irrigation. Well M: 108588, also located in this area, returned to within 90 percent of pre-irrigation levels by late August – even at about 90 percent of pre-irrigation levels ground water was still about 7 feet above the pre-irrigation level.

Ground water in the shallow piezometer, M: 221759 still had not returned to within 90 percent of pre-irrigation levels by November/December. Water was ponded around this piezometer during the height of the irrigation season. The delayed return to baseline may be due to the fact that since the unsaturated/soil zone was inundated with water it took longer for this area to drain. Three shallow piezometers located near Little Lake Creek (M: 221762, M: 221766, 221767) returned to within 90 percent of pre-irrigation levels by mid-August so the ground water discharged fairly quickly. The declining ground-water levels in the hydrograph for shallow piezometer M: 221763, located near Peter Jensen Creek, had a more delayed response. This piezometer was located about 250-feet upgradient and about 10 to 15 feet higher than the creek.

Multiple factors contribute to the hydrograph responses and the length of time it takes for ground water to recede to pre-irrigation levels for this area. The change in aquifer storage is a complex issue since the geology is not homogeneous. Factors that dictate the ground water response include:

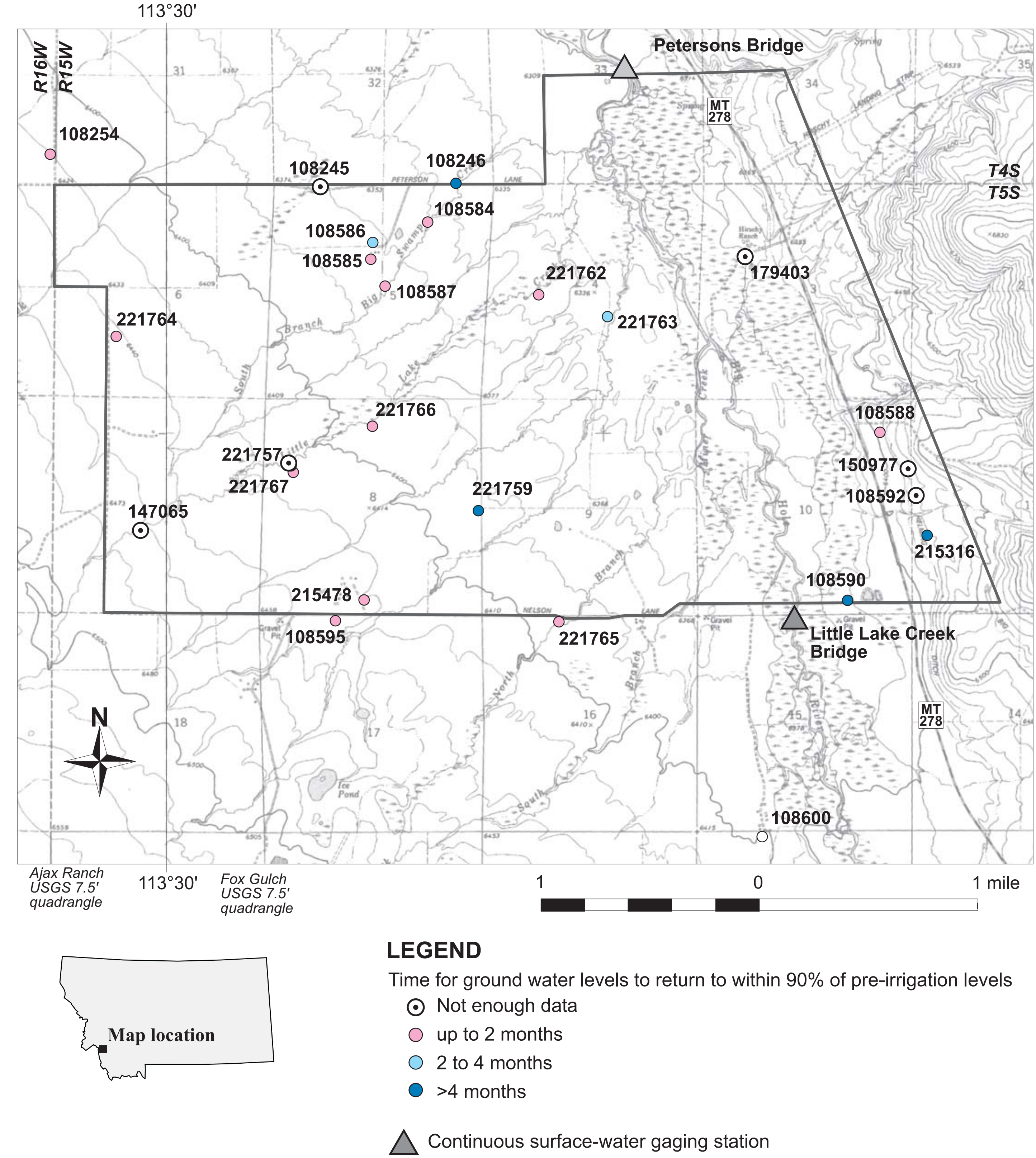



**Figure 13.** General estimate of the time for ground water to return from peak irrigation levels to within 90 percent of pre-irrigation levels.

- The geologic material which controls the transmissivity and storage coefficient of the aquifer. Aquifers with a lower transmissivity and storage coefficient would have a slower ground water response resulting in a longer lag time in releasing ground water from storage.
- Topographic position (floodplain versus upland areas), proximity to streams and depth of the well – those shallow wells located close to tributaries are controlled by stream stage more than they are irrigation. Therefore, they usually return to pre-irrigation levels relatively quickly.
- Volume and timing of recharge which can offset the amount of water going into/released from storage.

**Aquifer Characteristics**
Eight wells were pumped from about 1 to 8 hours to estimate the hydraulic conductivity of the aquifer. Although using domestic/stock wells is not ideal for estimating aquifer characteristics, the data provided useful estimates of hydraulic conductivity. Hydraulic conductivity is the capacity of a porous medium to transmit water. If the interconnecting spaces between pores are small, the volume of water passing from pore to pore is restricted resulting in low values for hydraulic conductivity (Driscoll, 1986). Wells were pumped at a rate of 4 to 20 gallons per minute. The drawdown or change in water level was monitored along with the pumping rate. The data was analyzed using AQTESOLV, a computer program that assists in analyzing aquifer test data.

Several of the time-drawdown graphs indicated that drawdown increased as pumping continued (figure 14). The steepening of the time drawdown plot indicated that cone of depression encountered a barrier to flow such as a finer grained unit or that the aquifer may thin laterally.

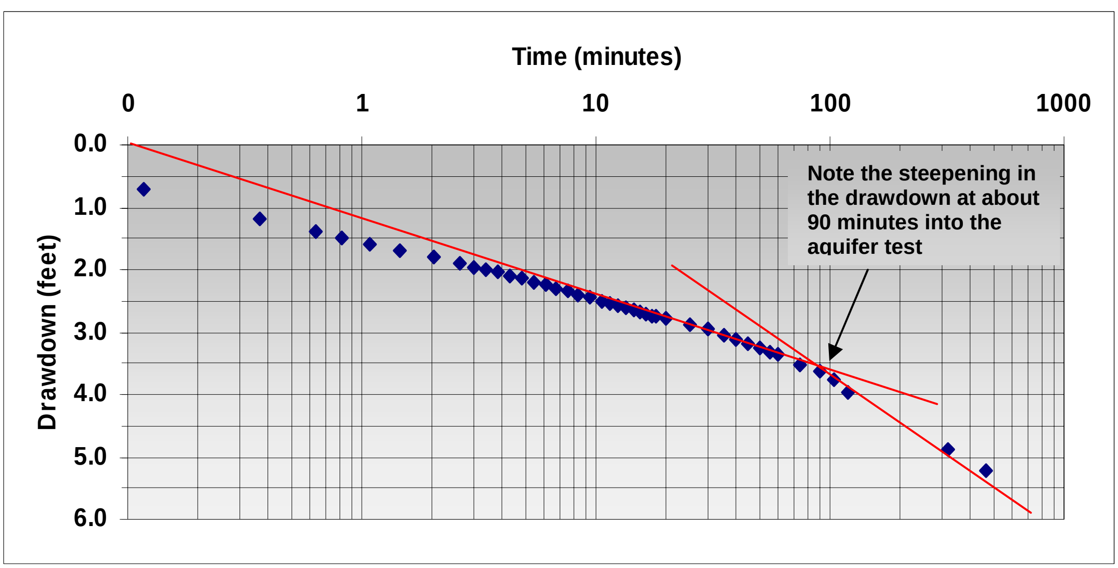



**Figure 14.** An example of barrier boundary encountered during pumping (well M: 108584). This is evident by the increase in the drawdown rate at 90 to 100 minutes after pumping started.

Hydraulic conductivity estimates were based on the earlier time data and were all within the same order of magnitude ranging from 1.4 to 8.6 ft/day, with an average of about 4 ft/day. These values fall within the range of silty to clean sand (Freeze and Cherry, 1979) and were similar to those obtained by Marvin and Voeller (2000) for glacial outwash and alluvial deposits. Unfortunately aquifer tests could not be performed on any wells completed in the Tertiary sediments located on the east side of the river. Marvin and Voeller (2000) presented a range of hydraulic conductivity values from 0.3 to 390 ft/day for Tertiary sediments in the upper Big Hole basin, with a median value of 5.9 ft/day.

The slope of the ground-water table, known as the horizontal gradient, is the change in ground-water elevation between two points divided by the distance between these points. Ground-water flow velocity was estimated during June 2005 using an average hydraulic conductivity of 4.14 ft/day, a ground-water gradient of 0.01 and 0.006 and an effective porosity of 0.14. During this period the ground-water velocity ranged from 0.18-0.30 ft/day.

**Ground-Water Movement**

Figure 15 is a ground-water flow map showing ground-water elevations during the peak of irrigation (June 22, 2005). The ground-water flow map for this date shows that ground water is flowing towards the river. The gradient was about 0.01 ft/ft; closer to river, the gradient was gentler (0.006 ft/ft). The gentler gradient along the river probably results from greater hydraulic conductivity in the sediments in this area.

Ground water moves not only horizontally towards the Big Hole River but also moves vertically. In discharge areas, there is an upward gradient and in recharge areas, the gradient is downwards from the shallow to the deeper ground-water flow system. In order to approximate the vertical gradient, ground-water levels in shallow and deeper wells located within 0.1 to about 0.5 miles of each other (well pairs M: 108245/108246, M: 108585/108587, M: 215478/108595, and M: 221757/221767; see figure 2 for locations) were examined. The gradient was approximated by dividing the difference in ground-water elevation by the vertical distance between the well screen/intake. The ground-water gradient in the well pairs examined was downward, indicating recharge is occurring from the shallow to the deeper ground-water flow system, averaging about 0.25 to 0.70 ft/ft. Although there were no well pairs located close to the river, artesian conditions in well M: 179403, located about a quarter mile from the Big Hole River, indicates an upward gradient in which ground water is a source of recharge to the river.

**Water Chemistry**

Members of the Big Hole Watershed Committee were interested in examining nitrate concentrations in ground water. As a result of this request, ground water from fourteen wells and two surface water samples from the Big Hole River were measured in the field for specific conductance, pH, temperature, nitrate/nitrite, and iron. Water-quality samples were obtained while pumping the wells to estimate aquifer characteristics. Hach test strips were used to test for field nitrate/nitrite and a Hach Colorimeter (DR/700) was used to estimate iron concentrations. Thirteen of the fourteen samples were sent to the lab for nitrate analysis and four samples were analyzed in the lab for iron and arsenic. The results of the laboratory analyses for the samples analyzed for iron and arsenic, and two complete analyses performed on well M: 108595 are included in appendix D. Well M: 108595 was sampled in 2001 and again during this study as part of the Montana Bureau of Mines and Geology Ground-Water Monitoring Program.

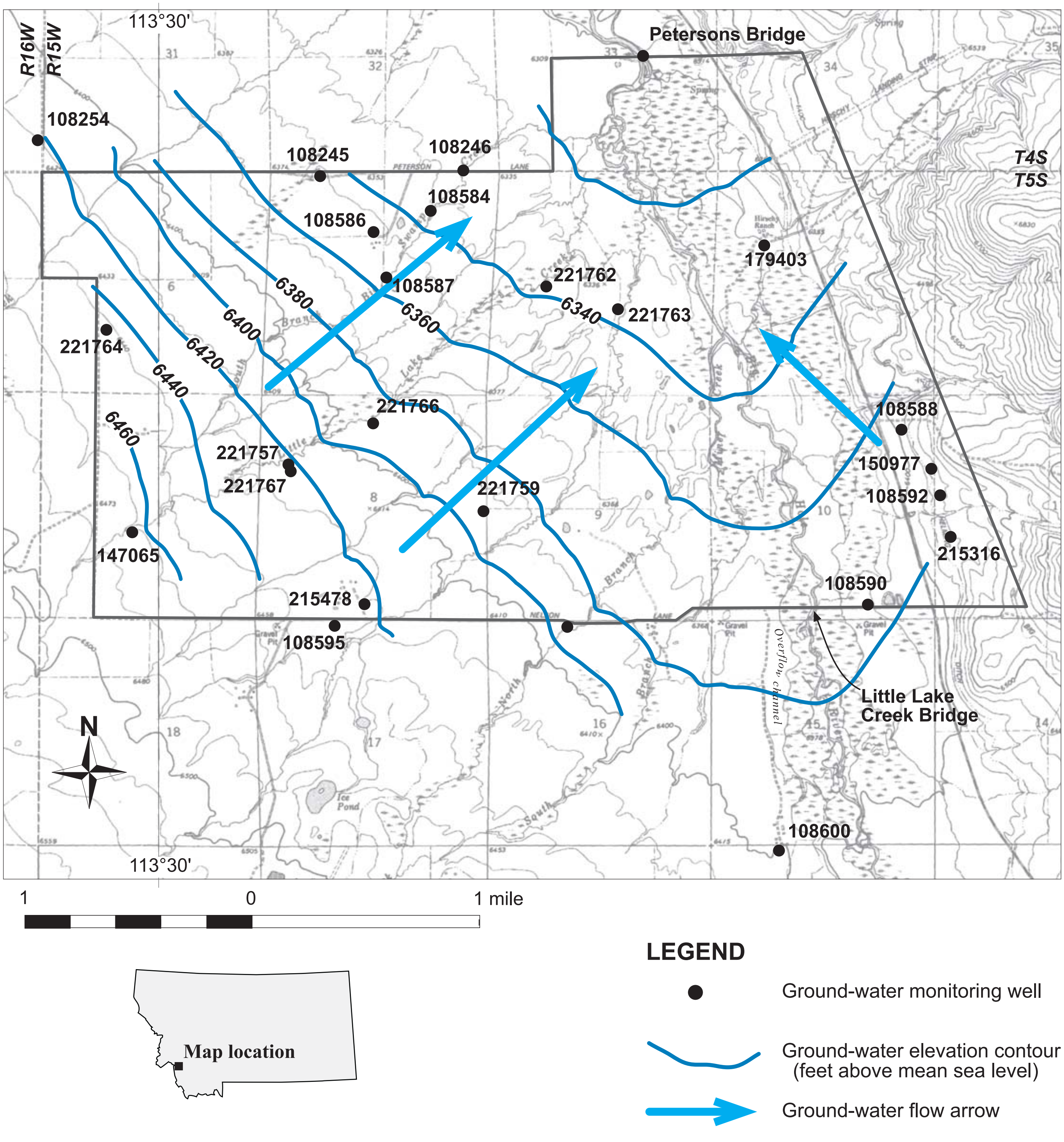



**Figure 15.** Ground-water contour map of the study area during June 2005 showing that ground-water flows towards the Big Hole River.

This program consists of a statewide network of wells in which ground-water quality and quarterly water level information is collected.

Table 2 provides the results from the water quality analyses performed within the study area. The pH ranged from 6.06 to 7.96. The three highest pH values were found in the Big Hole River and in ground water from well M: 179403, an artesian well located about 0.3 miles from the river. The similarity of the pH in ground water and the surface water suggests a more direct connection to the Big Hole River as compared to ground water in wells further away. Specific conductance, a measurement of the water's capacity to conduct an electric current, ranged from 91 to 445 micromhos/cm. Specific conductance varies with the concentration of dissolved solids in the water and their degree of ionization; the higher the specific conductance – the greater the dissolved minerals in the ground water. The specific conductance of 445 micromhos/cm occurred in well M: 215478. While pumping this well, the water level fell below the pump.

Temperatures ranged from 5.1°C to 10.8°C. The warmest waters were found in M: 108588 and M: 108592, both wells are located on the east side of the study area above the floodplain. The warmer temperature in M: 221767 maybe due to the shallow depth of the piezometer and limited purging prior to collecting the sample.

The nitrate field test strips did not indicate a presence of nitrate in the water samples. This was confirmed by the laboratory analyses in which nitrate concentrations were below detection limit (0.5 mg/L). The only detectable amount of nitrate, 0.951 mg/L, was in a sample collected from well M: 108585 (table 2). This is below the maximum limit of 10 mg/L recommended by U.S. Environmental Protection Agency. Although this limit is for public water supplies, it serves as a guideline for domestic well owners. It should be noted that these results reflect concentrations during low flow conditions since samples were collected in October 2006. The results may vary if samples were collected during a different time of the year. Regardless, the data indicates that nitrates are most likely not a problem in the study area.

Iron concentrations ranged from 0.04 to above 5.1 mg/L (the upward limit of detection for the Hach colorimeter). Four of the samples were also analyzed in the lab to verify the iron concentrations obtained in the field. There was a good correlation between the field and lab analyses. Eleven of the 14 ground water samples had iron concentrations above the recommended drinking water level of 0.3 mg/L. Four samples had concentrations of field iron above 5.0 mg/L. Of the four samples analyzed in the lab, iron was highest in well M: 215478 at 7.78 mg/L (table 2). The recommended concentration for iron in drinking water is based on aesthetic quality of water (i.e. odor, color, etc.) and is not a health standard. Concentrations greater then 0.3 mg/L can cause unpleasant taste, staining and favor growth of iron bacteria but do not endanger health. Iron concentrations in the Big Hole River sampled at the upstream and downstream end of the study area were about 0.4 mg/l.

Iron is a common constituent of many different rocks and sediments. Ground water has a tendency to develop chemical characteristics of the rock/sediment through which it flows. Manganese often occurs in iron-rich minerals and typically when iron concentrations are elevated so is manganese. Manganese concentrations in ground water were only available for well M: 108595 and were 1.1 mg/L in 2001 and 1.3 mg/L in 2006. These concentrations are above the recommended limit of 0.05 mg/L. Manganese imparts the same objectionable features as iron.

**Table 2.** Results of field and laboratory analyses (a blank indicates no analysis).

| Gwic Id | Date sample Collected | pH | SC | Temp °C | Field Nitrate (mg/L) | Lab Nitrate (mg/L) | Field Iron (mg/L) | Lab Iron (mg/L) | Lab Arsenic (µg/L) |
|---|---|---|---|---|---|---|---|---|---|
| 108245 | 10/23/2006 | 7.01 | 119.2 | 7.5 | NP | <0.5 | 0.09 | | |
| 108246 | 10/23/2006 | 6.46 | 362.2 | 7.5 | NP | <0.5 | <5.10 | | |
| 108584 | 10/6/2006 | 6.06 | 124.4 | 6.5 | NP | <0.5 | 1.75 | | |
| 108585 | 10/23/2006 | 6.64 | 110.9 | 7.6 | NP | 0.951 | 1.12 | 0.72 | <1.00 |
| 108586 | 10/18/2006 | 6.66 | 261.7 | 6.0 | NP | <0.5 | 5.10 | | |
| 108587 | 10/23/2006 | 6.96 | 138.6 | 6.0 | NP | | 4.87 | | |
| 108588 | 10/6/2006 | 7.09 | 313.5 | 10.8 | NP | <0.5 | 0.09 | | |
| 108592 | 10/3/2006 | 7.57 | 286.0 | 9.5 | NP | <0.5 | 0.04 | | |
| 108595 | 10/11/2006 | 7.42 | 196.6 | 7.7 | 0-1 | <0.5 | 1.24 | 1.23 | 9.62 |
| 147065 | 10/3/2006 | 6.60 | 91.2 | 6.9 | NP | <0.5 | 0.44 | | |
| 179403 | 10/11/2006 | 7.96 | 161.9 | 7.1 | NP | <0.5 | 1.12 | 1.11 | <1.00 |
| 215478 | 10/5/2006 | 6.53 | 445.0 | 8.1 | NP | <0.5 | <5.10 | 7.78 | 16.60 |
| 221757 | 10/5/2006 | 6.17 | 207.7 | 5.1 | NP | <0.5 | 1.09 | | |
| 221767 | 10/6/2006 | 6.54 | 332.5 | 10.2 | NP | <0.5 | 5.10 | | |
| BHR South | 10/18/2006 | 7.89 | 113.4 | 6.1 | NP | | 0.39 | | |
| BHR North | 10/18/2006 | 7.78 | 115.6 | 6.0 | NP | | 0.40 | | |

BHR: Big Hole River NP: Not Present
Nitrate maximum contaminant limit 10 mg/L
Iron recommended limit 0.3 mg/L
Arsenic recommended limit of 10 µg/L

Iron bacteria were a suspected problem in many of the wells that have high iron concentrations. These bacteria grow and multiply in water using dissolved iron and/or manganese with oxygen as part of their metabolism. During this process the bacteria produce a slime that builds up in well screens, casing, pipes and plumbing parts. These bacteria do not cause health problems but can cause odors, corrode plumbing equipment and reduce well yields by clogging screens and pipes.

Ground water from four domestic wells was analyzed for arsenic. Ground-water samples collected previously in the area by the Montana Bureau of Mines and Geology and United States Geological Survey (GWIC, 2007) indicated the presence of arsenic in ground water, especially near and in the town of Jackson, a known geothermal area (Jardine Hot Springs). Ground water from Jardine Hot Springs sampled by the United States Geologic Survey in 1981 showed an arsenic concentration of 53.20 µg/L. About 1.4 miles north west of the hot springs on the same side of the river, a domestic well sampled twice in 1981, had arsenic concentrations of 37 and 21 µg/L. Interestingly, a domestic well (M: 108595) in the present study area had an arsenic concentration of 10.8 µg/L in 2001. This well, located on the opposite side of the river from Jardine Hot Springs, is part of the Montana Bureau of Mines and Geology state-wide monitoring network. In comparison, an arsenic concentration of 9.62 µg/L was obtained during the 2006 sampling. A domestic well sampled during this investigation (M: 215478), only 0.15 miles to the north east had a concentration of 16.6 µg/L. The two other domestic wells (M: 108585 and M: 179403, see figure 2) sampled as part of this study had arsenic concentrations less than 1 µg/L.

Arsenic is common in geothermal areas as a result of dissolution of the arsenic from rocks and sediments in contact with the geothermal water. The geothermal waters probably issue from a deep underlying fracture network. Although the ground water cools as it migrates away from the source, it imparts a geochemical signature to the ground water. A maximum limit for arsenic in drinking water supplies is 10 μg/L mandated by U.S. Environmental Protection Agency. Long-term exposure to arsenic in drinking water may cause cancer of the skin, lungs, urinary bladder, and kidney (World Health Organization, 2001). A median ground water arsenic concentration for Montana has been sited at 2 μg/L based on the occurrence of arsenic in ground water resources of the United States (Focazio and others, 1999).

**Synoptic Measurements on the Ditch/Creek Systems**

Several measurements were made on segments of four creeks/ditches (figure 16) to examine the seepage loss/gain dynamics as the surface water was conveyed. These include Helming Ditch, Big Swamp Creek, Peter Jensen Creek and a diversion to Big Swamp Creek. The data are summarized in table 3.

<u>Helming Ditch</u>

The Helming ditch flows south to north along an upland area east of the Big Hole River and is used to irrigate the land between the ditch and Highway 278. In 2006, flows were measured at the height of the irrigation season (June 20) and about two weeks later when most of the ditch was shut down (July 6).

The amount of water lost/gained along the Helming Ditch was estimated by summing all the inflows and outflows.

$$\text{Ditch Loss/Gain} = ((\Sigma\text{outflows}) - (\Sigma\text{inflows}))$$

On June 20, 10.85 cfs was measured as the ditch entered the study area (HD-1; figure 16) and 0.28 cfs as the ditch left the study area (HD-2; figure 16). Additional inflows of 0.73 cfs were measured as they came into the ditch. Water diverted from the ditch for irrigation was measured where it flowed under the highway and totaled 4.65 cfs (HD-3-10; figure 16).

$$\text{Ditch Loss/Gain} = (\underbrace{(0.28+4.65)}_{\Sigma\text{outflows}} - \underbrace{(10.85 + 0.73)}_{\Sigma\text{inflows}}) = -6.65 \text{ cfs}$$

The 6.65 cfs (1.94 cfs/mile) represents water lost to ground water and/or evapotranspiration, not only from the ditch itself but from between the ditch and where it flowed under the highway (HD-3-10). Therefore, this value is an overestimate of water loss just from the ditch. On July 6, there was much less water coming into the ditch at HD-1 (0.71 cfs) and leaving the ditch (HD-2, 0.032 cfs). Water diverted from the ditch was measured close to the main ditch (0.16 cfs) instead of the highway locations. Accounting for all inflows (0.78 cfs) and outflows (0.19 cfs) the ditch lost 0.59 cfs or about 0.16 cfs/mile.

$$\text{Ditch Loss/Gain} = (\underbrace{(0.16 + 0.03)}_{\Sigma\text{outflows}} - \underbrace{(0.71 + .07)}_{\Sigma\text{inflows}}) = -0.59 \text{ cfs}$$

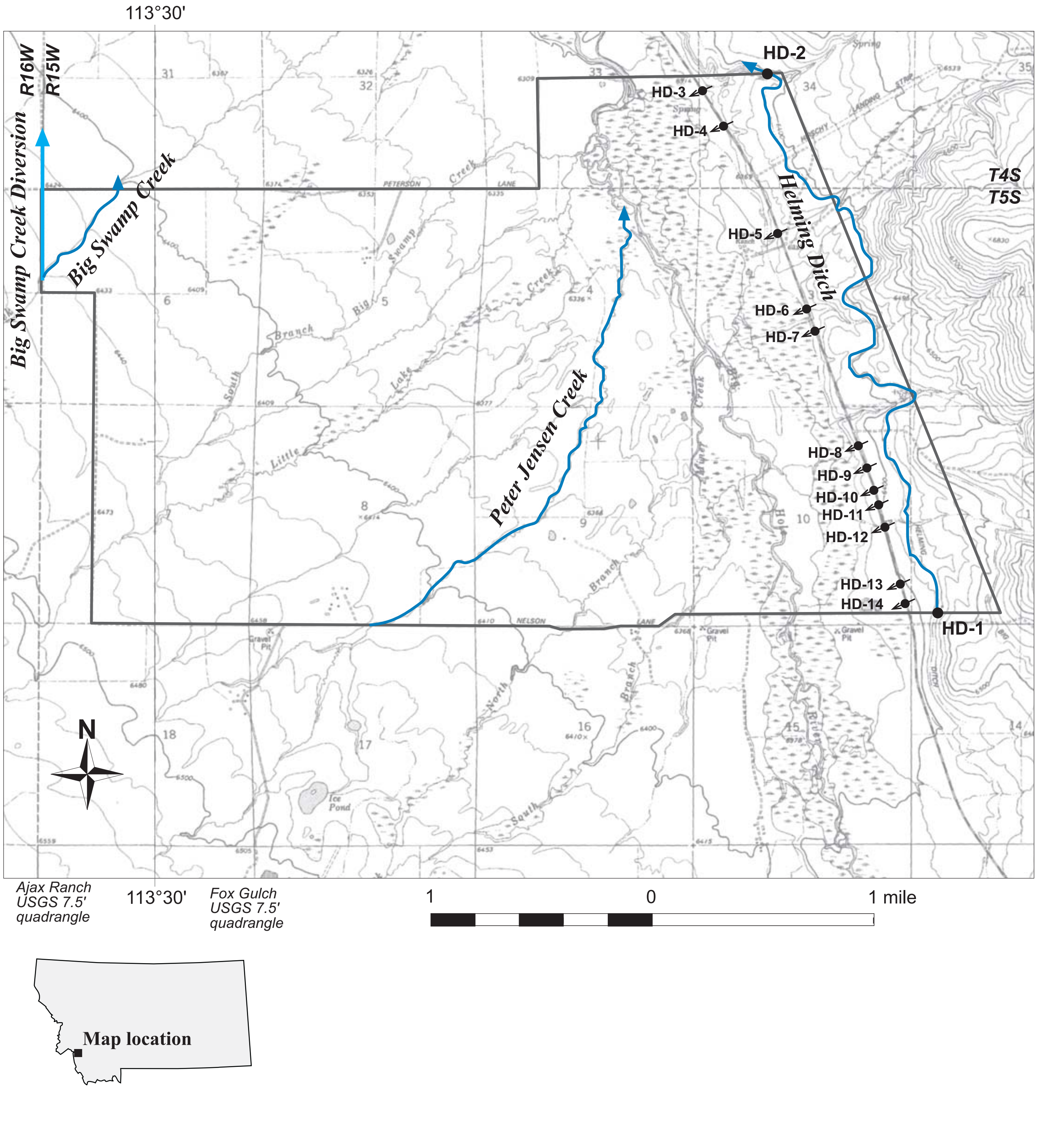



**Figure 16.** Map showing drainages and locations of surface water measured as it crossed Highway 278 . This information was used to determine the surface water gains and losses.

**Table 3.** Inflow and outflow measurements made along segments of four drainages. A negative value indicates a loss of water and a positive value indicates a gain.

**Helming Ditch**

| | Inflow | Outflow | Difference) | Distance (mile) | Gain/loss (cfs/mile) |
|---|---|---|---|---|---|
| 10-Jun-06 | 11.58 | 4.93 | -6.65 | 3.8 | -1.75 |
| 6-Jul-06 | 0.78 | 0.19 | -0.59 | 3.8 | -0.16 |

**Big Swamp Creek**

| | Inflow | Outflow | Difference | Distance (miles) | Gain/loss (cfs/mile) |
|---|---|---|---|---|---|
| 26-Apr-05 | 1.49 | 1.21 | -0.28 | 0.5 | -0.56 |
| 24-May-05 | 1.89 | 2.6 | 0.71 | 0.5 | 1.42 |
| 22-Jun-05 | 4.49 | 9.35 | 4.86 | 0.5 | 9.72 |
| 28-Jul-05 | 0.91 | 0.764 | -0.146 | 0.5 | -0.29 |
| 24-Aug-05 | 0.068 | 0.128 | 0.06 | 0.5 | 0.12 |
| 21-Sep-05 | 1.48 | 1.74 | 0.26 | 0.5 | 0.52 |
| 17-Oct-05* | 3.096 | 3.23 | 0.134 | 0.5 | 0.27 |
| 3-May-06 | 25.51 | 29.33 | 3.82 | 0.5 | 7.64 |
| 20-Jun-06 | 2 | 3.11 | 1.11 | 0.5 | 2.22 |
| 07-Jul-06* | 2.86 | 2.66 | -0.2 | 0.5 | -0.40 |
| 17-Aug-06 | 0.68 | 0 | -0.68 | 0.5 | -1.36 |
| 13-Sep-06 | 0 | 0.125 | 0.125 | 0.5 | 0.25 |
| 10/18/2006* | 1.605 | 1.614 | 0.009 | 0.5 | 0.02 |

**South Branch Big Swamp Creek – diversion**

| | Inflow | Outflow | Difference | Distance (miles) | Gain/loss (cfs/mile) |
|---|---|---|---|---|---|
| 10-Jun-05 | 13.55 | 15.46 | 1.91 | 0.85 | 2.25 |
| 24-Jun-05* | 37.02 | 37.05 | 0.03 | 0.4 | 0.08 |
| 23-Aug-05 | 1.02 | 0.43 | -0.59 | 0.4 | -1.48 |
| 06-Jul-06* | 14.94 | 15.05 | -0.11 | 0.4 | -0.28 |

**Peter Jensen Creek**

| | Inflow | Outflow | Difference | Distance (miles) | Gain/loss (cfs/mile) |
|---|---|---|---|---|---|
| 3-May-06 | 6.56 | 12.76 | 6.2 | 2.6 | 2.38 |
| 20-Jun-06 | 4.76 | 18.88 | 14.12 | 2.6 | 5.43 |
| 20-Jul-06 | 1.12 | 2.9 | 1.78 | 2.6 | 0.68 |
| 17-Aug-06 | 0.51 | 1.98 | 1.47 | 2.6 | 0.57 |
| 13-Sep-06* | 0.99 | 0.92 | -0.07 | 2.6 | -0.03 |
| 18-Oct-06* | 3.07 | 2.97 | -0.1 | 2.6 | -0.04 |

[shaded] Flood irrigation was occurring during these periods with the possibility of unaccounted irrigation overland flow

* Accuracy: Inflow and outflow measurements were within 100 percent of actual values due to site variables and instrument operator/error

Big Swamp Creek
A small segment (0.5 miles) of Big Swamp Creek was measured during the synoptic runs in 2005 and 2006. Because flood irrigation was occurring during the May 24 and June 22, 2005 and June 20, 2006 synoptic runs, the gain in water during these times may have been from irrigation overland flow. Excluding data from these dates, this segment of Big Swamp Creek lost up to 1.4 cfs/mile and gained up to 7.64 cfs/mile. The highest gain was on May 3, 2006. This was prior to irrigation but at a period of recharge from snowmelt. Since irrigation started in mid-May during 2006 it is unlikely this gain was the result of recharge from overland flow as a result of flood irrigation; therefore, the gain was attributed to ground-water recharge.

Big Swamp Creek - diversion
Water was diverted from Big Swamp Creek along a ditch that runs north (Big Swamp Creek diversion, figure 16). This diversion/drainage flows all year long. This segment of ditch was chosen because there were no surface water inflows or outflows influencing water flow in the ditch. At the height of irrigation (June 24, 2005), the flow measurements between the inflow and outflow measured along the segment diversion were essentially the same. This suggests the surface water was at a steady state in which potential ditch loss was balanced by ground-water recharge to the ditch. Flow measurements after the irrigation season was over (August 23, 2005 and July 6, 2006) indicate a loss of 1.48 and 0.28 cfs/mile, respectively.

Peter Jensen Creek
A tributary locally known as Peter Jensen Creek flows towards the Big Hole River (figure 16). This drainage was not examined on foot so additional inflows and/or outflows to the drainage are unknown. However, Roberts (2006) stated that additional inflows/outflows to the drainage were unlikely except during the flood irrigation. Therefore, it was more than likely that the June 20, 2006 inflow may be influenced by flood irrigation. Excluding this period, the drainage gained its greatest amount of water in early May 2006 (2.38 cfs/mile) possibly due to snowmelt and also showed gains in July and August once flood irrigation was over (0.68 and 0.57 cfs/mile, respectively). Figure 17 shows ground-water levels in well M: 221763 located about 150 feet from the creek. The gain in flow in July and August corresponds to a period when ground water was discharging at a greater rate than in September and October. The inflow and outflow measured in September and October show a slight loss; however, the difference in flow was within 10 percent and could be accounted for by site variables and instrument and human error.

It is likely that the gains in July and August were the result of ground-water discharge. Although the ground-water table was still declining in September and October, most of the ground water had already been discharged by this time. Without longer term and more consistent measurements in multiple drainages, it is difficult to discern a loss/gain pattern due to many variables influencing flow in the ditches and creeks. These variables include the timing and magnitude of precipitation and snowmelt, air temperatures, timing of irrigation and the soils/sediment that compose drainage and conveyance systems.

**Total Surface-Water Inflows and Outflows**
The most useful insight into how the hydrologic system responds is to look at how much surface water is coming into and how much surface water is leaving the study area. The difference between these amounts represents the integrated response of the components affecting the watershed dynamics. Comparing surface water inflow as the Big Hole River enters the study area at Little Lake Creek Bridge

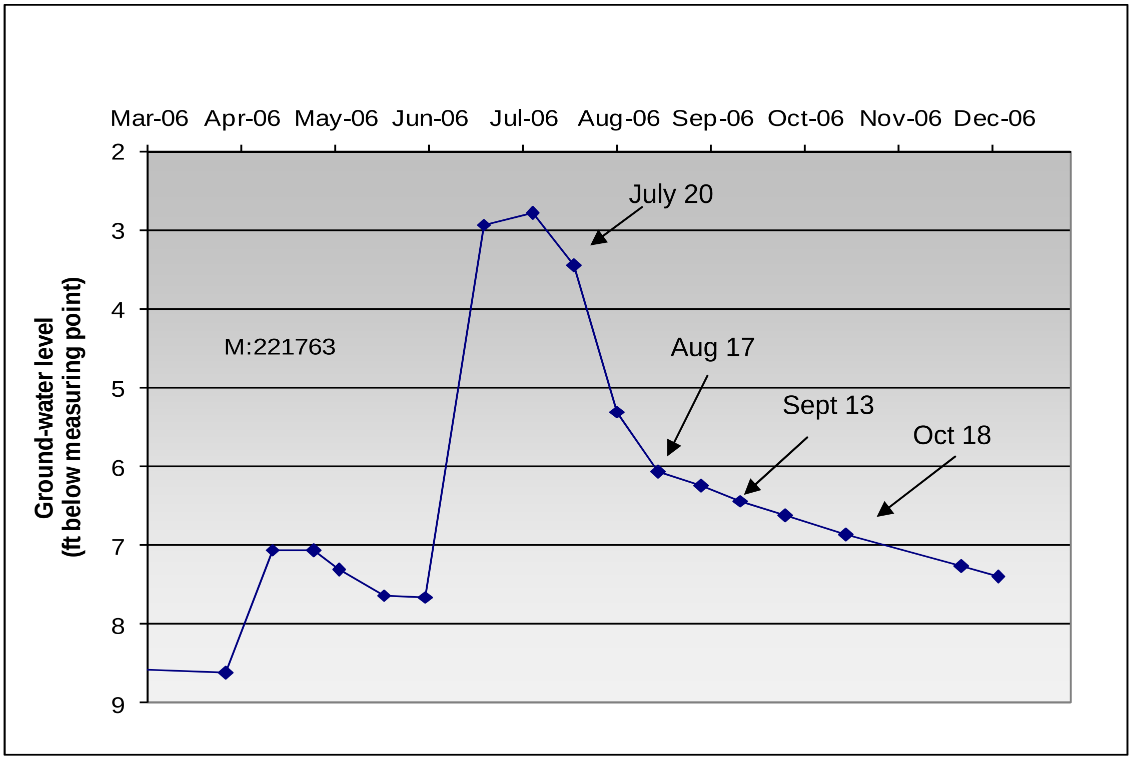
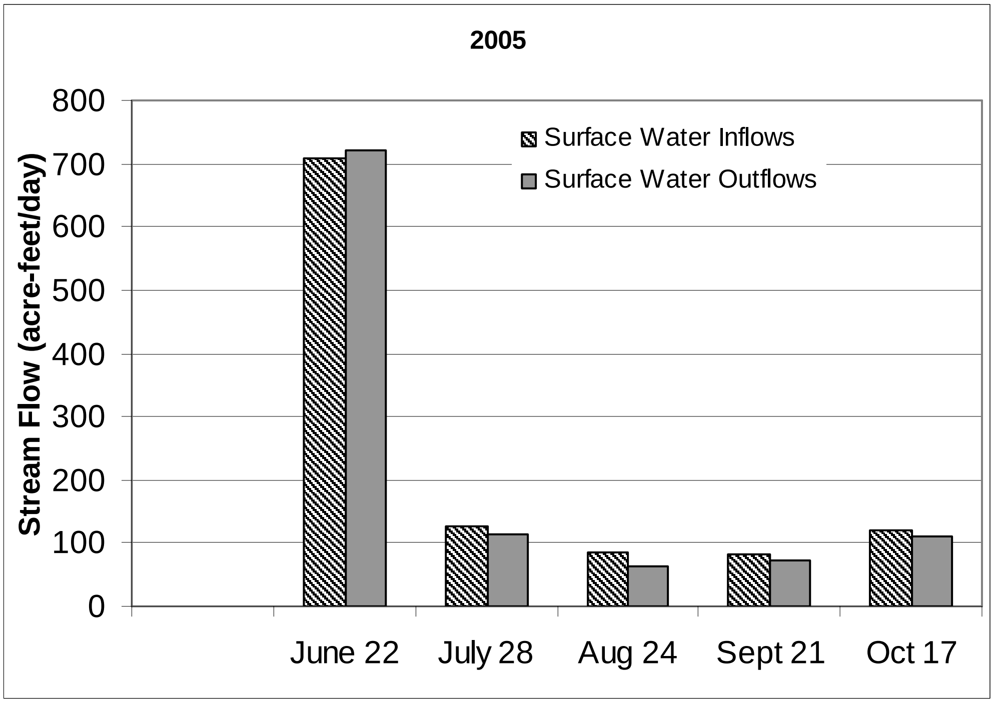



**Figure 17.** Ground-water hydrograph for well 221763 which was located near Peter Jensen Creek. The dates on the hydrograph indicate when surface water was measured in the creek. During September and October there was no significant inflow or outflow into or out of the creek.

to the stream flow at Petersons Bridge where the Big Hole River exits the study area presents only part of the picture. To account for all inflows and outflows affecting river flows, measurements were made of all tributaries, seeps, springs, irrigation overland flow, etc. as they entered and exited the Big Hole River within the study area. These data are presented graphically in figure 18 and tabulated in table 4.

These data show that the surface water only gained water during three of 11 synoptic runs, those conducted in June 22, 2005, May 3, 2006 and June 20, 2006. The inflow and outflow measurements were within 10 percent of one another and in effect could indicate there was no net gain or loss in surface water; however, the June 22, 2005 and June 26, 2006 measurements were consistent in that amount of water exiting the study area was greater than that entering. Although these numbers are within 10 percent of one another, the consistency lends credibility that this was a true gain in surface water. Because all surface water was accounted for in this analysis – the data imply that the gain in water is primarily from ground water. The synoptic run in May 2006 was prior to flood irrigation and represents a period where natural recharge from snowmelt and precipitation results in increases to stream flow. The June 2005 and 2006 synoptic run measurements were made at the height of irrigation. During this period, the shallow aquifer is near or at saturation and the amount of ground water added to storage nearly equals the amount of ground-water released from the aquifer.



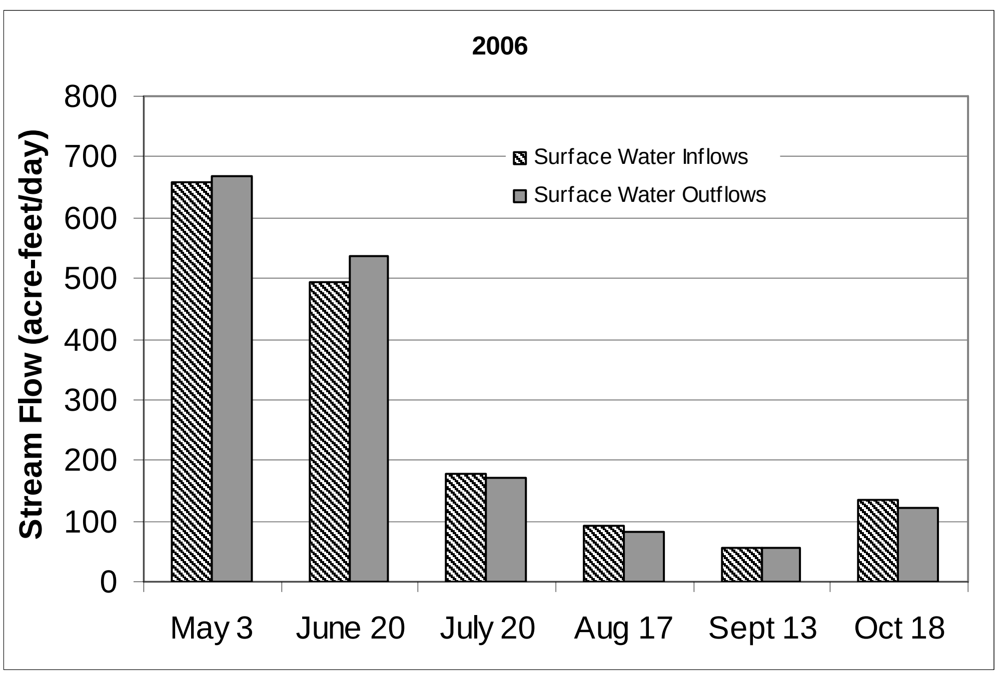




**Figure 18.** These bar graphs represent the total of all inflows and outflows to the study area. Surface water inflows and outflows were nearly equal during the months of July through October.

**Table 4.** Total of all surface water coming into the study area (inflow) and surface water leaving the study area (outflow) in acre-feet/day.

| | **Inflow** (cfs) | **Outflow** (cfs) | **Difference*** (cfs) |
|---|---|---|---|
| June 22, 2005 | 708 | 722 | 14* |
| July 28, 2005 | 128 | 115 | -13 |
| Aug 24, 2005 | 84 | 62 | -22 |
| Sep 21, 2005 | 83 | 73 | -10 |
| Oct 17, 2005 | 121 | 110 | -11 |
| May 3, 2006 | 657 | 669 | 12* |
| Jun 20, 2006 | 493 | 538 | 44* |
| July 20, 2006 | 178 | 172 | - 6* |
| Aug 17, 2006 | 91 | 82 | - 9 |
| Sept 13, 2006 | 56 | 55 | - 1* |
| Oct 18, 2006 | 133 | 122 | -11* |

Positive number indicates that there was more outflow than inflow, the gain attributed to ground water.
Negative number indicates more inflow than outflow.
* Difference between inflow and outflow were within 10 percent

In spite of the fact that ground water is being released from storage after flood irrigation ceases, there were no apparent gains in surface water during the July through October 2005 and 2006 measurements. In fact, the data indicate that there was a loss in surface water during this period in both 2005 and 2006. Most of the losses in 2006 were within instrument/human error (10 percent) indicating that it was difficult to discern a true gain or loss and essentially the inflows and outflows were close to balancing.

**Water Budget**

A water budget was approximated for the study area to examine the components that contribute water (sources) and losses (sinks) to the hydrogeologic system. In theory, the budget should balance between the amount of water coming into and the amount of water that exits the study area. However, uncertainties and errors in each of the water budget components do not result in a perfect balance. Only that portion of the study area that contributed ground water and surface water was considered in the water budget. For instance, the surface and ground water in the northwest section of the study area moves off site and recharges the hydrogeologic system further down stream, therefore this area was not factored into the budget.

Although the budget was estimated only during the synoptic run dates, it does provide information on how the hydrogeologic system responds during periods of pre-irrigation, at the height of irrigation and later on in the summer/fall. The water budget was estimated using the following equation:

*Surface water inflow (IN) + Precipitation (IN) + Ground water (IN) =*
*Surface water outflow (OUT) + Evapotranspiration (OUT) + Ground water (OUT)*

| | |
|---|---|
| Precipitation (IN) | Precipitation (acre-feet) |
| Ground water (IN) | Ground - water released from storage (acre-feet) |
| Surface water inflow (IN) | All surface water coming into the study area (acre-feet) |
| Evapotranspiration (OUT) | Evapotranspiration (acre-feet) |
| Ground water (OUT) | Ground water added to storage (acre-feet) |
| Surface water outflow (OUT) | All surface water leaving the study area (acre-feet) |

Sources to the **system** are denoted as (IN) while losses were denoted as (OUT).

**Precipitation (IN)**
Precipitation data from the on-site weather station were used in estimating this component. The precipitation data during October 18, 2006 synoptic run were in error at the on-site weather station, therefore, data from the Jackson weather station were used. A three-day precipitation average prior to and including the synoptic run date was used in the estimation.

**Ground Water (IN)**
This component was an estimate of the amount ground water that was released or discharged from storage and had the potential to recharge the river. The greatest releases from ground-water storage occur at the height of irrigation and in the couple months following the end of flood irrigation.

To calculate the amount of ground water released from storage (IN) and the amount added to storage (OUT), the study area was broken into three sections and the physical area was determined for each section. These sections consisted of the floodplain on the east side of the river, the area to the east of the highway above the flood plain, and that portion of the study area on the west side of the river. The average amount of ground water discharge from each section was estimated by comparing the ground-water level on the synoptic run date to the previous measurement and estimating an average discharge per day. A specific yield of 0.1, which is representative of aquifers composed of silty fine sand and gravel (Fetter, 1994), was then multiplied by the amount of average net ground-water discharge and the area of each section.

During the height of irrigation the aquifer was saturated and the hydrograph shows ground-water levels at their highest with a small amount of water going into storage. During this time, when the aquifer is near equilibrium, there is also water being released from storage. To estimate this amount, the total amount of rise in the hydrograph from spring/summer recharge was estimated and averaged over that period as an approximation of the amount of water discharged from the aquifer on the synoptic run dates for June 2005 and 2006.

**Surface Water (IN)**
This component accounts for all the surface water entering the study area and includes the Big Hole River at the Little Lake Creek Bridge, tributaries, seeps and springs. The surface water component also includes any ground-water baseflow entering the study area.

**Evapotranspiration (OUT)**
An estimate of crop evapotranspiration (ET) was determined by using the Blaney Criddle equation (Brouwer and Heibloem, 1986). This is a simplified theoretical approach that uses temperature data and the mean daily percentage of annual daytime hours to estimate the crop ET. Crop ET is estimated

by determining the reference crop evapotranspiration (ETo), which is a function of the influence of climate on crop water needs and then relating that value to the specific crop grown in the field using a crop coefficient (Kc). Kc was approximated from data provided by the U.S. Bureau of Reclamation (USBR) that relates percent growth stage to the crop coefficient for grass hay (USBR, 2007). The ET estimate for grass hay was determined by multiplying ETo by Kc.

Grass hay was estimated to emerge on April 2 during the 2005 growing season and April 8 in 2006. The emergence date was based on the first day soil temperature was above 32°F (0°C). The grass hay termination date (when the hay was cut) was estimated to be August 3rd for both 2005 and 2006. ET rates after the cutting of the grass hay were based on a Kc as if the hay was first emerging (reflecting the reduced water consumption) (Palmer, 2007). The killing frost occurred on September 1 in 2005 and September 11 in 2006 when the minimum daily temperature dropped below 24°F. Theoretically, this is when the crop goes dormant; however, evaporation still occurs from the soil surface.

To estimate evaporation after the killing frost, several approaches were examined. According to research by Wright (2001), the Kimberly-Penman alfalfa reference ET (ETr) is essentially equal to the potential ET from bare wet soil. Reference ET for alfalfa was obtained from Dillon, Montana Agrimet Station for 2005 and 2006 and multiplied by a factor of 0.7 in order to better approximate a dry soil surface (Wright, 2001). A second approach to estimating this was using the Blaney Criddle ETo values determined for the synoptic run dates in September and October and multiplying these values by the 0.7 factor. Both these values were compared to numbers generated from the Natural Resource Conservation Service (NRCS) by using long term weather data from Wisdom, Montana and TR 21 (Blaney Criddle Equation). The daily values generated by TR 21 were 0.005 ft for September and 0.0025 ft for October (NRCS, 2006). The September/October estimated evaporation rates are presented in table 5.

**Table 5.** Evapotranspiration estimated from three different methods after the killing frost for September and October within the study area (4760 acres).

| | **Alfalfa ETr * 0.7** ft/day (Wright, 2001) | **ETo *0.7** ft/day (Blaney Criddle) | **NRCS** ft/day (NRCS, 2006) | **Average** ft/day | **Average** acre-ft/day |
|---|---|---|---|---|---|
| **9/21/2005** | 0.009 | 0.006 | 0.005 | 0.0067 | 32 |
| **10/17/2005** | 0.008 | 0.005 | 0.003 | 0.0052 | 25 |
| | | | | | |
| **9/13/2006** | 0.012 | 0.005 | 0.005 | 0.0076 | 36 |
| **10/18/2006** | .001 | 0.004 | 0.003 | 0.0035 | 17 |

**Surface Water (OUT)**
This component accounts for all the surface water exiting the study area and includes the Big Hole River at Petersons Bridge. The surface water component also includes any ground-water baseflow exiting the study area.

**Ground Water (OUT)**
Ground water was added to aquifer storage during different times of the year; the largest increases typically occurred in May and June when ground water was being recharged by natural and flood irrigation water. During these periods, when aquifer storage was increasing, this amount was considered

a sink since it was not directly available to supplement stream flow. However, it should be noted that contributions to stream flow continue to occur year round through ground-water base flow.

**Results**

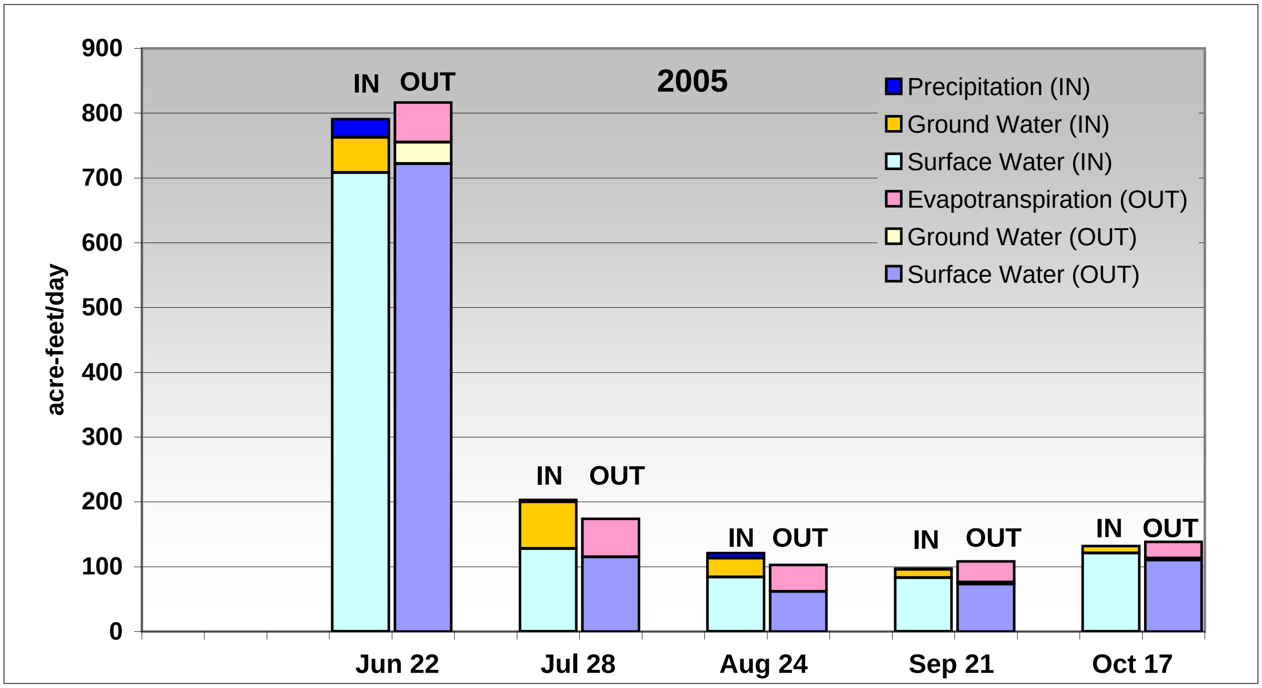
The components of the water budget for 2005 and 2006 are presented in table 6 and illustrated graphically in figure 19. For the most part, the sources (IN) and sinks (OUT) nearly balance; differences are within range of uncertainties/errors in the estimates for the each component. Figure 19 illustrates the overwhelming nature of the surface-water component when compared to the other factors. Note the large reduction in the surface-water component in the later part of the summer/fall when compared to spring (May 2006) and at the height of the irrigation season (June 2005, May and June 2006). Within the study area, after the irrigation season ends and water is no longer being diverted from tributaries, the decrease in the surface-water component is due to the absence of snowpack which typically melts off at the higher elevations by mid to late June and the losses by 'sinks'.

**Table 6.** The estimated amounts (acre-feet/day) contributed by the water budget components.

| | Precipitation (IN) | Ground Water Released (IN) | Surface water (IN) | Evapotranspiration (OUT) | Ground Water Stored (OUT) | Surface water (OUT) |
|---|---|---|---|---|---|---|
| **6/22/2005** | 28 | 55 | 708 | 61 | 33 | 722 |
| **7/28/2005** | 3 | 72 | 128 | 59 | 0 | 115 |
| **8/24/2005** | 8 | 29 | 84 | 41 | 0 | 62 |
| **9/21/2005** | 1 | 13 | 83 | 32 | 3 | 73 |
| **10/17/2005** | 0 | 11 | 121 | 25 | 3 | 110 |
| | | | | | | |
| **5/3/2006** | 4 | 22 | 657 | 31 | 55 | 669 |
| **6/20/2006** | 9 | 51 | 493 | 55 | 44 | 538 |
| **7/20/2006** | 0 | 39 | 178 | 67 | 0 | 172 |
| **8/17/2006** | 3 | 21 | 91 | 43 | 11 | 82 |
| **9/13/2006** | 0 | 11 | 56 | 36 | 4 | 55 |
| **10/18/2006** | 6 | 10 | 133 | 17 | 3 | 122 |

Because the surface-water component dominates the water budget, it was difficult to discern the influences of the other components affecting the budget. To examine the influences of the other components, the surface-water component was removed and the other sources and sinks were plotted in figure 20 to help explain their influence on the water budget. Since these components are only part of the picture, the sources and sinks were not supposed to balance and the deficit between these is the surface water component.

The 'sources' include precipitation and ground-water released from storage. The role of precipitation is dependent on climatic conditions; for example, during wetter years precipitation can contribute significantly to the overall budget. The greatest amount of ground-water released was estimated to occur in June at the height of irrigation and during July, once irrigation has ended. By September and October the amount of water released from aquifer storage dropped off to less than 15 acre-feet per day during the synoptic run dates. This was consistent for both 2005 and 2006.



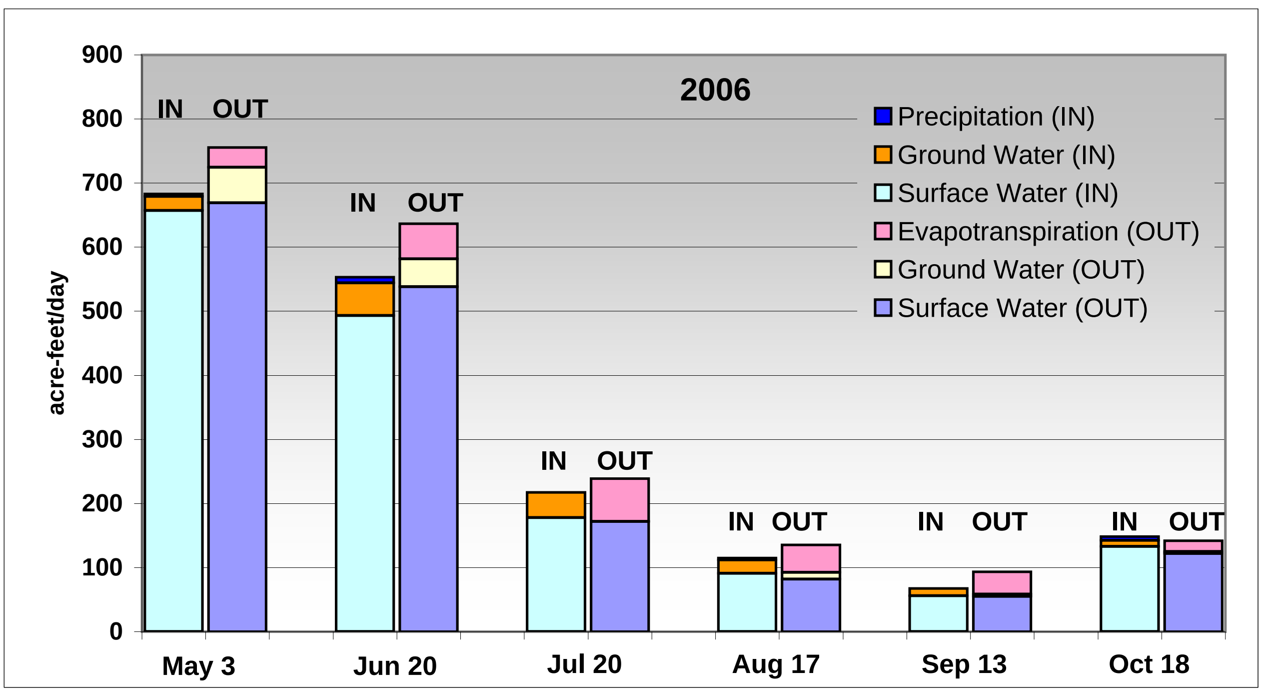
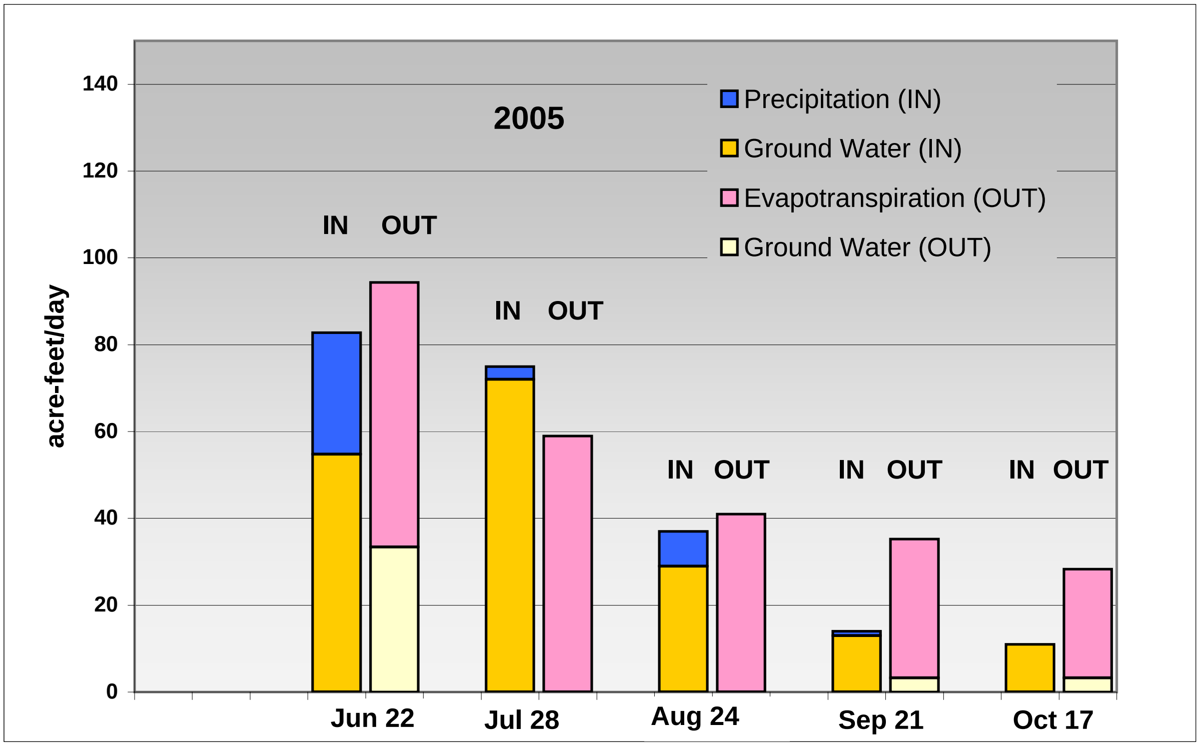




**Figure 19.** These bar charts represent estimates of the water budget components, the components on the left bar were inflows or sources (IN) to the system and the bar on the right were outflows or sinks (OUT) to the system.



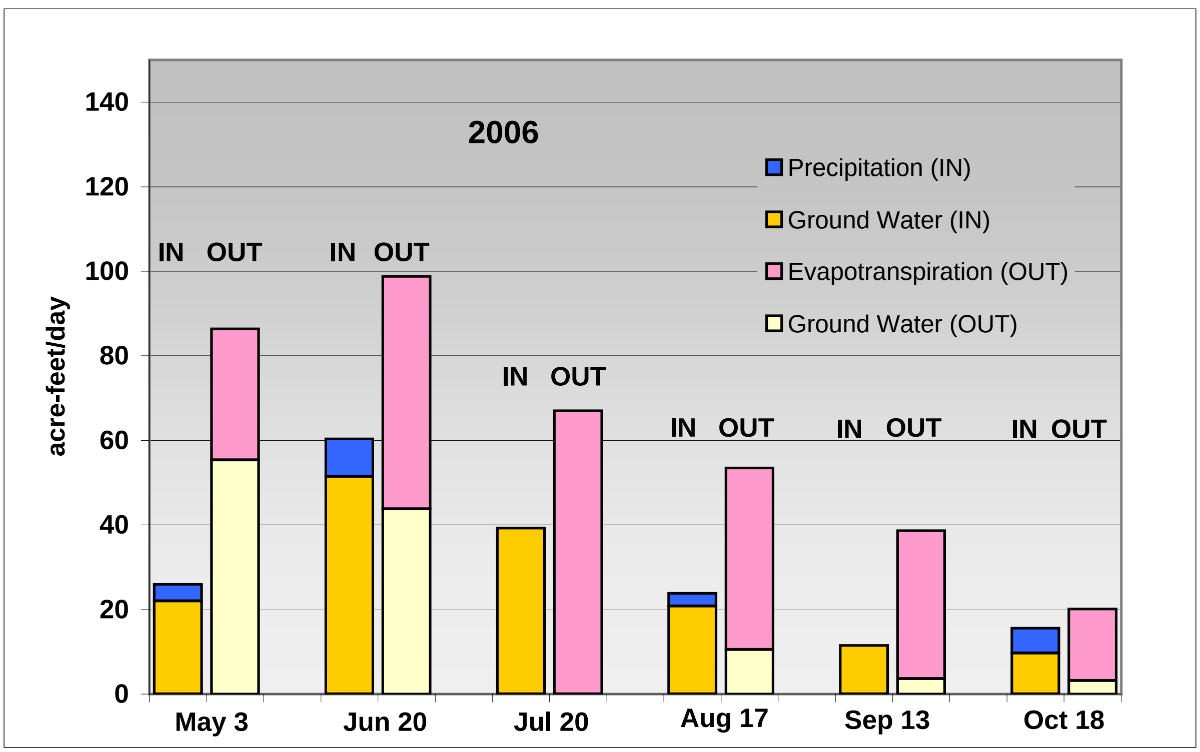




**Figure 20.** These bar charts give an estimate of the components that affect the water budget with the surface-water component removed.

The ‘sinks’ are ground water that has gone into aquifer storage and evapotranspiration. Most of the ground water going into storage occurs during May and June from natural recharge and from flood irrigation. By July (2005 and 2006), after irrigation had ended, the declining hydrographs indicate that ground water was being released from storage. This trend continued during August 2005 but by September and October (2005) although there was discharge from the aquifer, water had started going back into storage at some locations. During 2006 some ground water started to go back into storage at some locations in August, earlier than in 2005 and ground water continued to go back into storage through September and October.

Figure 20 shows the relative importance of evapotranspiration as it relates to the other components besides surface water. Evapotranspiration is greatest during June and July and begins tapering off after the grass hay is cut in August and air temperatures cool down in September and October. During most synoptic run dates, the estimated amount of evapotranspiration exceeded the amount of ground water being released from storage. Evapotranspiration exceeded ground water discharge by about 60 to 70 percent in September (2005 and 2006, respectively) and about 7 to 10 percent in June (2005 and 2006, respectively). The synoptic run during July 28, 2005 was the only period in which ground-water discharge may have exceeded evapotranspiration (by about 22 percent). In spite of this, there was a loss or no net gain in surface water as it exited the study area (Figure 18).

In essence, evapotranspiration negates discharges from ground-water storage that may provide a source to the surface water. In other words, if actual return flows were occurring, evapotranspiration matched or exceeded gains from ground-water storage.

## SUMMARY

Although the study area was relatively small (about 10 $mi^2$), there was significant variability in how the ground water responded to natural and man-made influences such as irrigation. Ground-water levels ranged from artesian conditions to depths of about 90 feet below the surface. Ground water fluctuated from about 2 to 29 feet in individual wells, with the greatest amount of fluctuation in wells located in the Tertiary sediments on the east side of the river. Ground-water response depends upon climatic conditions, location of the monitoring well within the watershed, the geologic material within which the well is completed, hydraulic characteristics of the aquifer, and the timing and magnitude of flood irrigation.

Short-term aquifer testing of 8 wells indicated that the hydraulic conductivity ranged from 1.4 to 8.6 ft/day. A ground-water flow map constructed during the height of the irrigation season (June 2005) shows flow towards the river. The gentler horizontal ground-water gradient (0.006 ft/ft) near the river indicates that sediments probably have a greater hydraulic conductivity when compared to sediments distal to the river.

Water-quality analyses indicate an absence or minimal amounts of nitrate in ground water. Iron was elevated in 80 percent of the wells sampled, with iron-rich seeps noted at several locations along the river. Arsenic was above the maximum contaminant level of 10 µg/L in two wells sampled within the study area. The source of arsenic is most likely associated with geothermal activity. Jardine Hot Springs is located about three miles south of the study area.

Flood irrigation has a pronounced affect on the ground-water hydrographs, with peaks occurring during June at the height of irrigation and lowest ground-water levels occurring in the late fall through early spring. Usually the shallow ground-water flow system responds quicker to natural and man-induced recharge than the deeper ground-water flow system.

In more than half of the wells examined, ground-water irrigation return flows discharged from aquifer storage quickly, returning to within 90 percent of their pre-irrigation levels by mid-August, approximately 6 weeks after irrigation ended. Although some ground water was still being released from storage into the late fall/winter, by mid-October ground water had returned to within 90 percent of pre-irrigation levels in 80 percent of the ground-water monitoring wells. Estimates of ground water released from storage during November through February of 2005 ranged from about 4 to 10 acre-feet per day within the study area. These small amounts were derived not just from irrigation during the summer but natural recharge from the previous spring.

During June 2005, and May and June 2006 surface-water outflows from the study area exceeded inflows. Although the inflow and outflow amounts were within the margin of error (10 percent) and may have indicated no net gain or loss, the June 22, 2005 and June 26, 2006 measurements were consistent in that water exiting the study area was greater than that entering, lending credibility that this was a true gain in surface-water flows from ground water. Sources to the ground water during May and June result from precipitation, which includes snowmelt, but more dramatically from flood irrigation.

The same comparison during July through October showed inflows exceeded outflows during this period, indicating a loss in surface water as it exited the study area. In spite of the fact that ground water was being released from storage, this did not result in a gain of water in the surface water network.

A water budget was estimated for the synoptic run dates to help explain the sources and sinks affecting the budget. Although the budget was estimated only during these dates, it provided information on how the hydrogeologic system responds during periods of pre-irrigation, at the height of irrigation and later on in the summer/fall. The surface-water component, which includes ground-water baseflow, is by far the largest contributor to the overall budget. Evapotranspiration estimates were nearly equal to or exceeded the amount of ground water being released from storage. This does not mean that ground-water returns did not occur. The premise that excess water from flood irrigation recharges the local aquifer and after a period of time, returns to the river as discharge is true, but evapotranspiration takes an equivalent amount of water, or more, out of the hydrogeologic system. Thus, any increases in surface flow that might occur from ground-water irrigation return flows are not evident in increased surface water flow.

These results are consistent with those presented by Marvin and Voeller (2000). Their study of the Francis Creek drainage, located about 7 miles north of this study area on the east side of the river, showed that irrigation return flows only occurred in Francis Creek during a 4-day period in June and that evapotranspiration accounted for the ground water lost from storage during July – September. The consistency in the results of the two study areas suggests that the overall hydrologic response is similar in the upper Big Hole River basin.

Table 6 indicates that augmentation of surface flow by irrigation return flow is potentially most significant during June, July and August when the highest quantity of ground water is released from storage. As the demand for ground-water storage is met during June, it is likely that some ground-water and overland return flow contributes to surface water. However, any gains from return flow during

June-August are masked by evapotranspiration losses that occur at this same time. In fact, during these months when ground water potentially contributed the most water to surface flows, surface outflows showed only a slight increase during June and were at a net loss through the study area during July and August.

Due to the variable nature of flood irrigation in the upper Big Hole basin, it is difficult to quantify the impacts of a reduction in the amount of water used to flood irrigate, even at a study area scale. However, many of the operators flood irrigate to the point of field saturation thus promoting surface ponding and tailwater runoff of excess diverted waters. In these cases, ground-water recharge has been satisfied and a reduction in the amount of water diverted would not likely impact ground-water storage. In addition, with more efficient irrigation management, which may include a reduction in the amount of water diverted, evapotranspiration in some areas would decrease due to the conversion of more consumptive plants, such as sedges, to grass hay.

## RECOMMENDATIONS

Investigating smaller study areas within a watershed allows for more control in the monitoring and logistical aspects of the study. However, it can be difficult to extrapolate these data when assessing basin-wide changes that might be incurred by altering land-use practices. These changes may consist of altering the types of crops grown and riparian vegetation, water management practices such as those that may be induced as part of the CCAA, the potential of changing irrigation methods from flood to sprinkler irrigation, converting hay land to pasture that typically is irrigated longer, residential development, and climate.

The results of this study suggest that evapotranspiration is a significant sink in the water budget, and therefore it might be beneficial to investigate the cultivation of crops that use less water. This study provides evidence that return flow from flood irrigation does occur but does not necessarily equate to increases in stream flow in late July through October. Typical irrigation practices in the upper Big Hole Valley apply water in excess of the requirements of grass hay and pasture grass. Reducing diversions to meet the irrigation demands of grass hay would not likely result in depletions to the surface water and may increase yields of grass hay and pasture by reducing water submergent conditions that can inhibit grass growth and in some areas replace grass with more consumptive plants (e.g. sedges). The challenge of implementing diversion reductions without a loss in production is to develop strategies to adequately distribute diverted water to meet crop demand without overwatering. This may require infrastructure improvements (headgates, measuring devices, ditch maintenance, etc.), diversion scheduling, and physical manipulation of distribution systems. All of these approaches are currently being investigated with landowner enrollees as part of the CCAA requirements.

The CCAA, initiated by federal and state agencies in cooperation with landowners, has several goals, including providing management plans for area ranchers that will help keep more water in the river for fisheries. Altering current irrigation practices can have an effect on the water budget and warrants increased monitoring in the upper basin to evaluate these changes. Current monitoring for the CCAA involves surface water only, which is only one component of a complex scenario. Several ground-water monitoring wells should be installed to track the effects of the CCAA.

It is recommended that computer modeling be used as a tool to help evaluate human-induced and natural changes to the water balance. A reality in the upper basin is improving irrigation efficiency, which could result in less water diverted to flood irrigate. A model can be used to simulate the changes incurred to the water budget though more efficient irrigation and the effect of cultivating crops that use less water (decreasing evapotranspiration). For example, in many basins in Montana, the conversion from flood to sprinkler irrigation is occurring. While basin-wide conversion is unlikely due to a short growing season and one cutting of hay, it is possible some ranchers in the upper Big Hole may someday consider this change to alleviate low flow conditions and labor costs. The conversion to sprinkler irrigation typically increases production due to more efficient distribution of water. It is also likely that aquifer recharge would decrease. In this case, modeling would be helpful to simulate water availability changes resulting from such conversions.

Responsible water management decisions can only be made by understanding the components that comprise the water budget and how changes would affect those components and ultimately the overall hydrogeologic system. Changes to make surface and ground-water use more efficient usually results in expenditures of time and money. Computer modeling provides the capability to evaluate various components of the water budget under differing hydrologic conditions before actually implementing those changes on the land.

Because modeling projects are dependent on sufficient data so that the model reflects the real world as accurately as possible, an effort such as this would require intensive basin-wide data collection. By altering characteristics of the model to simulate land use changes, predictions can be made as to how the water availability would be affected by these changes and whether or not the desired results could be achieved.

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# Appendix A

Ground-water measurements

| | |
|---|---|
| **GWIC ID:** | **M: 108588** |
| **1:24k Quad:** | **FOX GULCH** |
| **TRST:** | **05S15W10AADB** |
| **Ground Elevation (ft):** | **6413.21** |
| **MP from Land Surface (ft):** | **2.17** |
| **MP Elevation (ft)** | **6415.38** |
| **Total Depth from MP (ft):** | **97.17** |

| Date | Depth to Water from MP (ft) | Ground water Elevation |
|---|---|---|
| 07/08/04 | 55.16 | 6360.22 |
| 09/07/04 | 62.79 | 6352.59 |
| 10/13/04 | 64.22 | 6351.16 |
| 11/18/04 | 65.20 | 6350.18 |
| 01/21/05 | 66.30 | 6349.08 |
| 02/26/05 | 71.54 | 6343.84 |
| 03/21/05 | 67.79 | 6347.59 |
| 04/11/05 | 69.10 | 6346.28 |
| 04/26/05 | 65.63 | 6349.75 |
| 05/10/05 | 63.60 | 6351.78 |
| 05/24/05 | 57.00 | 6358.38 |
| 06/10/05 | 50.80 | 6364.58 |
| 06/22/05 | 48.95 | 6366.43 |
| 07/07/05 | 51.52 | 6363.86 |
| 07/21/05 | 56.50 | 6358.88 |
| 07/28/05 | 58.19 | 6357.19 |
| 08/11/05 | 60.63 | 6354.75 |
| 08/24/05 | 62.00 | 6353.38 |
| 09/07/05 | 63.07 | 6352.31 |
| 09/21/05 | 63.84 | 6351.54 |
| 10/17/05 | 64.90 | 6350.48 |
| 11/22/05 | 65.94 | 6349.44 |
| 12/20/05 | 67.80 | 6347.58 |
| 01/23/06 | 67.36 | 6348.02 |
| 02/24/06 | 67.98 | 6347.40 |
| 03/27/06 | 68.51 | 6346.87 |
| 04/11/06 | 68.70 | 6346.68 |
| 04/25/06 | 71.00 | 6344.38 |
| 05/03/06 | 71.40 | 6343.98 |
| 05/18/06 | 62.46 | 6352.92 |
| 06/01/06 | 58.90 | 6356.48 |
| 06/20/06 | 55.35 | 6360.03 |
| 07/06/06 | 56.30 | 6359.08 |
| 07/20/06 | 59.11 | 6356.27 |
| 08/03/06 | 60.88 | 6354.50 |
| 08/17/06 | 62.16 | 6353.22 |
| 08/31/06 | 63.07 | 6352.31 |
| 09/13/06 | 63.72 | 6351.66 |
| 09/28/06 | 64.37 | 6351.01 |
| 10/18/06 | 65.08 | 6350.30 |
| 11/25/06 | 66.15 | 6349.23 |

| | |
|---|---|
| **GWIC ID:** | **M: 108592** |
| **1:24k Quad:** | **FOX GULCH** |
| **TRST:** | **05S15W11CBCC** |
| **Ground Elevation (ft):** | **6427.1** |
| **MP from Land Surface (ft):** | **1.47** |
| **MP Elevation (ft)** | **6428.57** |
| **Total Depth from MP (ft):** | **100.47** |

| Date | Depth to Water from MP (ft) | Ground water Elevation |
|---|---|---|
| 05/24/05 | 69.72 | 6358.85 |
| 06/10/05 | 61.49 | 6367.08 |
| 06/22/05 | 61.20 | 6367.37 |
| 07/07/05 | 64.10 | 6364.47 |
| 07/21/05 | 69.30 | 6359.27 |
| 07/28/05 | 70.50 | 6358.07 |
| 08/11/05 | 73.20 | 6355.37 |
| 08/24/05 | 74.57 | 6354.00 |
| 09/07/05 | 75.80 | 6352.77 |
| 09/21/05 | 76.45 | 6352.12 |
| 10/17/05 | 77.49 | 6351.08 |
| 11/22/05 | 78.59 | 6349.98 |
| 12/20/05 | 81.58 | 6346.99 |
| 01/23/06 | 80.04 | 6348.53 |
| 02/24/06 | 80.62 | 6347.95 |
| 04/11/06 | 80.94 | 6347.63 |
| 04/25/06 | 84.10 | 6344.47 |
| 05/03/06 | 84.97 | 6343.60 |
| 05/18/06 | 75.40 | 6353.17 |
| 08/31/06 | 75.60 | 6352.97 |
| 09/13/06 | 76.30 | 6352.27 |
| 09/28/06 | 76.93 | 6351.64 |
| 10/18/06 | 77.65 | 6350.92 |
| 11/25/06 | 78.73 | 6349.84 |

| | |
|---|---|
| **GWIC ID:** | **M: 108600** |
| **1:24k Quad:** | **JACKSON** |
| **TRST:** | **05S15W22BABB** |
| **MP Ground Elevation (ft):** | **6402.98** |
| **MP from Land Surface (ft):** | **N/A** |
| **MP Elevation (ft)** | **6402.98** |
| **Total Depth from MP (ft):** | **119.00** |

| Date | Depth to Water from MP (ft) | Ground water Elevation |
|---|---|---|
| 08/11/04 | 5.69 | 6397.29 |
| 06/22/05 | 3.22 | 6399.76 |
| 08/24/05 | 6.60 | 6396.38 |
| 09/21/05 | 5.70 | 6397.28 |
| 10/17/05 | 5.11 | 6397.87 |
| 12/20/05 | 5.41 | 6397.57 |
| 05/03/06 | 2.83 | 6400.15 |
| 06/20/06 | 1.94 | 6401.04 |
| 07/20/06 | 3.47 | 6399.51 |
| 08/17/06 | 4.96 | 6398.02 |
| 10/18/06 | 3.65 | 6399.33 |

| | |
|---|---|
| **GWIC ID:** | **M: 150977** |
| **1:24k Quad:** | **FOX GULCH** |
| **TRST:** | **05S15W11BCBC** |
| **Ground Elevation (ft):** | **6436.43** |
| **MP from Land Surface (ft):** | **1.63** |
| **MP Elevation (ft)** | **6438.06** |
| **Total Depth from MP (ft):** | **116.63** |

| Date | Depth to Water from MP (ft) | Ground water Elevation |
|---|---|---|
| 05/10/05 | 84.35 | 6353.71 |
| 05/24/05 | 79.31 | 6358.75 |
| 06/10/05 | 72.93 | 6365.13 |
| 06/22/05 | 71.00 | 6367.06 |
| 07/07/05 | 73.54 | 6364.52 |
| 07/21/05 | 78.46 | 6359.60 |
| 07/28/05 | 80.25 | 6357.81 |
| 08/11/05 | 82.78 | 6355.28 |
| 08/24/05 | 84.16 | 6353.90 |
| 09/07/05 | 85.27 | 6352.79 |
| 09/21/05 | 86.07 | 6351.99 |
| 10/17/05 | 87.13 | 6350.93 |
| 11/22/05 | 88.24 | 6349.82 |
| 12/20/05 | 88.95 | 6349.11 |
| 01/23/06 | 89.71 | 6348.35 |
| 02/24/06 | 90.32 | 6347.74 |
| 03/27/06 | 90.83 | 6347.23 |
| 04/11/06 | 90.58 | 6347.48 |
| 04/25/06 | 90.61 | 6347.45 |
| 05/03/06 | 90.70 | 6347.36 |
| 05/18/06 | 84.90 | 6353.16 |
| 06/01/06 | 81.25 | 6356.81 |
| 06/20/06 | 77.60 | 6360.46 |
| 07/06/06 | 78.49 | 6359.57 |
| 07/20/06 | 81.21 | 6356.85 |
| 08/03/06 | 83.04 | 6355.02 |
| 08/17/06 | 84.31 | 6353.75 |
| 08/31/06 | 85.27 | 6352.79 |
| 09/13/06 | 85.93 | 6352.13 |
| 09/28/06 | 86.61 | 6351.45 |
| 10/18/06 | 87.32 | 6341.25 |
| 11/25/06 | 88.41 | 6340.16 |

| | |
|---|---|
| **GWIC ID:** | **M: 215316** |
| **1:24k Quad:** | **FOX GULCH** |
| **TRST:** | **;S15W11CBCA** |
| **Ground Elevation (ft):** | **6455.29** |
| **MP from Land Surface (ft):** | **1.93** |
| **MP Elevation (ft)** | **6456.62** |
| **Total Depth from MP (ft):** | **101.93** |

| Date | Depth to Water from MP (ft) | Ground water Elevation |
|---|---|---|
| 11/18/04 | 30.89 | 6425.73 |
| 01/21/05 | 33.38 | 6423.24 |
| 02/23/05 | 34.34 | 6422.28 |
| 03/21/05 | 35.10 | 6421.52 |
| 04/11/05 | 35.93 | 6420.69 |
| 05/10/05 | 36.48 | 6420.14 |
| 05/24/05 | 28.32 | 6428.30 |
| 06/10/05 | 18.72 | 6437.90 |
| 06/22/05 | 9.24 | 6447.38 |
| 07/07/05 | 9.84 | 6446.78 |
| 07/21/05 | 16.10 | 6440.52 |
| 07/28/05 | 18.68 | 6437.94 |
| 08/11/05 | 21.74 | 6434.88 |
| 08/24/05 | 23.44 | 6433.18 |
| 09/07/05 | 25.14 | 6431.48 |
| 09/21/05 | 26.42 | 6430.20 |
| 10/17/05 | 28.36 | 6428.26 |
| 11/22/05 | 30.35 | 6426.27 |
| 12/20/05 | 31.70 | 6424.92 |
| 01/23/06 | 33.05 | 6423.57 |
| 02/24/06 | 33.90 | 6422.72 |
| 03/27/06 | 34.73 | 6421.89 |
| 04/11/06 | 34.78 | 6421.84 |
| 04/25/06 | 32.70 | 6423.92 |
| 05/03/06 | 25.96 | 6430.66 |
| 05/18/06 | 13.89 | 6442.73 |
| 06/01/06 | 9.01 | 6447.61 |
| 06/20/06 | 7.58 | 6449.04 |
| 07/06/06 | 11.57 | 6445.05 |
| 07/20/06 | 17.18 | 6439.44 |
| 08/03/06 | 20.83 | 6435.79 |
| 08/17/06 | 22.91 | 6433.71 |
| 08/31/06 | 24.54 | 6432.08 |
| 09/13/06 | 25.62 | 6431.00 |
| 09/28/06 | 26.90 | 6429.72 |
| 10/18/06 | 28.26 | 6400.31 |
| 11/25/06 | 30.15 | 6398.42 |

| | |
|---|---|
| **GWIC ID:** | **M: 108590** |
| **1:24k Quad:** | **FOX GULCH** |
| **TRST:** | **05S15W10DCDA** |
| **Ground Elevation (ft):** | **6376.38** |
| **MP from Land Surface (ft):** | **0.88** |
| **MP Elevation (ft)** | **6377.26** |
| **Total Depth from MP (ft):** | **75.88** |

| Date | Depth to Water from MP (ft) | Ground water Elevation |
|---|---|---|
| 07/07/04 | 5.71 | 6371.55 |
| 09/07/04 | 11.09 | 6366.17 |
| 10/13/04 | 13.22 | 6364.04 |
| 11/18/04 | 15.14 | 6362.12 |
| 12/18/04 | 16.55 | 6360.71 |
| 01/21/05 | 17.68 | 6359.58 |
| 02/23/05 | 18.70 | 6358.56 |
| 03/21/05 | 19.32 | 6357.94 |
| 04/11/05 | 19.04 | 6358.22 |
| 04/26/05 | 18.70 | 6358.56 |
| 05/10/05 | 14.93 | 6362.33 |
| 05/24/05 | 8.73 | 6368.53 |
| 06/10/05 | 4.82 | 6372.44 |
| 06/22/05 | 3.87 | 6373.39 |
| 07/07/05 | 4.40 | 6372.86 |
| 07/21/05 | 6.68 | 6370.58 |
| 07/28/05 | 7.30 | 6369.96 |
| 08/11/05 | 8.90 | 6368.36 |
| 08/24/05 | 10.16 | 6367.10 |
| 09/07/05 | 11.50 | 6365.76 |
| 09/21/05 | 12.40 | 6364.86 |
| 10/17/05 | 14.20 | 6363.06 |
| 11/22/05 | 16.20 | 6361.06 |
| 12/20/05 | 17.40 | 6359.86 |
| 01/23/06 | 18.67 | 6358.59 |
| 02/24/06 | 19.65 | 6357.61 |
| 03/27/06 | 20.44 | 6356.82 |
| 04/11/06 | 18.77 | 6358.49 |
| 04/25/06 | 18.50 | 6358.76 |
| 05/03/06 | 19.25 | 6358.01 |
| 05/18/06 | 13.10 | 6364.16 |
| 06/01/06 | 8.85 | 6368.41 |
| 06/20/06 | 5.70 | 6371.56 |
| 07/06/06 | 5.60 | 6371.66 |
| 07/20/06 | 7.60 | 6369.66 |
| 08/03/06 | 9.22 | 6368.04 |
| 08/31/06 | 11.57 | 6365.69 |
| 09/13/06 | 12.30 | 6364.96 |
| 09/28/06 | 13.31 | 6363.95 |
| 10/18/06 | 14.50 | 6362.76 |
| 11/25/06 | 16.35 | 6360.91 |

| | |
|---|---|
| **GWIC ID:** | **M:221765** |
| **1:24k Quad:** | **FOX GULCH** |
| **TRST:** | **05S15W16BABA** |
| **Ground Elevation (ft):** | **6398.29** |
| **MP from Land Surface (ft):** | **3.86** |
| **MP Elevation (ft)** | **6402.15** |
| **Total Depth from MP (ft):** | **13.25** |

| Date | Depth to Water from MP (ft) | Ground water Elevation |
|---|---|---|
| 11/18/04 | 5.42 | 6396.73 |
| 12/18/04 | 5.30 | 6396.85 |
| 01/21/05 | 4.23 | 6397.92 |
| 02/23/05 | 3.91 Frozen | |
| 03/21/05 | 3.92 Frozen | |
| 04/11/05 | 3.92 Frozen | |
| 04/26/05 | 4.83 Frozen | |
| 05/24/05 | 4.08 | 6398.07 |
| 06/10/05 | 4.34 | 6397.81 |
| 06/22/05 | 4.23 | 6397.92 |
| 07/07/05 | 4.52 | 6397.63 |
| 07/21/05 | 5.67 | 6396.48 |
| 07/28/05 | 5.86 | 6396.29 |
| 08/11/05 | 5.60 | 6396.55 |
| 08/24/05 | 5.96 | 6396.19 |
| 09/07/05 | 6.04 | 6396.11 |
| 09/21/05 | 5.61 | 6396.54 |
| 10/17/05 | 5.33 | 6396.82 |
| 11/22/05 | 5.28 | 6396.87 |
| 12/20/05 | 5.39 | 6396.76 |
| 01/23/06 | 5.40 | 6396.75 |
| 02/24/06 | 4.74 | 6397.41 |
| 03/27/06 | 5.05 | 6397.10 |
| 04/11/06 | 4.54 | 6397.61 |
| 04/25/06 | 4.70 | 6397.45 |
| 05/03/06 | 4.75 | 6397.40 |
| 05/18/06 | 4.34 | 6397.81 |
| 06/01/06 | 4.53 | 6397.62 |
| 06/20/06 | 4.43 | 6397.72 |
| 07/06/06 | 4.44 | 6397.71 |
| 07/20/06 | 5.49 | 6396.66 |
| 08/03/06 | 5.83 | 6396.32 |
| 08/17/06 | 5.88 | 6396.27 |
| 08/31/06 | 6.00 | 6396.15 |
| 09/13/06 | 5.96 | 6396.19 |
| 09/28/06 | 5.63 | 6396.52 |
| 10/18/06 | 5.38 | 6396.77 |
| 11/25/06 | 5.09 | 6397.06 |
| 12/07/06 | 5.10 | 6397.05 |

| | |
|---|---|
| **GWIC ID:** | **M:215478** |
| **1:24k Quad:** | **FOX GULCH** |
| **TRST:** | **05S15W08CDAC** |
| **Ground Elevation (ft):** | **6443.18** |
| **MP from Land Surface (ft):** | **1.47** |
| **MP Elevation (ft)** | **6444.65** |
| **Total Depth from MP (ft):** | **81.47** |

| Date | Depth to Water from MP (ft) | Ground water Elevation |
|---|---|---|
| 10/13/04 | 34.11 | 6410.54 |
| 11/18/04 | 36.37 | 6408.28 |
| 12/18/04 | 39.31 | 6405.34 |
| 01/21/05 | 41.10 | 6403.55 |
| 02/23/05 | 46.90 | 6397.75 |
| 03/21/05 | 45.46 | 6399.19 |
| 04/11/05 | 42.22 | 6402.43 |
| 04/26/05 | 41.99 | 6402.66 |
| 05/10/05 | 44.12 | 6400.53 |
| 05/24/05 | 40.88 | 6403.77 |
| 06/10/05 | 40.34 | 6404.31 |
| 06/22/05 | 40.10 | 6404.55 |
| 07/07/05 | 39.85 | 6404.80 |
| 07/21/05 | 40.38 | 6404.27 |
| 07/28/05 | 42.72 | 6401.93 |
| 08/11/05 | 47.88 | 6396.77 |
| 08/24/05 | 49.30 | 6395.35 |
| 09/07/05 | 50.01 | 6394.64 |
| 09/21/05 | 50.00 | 6394.65 |
| 10/17/05 | 48.96 | 6395.69 |
| 11/22/05 | 47.53 | 6397.12 |
| 01/23/06 | 48.71 | 6395.94 |
| 02/24/06 | 48.08 | 6396.57 |
| 03/27/06 | 47.10 | 6397.55 |
| 04/11/06 | 45.98 | 6398.67 |
| 04/25/06 | 45.95 | 6398.70 |
| 05/03/06 | 45.11 | 6399.54 |
| 05/18/06 | 44.50 | 6400.15 |
| 06/01/06 | 43.70 | 6400.95 |
| 06/20/06 | 42.31 | 6402.34 |
| 07/06/06 | 42.00 | 6402.65 |
| 07/20/06 | 42.56 | 6402.09 |
| 08/03/06 | 43.15 | 6401.50 |
| 08/17/06 | 43.46 | 6401.19 |
| 08/31/06 | 43.64 | 6401.01 |
| 09/13/06 | 44.02 | 6400.63 |
| 09/28/06 | 44.11 | 6400.54 |
| 10/18/06 | 44.05 | 6400.60 |
| 11/25/06 | 44.14 | 6400.51 |
| 12/07/06 | 44.65 | 6400.00 |

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|---|---|
| **GWIC ID:** | **221757** |
| **1:24k Quad:** | **FOX GULCH** |
| **TRST:** | **05S15W08BCAA** |
| **Ground Elevation (ft):** | **6423.97** |
| **MP from Land Surface (ft):** | **1.35** |
| **MP Elevation (ft)** | **6425.32** |
| **Total Depth from MP (ft):** | **72.35** |

| Date | Depth to Water from MP (ft) | Ground water Elevation |
|---|---|---|
| 10/13/04 | 24.23 | 6401.09 |
| 04/11/05 | 38.33 | 6386.99 |
| 04/26/05 | 38.03 | 6387.29 |
| 05/24/05 | 24.81 | 6400.51 |
| 06/10/05 | 24.12 | 6401.20 |
| 06/22/05 | 23.60 | 6401.72 |
| 07/07/05 | 23.23 | 6402.09 |
| 07/21/05 | 23.33 | 6401.99 |
| 07/28/05 | 23.93 | 6401.39 |
| 08/11/05 | 27.79 | 6397.53 |
| 08/24/05 | 29.62 | 6395.70 |
| 09/07/05 | 30.66 | 6394.66 |
| 09/21/05 | 31.07 | 6394.25 |
| 10/17/05 | 30.95 | 6394.37 |
| 11/10/05 | 30.47 | 6394.85 |
| 04/25/06 | 30.86 | 6394.46 |
| 05/03/06 | 28.18 | 6397.14 |
| 05/18/06 | 27.88 | 6397.44 |
| 06/01/06 | 27.14 | 6398.18 |
| 06/20/06 | 26.31 | 6399.01 |
| 07/06/06 | 25.88 | 6399.44 |
| 07/20/06 | 25.98 | 6399.34 |
| 08/03/06 | 26.23 | 6399.09 |
| 08/17/06 | 26.37 | 6398.95 |
| 08/31/06 | 26.43 | 6398.89 |
| 09/13/06 | 26.43 | 6398.89 |
| 09/28/06 | 26.37 | 6398.95 |
| 10/18/06 | 26.38 | 6398.94 |

**GWIC ID:** M:221767
**1:24k Quad:** FOX GULCH
**TRST:** 5S15W08BCAA
**Ground Elevation (ft):** 6423.13
**MP from Land Surface (ft):** 2.65
**MP Elevation (ft)** 6425.78
**Total Depth from MP (ft):** 17.95

| Date | Depth to Water from MP (ft) | Ground water Elevation |
|---|---|---|
| 11/18/04 | 7.60 | 6418.18 |
| 12/18/04 | 7.11 | 6418.67 |
| 01/21/05 | 8.08 | 6417.70 |
| 02/23/05 | 8.31 | 6417.47 |
| 03/21/05 | 8.08 | 6417.70 |
| 04/11/05 | 7.78 | 6418.00 |
| 04/26/05 | 6.79 | 6418.99 |
| 05/24/05 | 3.81 | 6421.97 |
| 06/10/05 | 3.95 | 6421.83 |
| 06/22/05 | 3.91 | 6421.87 |
| 07/07/05 | 4.21 | 6421.57 |
| 07/21/05 | 5.94 | 6419.84 |
| 07/28/05 | 6.55 | 6419.23 |
| 08/11/05 | 7.09 | 6418.69 |
| 08/24/05 | 7.41 | 6418.37 |
| 09/07/05 | 7.67 | 6418.11 |
| 09/21/05 | 7.54 | 6418.24 |
| 10/17/05 | 7.25 | 6418.53 |
| 11/10/05 | 7.20 | 6418.58 |
| 11/22/05 | 7.51 | 6418.27 |
| 03/27/06 | 7.25 | 6418.53 |
| 04/11/06 | 3.97 | 6421.81 |
| 04/25/06 | 4.20 | Frozen |
| 05/03/06 | 5.17 | 6420.61 |
| 05/18/06 | 5.76 | 6420.02 |
| 06/01/06 | 3.75 | 6422.03 |
| 06/20/06 | 3.48 | 6422.30 |
| 07/06/06 | 3.47 | 6422.31 |
| 07/20/06 | 5.67 | 6420.11 |
| 08/03/06 | 6.45 | 6419.33 |
| 08/17/06 | 6.69 | 6419.09 |
| 08/31/06 | 6.83 | 6418.95 |
| 09/13/06 | 6.89 | 6418.89 |
| 09/28/06 | 6.66 | 6419.12 |
| 10/18/06 | 6.37 | 6419.41 |
| 11/25/06 | 6.39 | 6419.39 |

**GWIC ID:** M:221766
**1:24k Quad:** FOX GULCH
**TRST:** 05S15W09ABAB
**Ground Elevation (ft):** 6396.43
**MP from Land Surface (ft):** 2.78
**MP Elevation (ft)** 6399.21
**Total Depth from MP (ft):** 17.35

| Date | Depth to Water from MP (ft) | Ground water Elevation |
|---|---|---|
| 11/18/04 | 6.27 | 6392.94 |
| 12/18/04 | 6.14 | 6393.07 |
| 01/21/05 | 6.26 | 6392.95 |
| 02/23/05 | 6.22 | 6392.99 |
| 03/21/05 | 6.33 | 6392.88 |
| 04/11/05 | 6.19 | 6393.02 |
| 04/26/05 | 6.14 | 6393.07 |
| 05/24/05 | 5.28 | 6393.93 |
| 06/10/05 | 3.04 | 6396.17 |
| 06/22/05 | 2.99 | 6396.22 |
| 07/07/05 | 3.95 | 6395.26 |
| 07/21/05 | 5.30 | 6393.91 |
| 07/28/05 | 5.29 | 6393.92 |
| 08/11/05 | 5.53 | 6393.68 |
| 08/24/05 | 5.74 | 6393.47 |
| 09/07/05 | 5.93 | 6393.28 |
| 09/21/05 | 6.09 | 6393.12 |
| 10/17/05 | 6.20 | 6393.01 |
| 11/22/05 | 6.07 | 6393.14 |
| 03/27/06 | 6.21 | 6393.00 |
| 04/11/06 | 3.26 | 6395.95 |
| 04/25/06 | 4.28 | 6394.93 |
| 05/03/06 | 4.54 | 6394.67 |
| 05/18/06 | 4.84 | 6394.37 |
| 06/01/06 | 3.05 | 6396.16 |
| 06/20/06 | 3.14 | 6396.07 |
| 07/06/06 | 3.17 | 6396.04 |
| 07/20/06 | 5.10 | 6394.11 |
| 08/03/06 | 5.45 | 6393.76 |
| 08/17/06 | 5.64 | 6393.57 |
| 08/31/06 | 5.87 | 6393.34 |
| 09/13/06 | 6.00 | 6393.21 |
| 09/28/06 | 6.05 | 6393.16 |
| 10/18/06 | 6.12 | 6393.09 |
| 11/25/06 | 6.04 | 6393.17 |

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| **GWIC ID:** | **M:221759** |
| **1:24k Quad:** | **FOX GULCH** |
| **TRST:** | **05S15W08ADDA** |
| **Ground Elevation (ft):** | **6393.45** |
| **MP from Land Surface (ft):** | **3.10** |
| **MP Elevation (ft)** | **6396.55** |
| **Total Depth from MP (ft):** | **16.30** |

| Date | Depth to Water from MP (ft) | Ground water Elevation |
|---|---|---|
| 11/18/04 | 10.26 | 6386.29 |
| 12/18/04 | 9.69 | 6386.86 |
| 01/21/05 | 10.98 | 6385.57 |
| 02/23/05 | 11.77 | 6384.78 |
| 03/21/05 | 12.14 | 6384.41 |
| 04/11/05 | 12.29 | 6384.26 |
| 04/26/05 | 12.13 | 6384.42 |
| 05/10/05 | 11.77 | 6384.78 |
| 05/24/05 | 3.66 | 6392.89 |
| 06/10/05 | 2.38 | 6394.17 |
| 06/22/05 | 2.50 | 6394.05 |
| 07/07/05 | 2.75 | 6393.80 |
| 07/21/05 | 4.70 | 6391.85 |
| 07/28/05 | 5.60 | 6390.95 |
| 08/11/05 | 6.25 | 6390.30 |
| 08/24/05 | 7.05 | 6389.50 |
| 09/07/05 | 7.80 | 6388.75 |
| 09/21/05 | 8.13 | 6388.42 |
| 10/17/05 | 8.71 | 6387.84 |
| 11/22/05 | 10.00 | 6386.55 |
| 12/20/05 | 10.91 | 6385.64 |
| 01/23/06 | 11.81 | 6384.74 |
| 02/24/06 | 12.23 | 6384.32 |
| 03/27/06 | 12.43 | 6384.12 |
| 04/11/06 | 11.23 | 6385.32 |
| 04/25/06 | 6.45 | 6390.10 |
| 05/03/06 | 6.66 | 6389.89 |
| 05/18/06 | 6.25 | 6390.30 |
| 06/01/06 | 4.44 | 6392.11 |
| 06/20/06 | 2.40 | 6394.15 |
| 07/06/06 | 2.45 | 6394.10 |
| 07/20/06 | 3.83 | 6392.72 |
| 08/03/06 | 5.83 | 6390.72 |
| 08/17/06 | 6.62 | 6389.93 |
| 08/31/06 | 7.20 | 6389.35 |
| 09/13/06 | 7.72 | 6388.83 |
| 09/28/06 | 7.97 | 6388.58 |
| 10/18/06 | 8.25 | 6388.30 |
| 11/25/06 | 9.40 | 6387.15 |

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| **GWIC ID:** | **M: 108595** |
| **1:24k Quad:** | **FOX GULCH** |
| **TRST:** | **05S15W17BABA** |
| **Ground Elevation (ft):** | **6439.52** |
| **MP from Land Surface (ft):** | **1.73** |
| **MP Elevation (ft)** | **6441.25** |
| **Total Depth from MP (ft):** | **44.73** |

| Date | Depth to Water from MP (ft) | Ground water Elevation |
|---|---|---|
| 07/07/04 | 7.37 | 6433.88 |
| 09/08/04 | 9.75 | 6431.50 |
| 10/13/04 | 10.23 | 6431.02 |
| 11/18/04 | 9.83 | 6431.42 |
| 01/21/05 | 11.43 | 6429.82 |
| 02/23/05 | 13.73 | 6427.52 |
| 03/21/05 | 11.84 | 6429.41 |
| 04/11/05 | 10.11 | 6431.14 |
| 04/26/05 | 9.73 | 6431.52 |
| 05/10/05 | 11.06 | 6430.19 |
| 05/24/05 | 10.26 | 6430.99 |
| 06/10/05 | 7.97 | 6433.28 |
| 06/22/05 | 7.80 | 6433.45 |
| 07/07/05 | 8.31 | 6432.94 |
| 07/21/05 | 9.23 | 6432.02 |
| 07/28/05 | 9.40 | 6431.85 |
| 08/11/05 | 10.33 | 6430.92 |
| 08/24/05 | 11.40 | 6429.85 |
| 09/07/05 | 11.96 | 6429.29 |
| 09/21/05 | 11.90 | 6429.35 |
| 10/17/05 | 11.28 | 6429.97 |
| 11/22/05 | 10.26 | 6430.99 |
| 12/20/05 | 10.28 | 6430.97 |
| 01/23/06 | 10.52 | 6430.73 |
| 02/24/06 | 10.70 | 6430.55 |
| 03/27/06 | 11.74 | 6429.51 |
| 04/11/06 | 9.91 | 6431.34 |
| 04/25/06 | 8.35 | 6432.90 |
| 05/03/06 | 8.67 | 6432.58 |
| 05/18/06 | 8.92 | 6432.33 |
| 06/01/06 | 8.57 | 6432.68 |
| 06/20/06 | 6.95 | 6434.30 |
| 07/06/06 | 6.99 | 6434.26 |
| 07/20/06 | 8.10 | 6433.15 |
| 08/03/06 | 10.21 | 6431.04 |
| 08/17/06 | 11.10 | 6430.15 |
| 08/31/06 | 11.08 | 6430.17 |
| 09/28/06 | 10.62 | 6430.63 |
| 10/18/06 | 10.19 | 6431.06 |
| 11/25/06 | 9.93 | 6431.32 |
| 12/07/06 | 10.32 | 6430.93 |

**GWIC ID:** M: 147065
**1:24k Quad:** AJAX RANCH
**TRST:** 05S15W07CAAC
**Ground Elevation (ft):** 6472.12
**MP from Land Surface (ft):** 1.60
**MP Elevation (ft)** 6473.72
**Total Depth from MP (ft):** 69.60

| Date | Depth to Water from MP (ft) | Ground water Elevation |
|---|---|---|
| 07/07/04 | 4.98 | 6468.74 |
| 09/08/04 | 6.13 | 6467.59 |
| 10/13/04 | 6.36 | 6467.36 |
| 11/18/04 | 7.18 | 6466.54 |
| 12/18/04 | 6.74 | 6466.98 |
| 04/26/05 | 7.63 | 6466.09 |
| 05/10/05 | 6.70 | 6467.02 |
| 05/24/05 | 5.91 | 6467.81 |
| 06/10/05 | 5.36 | 6468.36 |
| 06/22/05 | 5.15 | 6468.57 |
| 07/07/05 | 5.09 | 6468.63 |
| 07/21/05 | 5.53 | 6468.19 |
| 07/28/05 | 5.36 | 6468.36 |
| 08/11/05 | 5.26 | 6468.46 |
| 08/24/05 | 5.78 | 6467.94 |
| 09/07/05 | 6.39 | 6467.33 |
| 09/21/05 | 6.77 | 6466.95 |
| 10/17/05 | 7.33 | 6466.39 |
| 04/25/06 | 9.39 | 6464.33 |
| 05/03/06 | 7.21 | 6466.51 |
| 05/18/06 | 7.07 | 6466.65 |
| 06/01/06 | 6.39 | 6467.33 |
| 06/20/06 | 6.00 | 6467.72 |
| 07/06/06 | 5.84 | 6467.88 |
| 07/20/06 | 6.23 | 6467.49 |
| 08/03/06 | 6.71 | 6467.01 |
| 08/17/06 | 6.98 | 6466.74 |
| 08/31/06 | 7.20 | 6466.52 |
| 09/13/06 | 7.34 | 6466.38 |
| 09/28/06 | 7.43 | 6466.29 |
| 10/18/06 | 7.45 | 6466.27 |

**GWIC ID:** M:221764
**1:24k Quad:** AJAX RANCH
**TRST:** 05S15W06CACB
**Ground Elevation (ft):** 6445.08
**MP from Land Surface (ft):** 2.58
**MP Elevation (ft)** 6447.66
**Total Depth from MP (ft):** 17.88

| Date | Depth to Water from MP (ft) | Ground water Elevation |
|---|---|---|
| 11/08/04 | 7.18 | 6440.48 |
| 12/18/04 | 6.74 | 6440.92 |
| 01/21/05 | 4.19 | 6443.47 |
| 02/23/05 | 3.54 | 6444.12 |
| 03/21/05 | 3.77 | 6443.89 |
| 04/11/05 | 4.23 | 6443.43 |
| 04/26/05 | 5.11 | 6442.55 |
| 05/10/05 | 5.64 | 6442.02 |
| 05/24/05 | 4.63 | 6443.03 |
| 06/10/05 | 2.83 | 6444.83 |
| 06/22/05 | 2.91 | 6444.75 |
| 07/07/05 | 2.97 | 6444.69 |
| 07/21/05 | 4.13 | 6443.53 |
| 07/28/05 | 4.94 | 6442.72 |
| 08/11/05 | 5.57 | 6442.09 |
| 08/24/05 | 6.33 | 6441.33 |
| 09/07/05 | 6.83 | 6440.83 |
| 09/21/05 | 6.74 | 6440.92 |
| 10/17/05 | 6.74 | 6440.92 |
| 11/22/05 | 6.85 | 6440.81 |
| 12/20/05 | 6.90 | 6440.76 |
| 01/23/06 | 6.71 | 6440.95 |
| 02/24/06 | 6.73 | 6440.93 |
| 03/27/06 | 3.35 | 6444.31 |
| 04/11/06 | 3.29 | 6444.37 |
| 04/25/06 | 3.29 | 6444.37 |
| 05/03/06 | 3.71 | 6443.95 |
| 05/18/06 | 4.48 | 6443.18 |
| 06/01/06 | 2.99 | 6444.67 |
| 06/20/06 | 2.85 | 6444.81 |
| 07/06/06 | 2.82 | 6444.84 |
| 07/20/06 | 3.96 | 6443.70 |
| 08/03/06 | 5.46 | 6442.20 |
| 08/17/06 | 6.75 | 6440.91 |
| 08/31/06 | 7.39 | 6440.27 |
| 09/13/06 | 7.55 | 6440.11 |
| 09/28/06 | 7.52 | 6440.14 |
| 10/18/06 | 7.38 | 6440.28 |
| 11/25/06 | 7.20 | 6440.46 |

| GWIC ID: | M: 108254 | |
|---|---|---|
| 1:24k Quad: | AJAX RANCH | |
| TRST: | 04S16W36DDDA | |
| Ground Elevation (ft): | 6425.11 | |
| MP from Land Surface (ft): | 1.77 | |
| MP Elevation (ft) | 6426.88 | |
| Total Depth from MP (ft): | 64.72 | |

| Date | Depth to Water from MP (ft) | Ground water Elevation |
|---|---|---|
| 07/07/04 | 3.86 | 6423.02 |
| 09/08/04 | 5.62 | 6421.26 |
| 10/13/04 | 4.95 | 6421.93 |
| 11/18/04 | 5.22 | 6421.66 |
| 12/18/04 | 5.06 | 6421.82 |
| 01/21/05 | 7.50 | 6419.38 |
| 02/23/05 | 7.95 | 6418.93 |
| 03/21/05 | 7.58 | 6419.30 |
| 04/11/05 | 5.50 | 6421.38 |
| 04/26/05 | 4.68 | 6422.20 |
| 05/10/05 | 3.48 | 6423.40 |
| 05/24/05 | 3.29 | 6423.59 |
| 06/10/05 | 3.54 | 6423.34 |
| 06/22/05 | 3.60 | 6423.28 |
| 07/07/05 | 4.43 | 6422.45 |
| 07/21/05 | 5.41 | 6421.47 |
| 07/28/05 | 5.05 | 6421.83 |
| 08/11/05 | 4.95 | 6421.93 |
| 08/24/05 | 5.63 | 6421.25 |
| 09/07/05 | 5.96 | 6420.92 |
| 09/21/05 | 5.71 | 6421.17 |
| 10/17/05 | 5.31 | 6421.57 |
| 11/22/05 | 5.20 | 6421.68 |
| 12/20/05 | 6.69 | 6420.19 |
| 01/23/06 | 6.76 | 6420.12 |
| 02/24/06 | 7.54 | 6419.34 |
| 03/27/06 | 7.41 | 6419.47 |
| 04/11/06 | 4.00 | 6422.88 |
| 04/25/06 | 4.14 | 6422.74 |
| 05/03/06 | 4.38 | 6422.50 |
| 05/18/06 | 3.36 | 6423.52 |
| 06/01/06 | 3.43 | 6423.45 |
| 06/20/06 | 4.01 | 6422.87 |
| 07/06/06 | 4.36 | 6422.52 |
| 07/20/06 | 5.32 | 6421.56 |
| 08/03/06 | 5.76 | 6421.12 |
| 08/17/06 | 5.82 | 6421.06 |
| 08/31/06 | 5.91 | 6420.97 |
| 09/13/06 | 5.94 | 6420.94 |
| 09/28/06 | 5.75 | 6421.13 |
| 10/18/06 | 5.48 | 6421.40 |
| 11/25/06 | 4.61 | 6422.27 |
| 12/07/06 | 5.15 | 6421.73 |

| GWIC ID: | M: 108245 | |
|---|---|---|
| 1:24k Quad: | FOX GULCH | |
| TRST: | 05S15W5BBAD | |
| Ground Elevation (ft): | 6369.57 | |
| MP from Land Surface (ft): | 2.30 | |
| MP Elevation (ft) | 6371.87 | |
| Total Depth from MP (ft): | 107.30 | |

| Date | Depth to Water from MP (ft) | Ground water Elevation |
|---|---|---|
| 10/13/04 | 48.57 | 6323.30 |
| 01/21/05 | 49.65 | 6322.22 |
| 04/26/05 | 49.97 | 6321.90 |
| 05/10/05 | 49.61 | 6322.26 |
| 05/24/05 | 49.66 | 6322.21 |
| 07/07/05 | 48.85 | 6323.02 |
| 07/21/05 | 50.45 | 6321.42 |
| 08/24/05 | 51.53 | 6320.34 |
| 09/21/05 | 51.93 | 6319.94 |
| 10/17/05 | 51.43 | 6320.44 |
| 12/20/05 | 51.72 | 6320.15 |
| 01/23/06 | 52.04 | 6319.83 |
| 03/27/06 | 51.83 | 6320.04 |
| 04/11/06 | 51.68 | 6320.19 |
| 04/25/06 | 50.48 | 6321.39 |
| 05/18/06 | 50.88 | 6320.99 |
| 06/01/06 | 50.07 | 6321.80 |
| 07/06/06 | 48.02 | 6323.85 |
| 07/20/06 | 49.45 | 6322.42 |
| 08/03/06 | 49.71 | 6322.16 |
| 08/17/06 | 50.03 | 6321.84 |
| 08/31/06 | 50.10 | 6321.77 |
| 09/13/06 | 50.61 | 6321.26 |
| 11/25/06 | 50.07 | 6321.80 |

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| **GWIC ID:** | **M: 108585** |
| **1:24k Quad:** | **FOX GULCH** |
| **TRST:** | **05S15W05BDAD** |
| **Ground Elevation (ft):** | **6373.01** |
| **MP from Land Surface (ft):** | **1.35** |
| **MP Elevation (ft)** | **6374.36** |
| **Total Depth from MP (ft):** | **113.35** |

| Date | Depth to Water from MP (ft) | Ground water Elevation |
|---|---|---|
| 09/08/04 | 31.97 | 6342.39 |
| 10/13/04 | 32.48 | 6341.88 |
| 11/18/04 | 32.92 | 6341.44 |
| 12/18/04 | 36.35 | 6338.01 |
| 01/21/05 | 35.86 | 6338.50 |
| 02/23/05 | 37.05 | 6337.31 |
| 04/11/05 | 34.52 | 6339.84 |
| 04/26/05 | 33.98 | 6340.38 |
| 05/10/05 | 33.08 | 6341.28 |
| 05/24/05 | 32.24 | 6342.12 |
| 06/10/05 | 31.91 | 6342.45 |
| 06/22/05 | 30.42 | 6343.94 |
| 07/07/05 | 30.12 | 6344.24 |
| 07/28/05 | 33.90 | 6340.46 |
| 08/11/05 | 34.51 | 6339.85 |
| 08/24/05 | 34.97 | 6339.39 |
| 09/07/05 | 34.94 | 6339.42 |
| 09/21/05 | 35.26 | 6339.10 |
| 10/17/05 | 35.17 | 6339.19 |
| 11/22/05 | 35.46 | 6338.90 |
| 01/23/06 | 36.00 | 6338.36 |
| 02/24/06 | 36.10 | 6338.26 |
| 03/27/06 | 36.28 | 6338.08 |
| 04/11/06 | 34.68 | 6339.68 |
| 04/25/06 | 34.80 | 6339.56 |
| 05/03/06 | 33.83 | 6340.53 |
| 05/18/06 | 33.41 | 6340.95 |
| 06/01/06 | 32.22 | 6342.14 |
| 06/20/06 | 31.47 | 6342.89 |
| 07/06/06 | 31.48 | 6342.88 |
| 07/20/06 | 32.28 | 6342.08 |
| 08/17/06 | 33.13 | 6341.23 |
| 08/31/06 | 33.61 | 6340.75 |
| 09/13/06 | 33.75 | 6340.61 |
| 10/18/06 | 33.94 | 6340.42 |
| 12/07/06 | 36.56 | 6337.80 |

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| **GWIC ID:** | **M: 108584** |
| **1:24k Quad:** | **FOX GULCH** |
| **TRST:** | **05S15W05ABDB** |
| **Ground Elevation (ft):** | **6352.57** |
| **MP from Land Surface (ft):** | **2.45** |
| **MP Elevation (ft)** | **6355.02** |
| **Total Depth from MP (ft):** | **50.45** |

| Date | Depth to Water from MP (ft) | Ground water Elevation |
|---|---|---|
| 09/08/04 | 22.38 | 6332.64 |
| 10/13/04 | 22.91 | 6332.11 |
| 11/18/04 | 23.18 | 6331.84 |
| 04/26/05 | 24.33 | 6330.69 |
| 05/10/05 | 23.38 | 6331.64 |
| 05/24/05 | 22.30 | 6332.72 |
| 06/10/05 | 20.90 | 6334.12 |
| 06/22/05 | 20.50 | 6334.52 |
| 07/07/05 | 20.60 | 6334.42 |
| 07/21/05 | 21.40 | 6333.62 |
| 07/28/05 | 22.15 | 6332.87 |
| 08/11/05 | 23.10 | 6331.92 |
| 08/24/05 | 23.77 | 6331.25 |
| 09/07/05 | 24.28 | 6330.74 |
| 09/21/05 | 24.28 | 6330.74 |
| 10/17/05 | 24.26 | 6330.76 |
| 03/27/06 | 26.61 | 6328.41 |
| 04/25/06 | 23.70 | 6331.32 |
| 05/03/06 | 23.32 | 6331.70 |
| 05/18/06 | 22.82 | 6332.20 |
| 06/01/06 | 21.69 | 6333.33 |
| 06/20/06 | 21.40 | 6333.62 |
| 07/06/06 | 21.10 | 6333.92 |
| 07/20/06 | 21.80 | 6333.22 |
| 08/03/06 | 22.81 | 6332.21 |
| 08/17/06 | 23.33 | 6331.69 |
| 08/31/06 | 23.66 | 6331.36 |
| 09/13/06 | 23.82 | 6331.20 |
| 09/28/06 | 23.82 | 6331.20 |
| 10/18/06 | 23.72 | 6331.30 |
| 11/25/06 | 25.15 | 6329.87 |

| | |
|---|---|
| **GWIC ID:** | **M: 108586** |
| **1:24k Quad:** | **FOX GULCH** |
| **TRST:** | **05S15W05BADD** |
| **Ground Elevation (ft):** | **6369.21** |
| **MP from Land Surface (ft):** | **2.12** |
| **MP Elevation (ft)** | **6371.33** |
| **Total Depth from MP (ft):** | |

| Date | Depth to Water from MP (ft) | Ground water Elevation |
|---|---|---|
| 07/07/04 | 12.36 | 6358.97 |
| 09/08/04 | 14.40 | 6356.93 |
| 10/13/04 | 14.69 | 6356.64 |
| 11/18/04 | 17.31 | 6354.02 |
| 01/21/05 | 22.29 | 6349.04 |
| 02/23/05 | 21.73 | 6349.60 |
| 03/21/05 | 19.14 | 6352.19 |
| 04/11/05 | 19.84 | 6351.49 |
| 04/26/05 | 14.35 | 6356.98 |
| 05/10/05 | 17.10 | 6354.23 |
| 05/24/05 | 16.84 | 6354.49 |
| 06/10/05 | 12.91 | 6358.42 |
| 06/22/05 | 12.30 | 6359.03 |
| 07/07/05 | 13.00 | 6358.33 |
| 07/21/05 | 13.87 | 6357.46 |
| 07/28/05 | 14.60 | 6356.73 |
| 08/11/05 | 15.08 | 6356.25 |
| 08/24/05 | 15.32 | 6356.01 |
| 09/07/05 | 18.09 | 6353.24 |
| 09/21/05 | 18.24 | 6353.09 |
| 10/17/05 | 18.06 | 6353.27 |
| 01/23/06 | 20.44 | 6350.89 |
| 02/24/06 | 20.18 | 6351.15 |
| 03/27/06 | 20.42 | 6350.91 |
| 04/25/06 | 17.20 | 6354.13 |
| 05/03/06 | 16.78 | 6354.55 |
| 05/18/06 | 16.40 | 6354.93 |
| 06/01/06 | 15.53 | 6355.80 |
| 06/20/06 | 14.82 | 6356.51 |
| 07/06/06 | 13.52 | 6357.81 |
| 07/20/06 | 14.32 | 6357.01 |
| 08/03/06 | 15.76 | 6355.57 |
| 08/17/06 | 15.41 | 6355.92 |
| 08/31/06 | 16.13 | 6355.20 |
| 09/13/06 | 15.97 | 6355.36 |
| 09/28/06 | 15.90 | 6355.43 |
| 10/18/06 | 17.46 | 6353.87 |
| 11/25/06 | 17.92 | 6353.41 |

| | |
|---|---|
| **GWIC ID:** | **M: 108587** |
| **1:24k Quad:** | **FOX GULCH** |
| **TRST:** | **05S15W05ACCC** |
| **Ground Elevation (ft):** | **6372.08** |
| **MP from Land Surface (ft):** | **1.66** |
| **MP Elevation (ft)** | **6373.74** |
| **Total Depth from MP (ft):** | **69.66** |

| Date | Depth to Water from MP (ft) | Ground water Elevation |
|---|---|---|
| 07/07/04 | 17.20 | 6356.54 |
| 09/08/04 | 19.39 | 6354.35 |
| 10/13/04 | 19.66 | 6354.08 |
| 11/18/04 | 19.96 | 6353.78 |
| 12/18/04 | 20.85 | 6352.89 |
| 01/21/05 | 22.18 | 6351.56 |
| 03/21/05 | 21.67 | 6352.07 |
| 04/11/05 | 22.18 | 6351.56 |
| 04/26/05 | 21.19 | 6352.55 |
| 05/10/05 | 19.93 | 6353.81 |
| 05/24/05 | 18.55 | 6355.19 |
| 06/10/05 | 17.38 | 6356.36 |
| 06/22/05 | 17.06 | 6356.68 |
| 07/07/05 | 17.60 | 6356.14 |
| 07/21/05 | 18.49 | 6355.25 |
| 07/28/05 | 19.26 | 6354.48 |
| 08/11/05 | 20.29 | 6353.45 |
| 08/24/05 | 20.62 | 6353.12 |
| 09/07/05 | 21.08 | 6352.66 |
| 09/21/05 | 21.03 | 6352.71 |
| 10/17/05 | 20.91 | 6352.83 |
| 11/22/05 | 21.53 | 6352.21 |
| 01/23/06 | 22.85 | 6350.89 |
| 02/24/06 | 23.15 | 6350.59 |
| 03/27/06 | 23.24 | 6350.50 |
| 04/11/06 | 20.64 | 6353.10 |
| 04/25/06 | 19.65 | 6354.09 |
| 05/03/06 | 19.53 | 6354.21 |
| 05/18/06 | 19.23 | 6354.51 |
| 06/01/06 | 18.33 | 6355.41 |
| 06/20/06 | 17.67 | 6356.07 |
| 07/06/06 | 17.81 | 6355.93 |
| 07/20/06 | 18.60 | 6355.14 |
| 08/03/06 | 20.62 | 6353.12 |
| 08/17/06 | 20.08 | 6353.66 |
| 08/31/06 | 20.70 | 6353.04 |
| 09/13/06 | 20.48 | 6353.26 |
| 09/28/06 | 20.50 | 6353.24 |
| 10/18/06 | 20.51 | 6353.23 |
| 11/25/06 | 20.63 | 6353.11 |

| | |
|---|---|
| **GWIC ID:** | **M: 108246** |
| **1:24k Quad:** | **FOX GULCH** |
| **TRST:** | **04S15W32DDCD** |
| **Ground Elevation (ft):** | **6338.41** |
| **MP from Land Surface (ft):** | **2.27** |
| **MP Elevation (ft)** | **6340.68** |
| **Total Depth from MP (ft):** | **47.27** |

| Date | Depth to Water from MP (ft) | Ground water Elevation |
|---|---|---|
| 07/07/04 | 5.79 | 6334.89 |
| 09/08/04 | 7.53 | 6333.15 |
| 10/13/04 | 8.80 | 6331.88 |
| 11/18/04 | 9.24 | 6331.44 |
| 04/11/05 | 11.49 | 6329.19 |
| 04/26/05 | 11.08 | 6329.60 |
| 05/10/05 | 8.81 | 6331.87 |
| 05/24/05 | 7.20 | 6333.48 |
| 06/10/05 | 6.50 | 6334.18 |
| 06/22/05 | 5.91 | 6334.77 |
| 07/07/05 | 6.15 | 6334.53 |
| 07/21/05 | 7.30 | 6333.38 |
| 07/28/05 | 7.83 | 6332.85 |
| 08/11/05 | 8.45 | 6332.23 |
| 08/24/05 | 9.00 | 6331.68 |
| 09/07/05 | 9.43 | 6331.25 |
| 09/21/05 | 9.43 | 6331.25 |
| 10/17/05 | 9.35 | 6331.33 |
| 11/22/05 | 10.20 | 6330.48 |
| 12/20/05 | 10.63 | 6330.05 |
| 05/03/06 | 8.48 | 6332.20 |
| 05/18/06 | 7.37 | 6333.31 |
| 06/01/06 | 6.50 | 6334.18 |
| 06/20/06 | 6.18 | 6334.50 |
| 07/06/06 | 6.11 | 6334.57 |
| 07/20/06 | 7.24 | 6333.44 |
| 08/03/06 | 8.36 | 6332.32 |
| 08/17/06 | 8.87 | 6331.81 |
| 08/31/06 | 9.26 | 6331.42 |
| 09/13/06 | 9.41 | 6331.27 |
| 09/28/06 | 9.43 | 6331.25 |
| 10/18/06 | 9.42 | 6331.26 |

| | |
|---|---|
| **GWIC ID:** | **179403** |
| **1:24k Quad:** | **FOX GULCH** |
| **TRST:** | **05S15W03BCAA** |
| **Ground Elevation (ft):** | **6325.49** |
| **MP from Land Surface (ft):** | **2.11** |
| **MP Elevation (ft)** | **6327.60** |
| **Total Depth from MP (ft):** | **62.11** |

| Date | Depth to Water from MP (ft) | Ground water Elevation |
|---|---|---|
| 08/11/04 | 0.87 | 6326.73 |
| 09/08/04 | 1.22 | 6326.38 |
| 11/18/04 | 1.52 | 6326.08 |
| 12/18/04 | 1.70 | 6325.90 |
| 04/11/05 | 1.99 | 6325.61 |
| 04/26/05 | 1.52 | 6326.08 |
| 05/10/05 | 0.98 | 6326.62 |
| 05/24/05 | 0.00 | +6327.6 |
| 06/10/05 | 0.00 | +6327.6 |
| 06/22/05 | 0.00 | +6327.6 |
| 07/07/05 | 0.00 | +6327.6 |
| 07/21/05 | 0.11 | 6327.49 |
| 07/28/05 | 0.00 | +6327.6 |
| 08/11/05 | 0.20 | 6327.40 |
| 08/24/05 | 0.73 | 6326.87 |
| 09/07/05 | 1.10 | 6326.50 |
| 09/21/05 | 1.30 | 6326.30 |
| 10/17/05 | 1.44 | 6326.16 |
| 11/22/05 | 1.78 | 6325.82 |
| 01/23/05 | Frozen | |
| 03/27/06 | Frozen | |
| 04/11/06 | 1.39 | 6326.21 |
| 04/25/06 | 1.43 | 6326.17 |
| 05/03/06 | 1.44 | 6326.16 |
| 06/01/06 | 0.00 | +6327.6 |
| 06/20/06 | 0.00 | +6327.6 |
| 07/06/06 | 0.00 | +6327.6 |
| 07/20/06 | 0.24 | 6327.36 |
| 08/03/06 | 0.65 | 6326.95 |
| 08/17/06 | 0.88 | 6326.72 |
| 08/31/06 | 1.13 | 6326.47 |
| 09/13/06 | 1.25 | 6326.35 |
| 09/28/06 | 1.38 | 6326.22 |
| 10/18/06 | 1.40 | 6326.20 |
| 11/25/06 | 1.47 | 6326.13 |

| | |
|---|---|
| **GWIC ID:** | **M:221763** |
| **1:24k Quad:** | **FOX GULCH** |
| **TRST:** | **05S15W04DBBD** |
| **Ground Elevation (ft):** | **6339.62** |
| **MP from Land Surface (ft):** | **2.04** |
| **MP Elevation (ft)** | **6341.66** |
| **Total Depth from MP (ft):** | **17.40** |

| Date | Depth to Water from MP (ft) | Ground water Elevation |
|---|---|---|
| 11/18/04 | 7.56 | 6334.10 |
| 12/18/04 | 7.89 | 6333.77 |
| 02/23/05 | 8.36 | 6333.30 |
| 03/21/05 | 8.43 | 6333.23 |
| 04/11/05 | 8.50 | 6333.16 |
| 04/26/05 | 8.54 | 6333.12 |
| 05/10/05 | 8.49 | 6333.17 |
| 05/24/05 | 7.67 | 6333.99 |
| 06/10/05 | 2.85 | 6338.81 |
| 06/22/05 | 2.78 | 6338.88 |
| 07/07/05 | 3.03 | 6338.63 |
| 07/21/05 | 4.21 | 6337.45 |
| 07/28/05 | 5.41 | 6336.25 |
| 08/11/05 | 6.11 | 6335.55 |
| 08/24/05 | 6.65 | 6335.01 |
| 09/07/05 | 6.99 | 6334.67 |
| 09/21/05 | 7.14 | 6334.52 |
| 10/17/05 | 7.43 | 6334.23 |
| 11/22/05 | 7.87 | 6333.79 |
| 12/20/05 | 8.03 | 6333.63 |
| 01/23/06 | 8.20 | 6333.46 |
| 02/24/06 | 8.56 | 6333.10 |
| 03/27/06 | 8.62 | 6333.04 |
| 04/11/06 | 7.05 | 6334.61 |
| 04/25/06 | 7.06 | 6334.60 |
| 05/03/06 | 7.31 | 6334.35 |
| 05/18/06 | 7.63 | 6334.03 |
| 06/01/06 | 7.65 | 6334.01 |
| 06/20/06 | 2.93 | 6338.73 |
| 07/06/06 | 2.79 | 6338.87 |
| 07/20/06 | 3.45 | 6338.21 |
| 08/03/06 | 5.30 | 6336.36 |
| 08/17/06 | 6.07 | 6335.59 |
| 08/31/06 | 6.25 | 6335.41 |
| 09/13/06 | 6.43 | 6335.23 |
| 09/28/06 | 6.62 | 6335.04 |
| 10/18/06 | 6.86 | 6334.80 |
| 11/25/06 | 7.27 | 6334.39 |
| 12/07/06 | 7.40 | 6334.26 |

| | |
|---|---|
| **GWIC ID:** | **M:221762** |
| **1:24k Quad:** | **FOX GULCH** |
| **TRST:** | **05S15W04BCDA** |
| **Ground Elevation (ft):** | **6338.37** |
| **MP from Land Surface (ft):** | **2.26** |
| **MP Elevation (ft)** | **6340.63** |
| **Total Depth from MP (ft):** | **16.26** |

| Date | Depth to Water from MP (ft) | Ground water Elevation |
|---|---|---|
| 11/18/04 | 4.89 | 6335.74 |
| 12/18/04 | 4.88 | 6335.75 |
| 01/21/05 | 4.95 | 6335.68 |
| 02/23/05 | 5.03 | 6335.60 |
| 03/21/05 | 5.06 | 6335.57 |
| 04/11/05 | 5.06 | 6335.57 |
| 04/26/05 | 4.89 | 6335.74 |
| 05/10/05 | 4.54 | 6336.09 |
| 05/24/05 | 2.71 | 6337.92 |
| 06/10/05 | 2.27 | 6338.36 |
| 06/22/05 | 2.07 | 6338.56 |
| 07/07/05 | 2.91 | 6337.72 |
| 07/21/05 | 4.40 | 6336.23 |
| 07/28/05 | 4.68 | 6335.95 |
| 08/11/05 | 4.85 | 6335.78 |
| 08/24/05 | 4.88 | 6335.75 |
| 09/07/05 | 4.95 | 6335.68 |
| 09/21/05 | 5.01 | 6335.62 |
| 10/17/05 | 5.01 | 6335.62 |
| 11/22/05 | 4.87 | 6335.76 |
| 12/20/05 | 4.92 | 6335.71 |
| 01/23/06 | 4.93 | 6335.70 |
| 02/24/06 | 5.09 | 6335.54 |
| 03/27/06 | 5.05 | 6335.58 |
| 04/11/06 | 3.49 | 6337.14 |
| 04/25/06 | 3.80 | 6336.83 |
| 05/03/06 | 4.09 | 6336.54 |
| 05/18/06 | 4.43 | 6336.20 |
| 06/01/06 | 4.78 | 6335.85 |
| 06/20/06 | 2.14 | 6338.49 |
| 07/06/06 | 2.36 | 6338.27 |
| 07/20/06 | 3.08 | 6337.55 |
| 08/03/06 | 3.37 | 6337.26 |
| 08/17/06 | 3.64 | 6336.99 |
| 08/31/06 | 3.91 | 6336.72 |
| 09/13/06 | 4.16 | 6336.47 |
| 09/28/06 | 4.35 | 6336.28 |
| 10/18/06 | 4.45 | 6336.18 |
| 11/25/06 | 4.52 | 6336.11 |

# Appendix B
Big Hole River Stream Flows

## 2005 and 2006 Bighole River Stream flows (cfs) at Little Lake Creek Bridge (LLC) and Petersons Bridge

| | Big Hole River LLC Bridge | Big Hole River Petersons Bridge |
|---|---|---|
| 27-Apr-05 | 66.2 | 95.7 |
| 28-Apr-05 | 56.9 | 94.6 |
| 29-Apr-05 | 53.1 | 88.2 |
| 30-Apr-05 | 46.2 | 74.3 |
| 1-May-05 | 36.1 | 60.6 |
| 2-May-05 | 31.6 | 53.3 |
| 3-May-05 | 33.4 | 52.6 |
| 4-May-05 | 39.7 | 64.3 |
| 5-May-05 | 43.8 | 67.1 |
| 6-May-05 | 68.5 | 101.6 |
| 7-May-05 | 94.6 | 134.7 |
| 8-May-05 | 99.1 | 129.6 |
| 9-May-05 | 132.9 | 175.4 |
| 10-May-05 | 167.9 | 250.7 |
| 11-May-05 | 205.4 | 322.7 |
| 12-May-05 | 171.5 | 278.9 |
| 13-May-05 | 116.3 | 190.1 |
| 14-May-05 | 85.4 | 131.7 |
| 15-May-05 | 87.3 | 131.9 |
| 16-May-05 | 101.7 | 168.7 |
| 17-May-05 | 232.0 | 384.4 |
| 18-May-05 | 234.9 | 361.0 |
| 19-May-05 | 268.1 | 413.9 |
| 20-May-05 | 337.6 | 471.5 |
| 21-May-05 | 317.4 | 464.0 |
| 22-May-05 | 292.7 | 440.5 |
| 23-May-05 | 321.5 | 455.4 |
| 24-May-05 | 288.9 | 427.8 |
| 25-May-05 | 216.7 | 353.2 |
| 26-May-05 | 168.5 | 281.0 |
| 27-May-05 | 151.1 | 251.9 |
| 28-May-05 | 150.7 | 255.4 |
| 29-May-05 | 155.4 | 260.2 |
| 30-May-05 | 161.0 | 276.0 |
| 31-May-05 | 158.5 | 286.5 |
| 1-Jun-05 | 346.8 | 465.9 |
| 2-Jun-05 | 369.8 | 467.7 |
| 3-Jun-05 | 339.5 | 473.2 |
| 4-Jun-05 | 276.4 | 446.0 |
| 5-Jun-05 | 213.6 | 381.3 |
| 6-Jun-05 | 206.8 | 374.1 |
| 7-Jun-05 | 269.7 | 448.4 |
| 8-Jun-05 | 231.1 | 408.7 |
| 9-Jun-05 | 235.0 | 408.9 |
| 10-Jun-05 | 208.3 | 381.8 |
| 11-Jun-05 | 170.0 | 328.8 |
| 12-Jun-05 | 347.9 | 467.8 |
| 13-Jun-05 | 441.1 | 391.0 |
| 14-Jun-05 | 265.0 | 440.0 |
| 15-Jun-05 | 194.1 | 360.4 |
| 16-Jun-05 | 177.1 | 337.3 |
| 17-Jun-05 | 207.9 | 384.4 |
| 18-Jun-05 | 273.1 | 443.8 |
| 19-Jun-05 | 233.5 | 414.0 |
| 20-Jun-05 | 187.4 | 359.2 |
| 21-Jun-05 | 152.8 | 300.1 |
| 22-Jun-05 | 179.9 | 348.5 |
| 23-Jun-05 | 196.8 | 368.0 |
| 24-Jun-05 | 175.1 | 344.8 |
| 25-Jun-05 | 152.1 | 300.6 |
| 26-Jun-05 | 153.9 | 305.0 |
| 27-Jun-05 | 175.4 | 347.0 |
| 28-Jun-05 | 191.8 | 372.4 |
| 29-Jun-05 | 207.1 | 395.7 |
| 30-Jun-05 | 165.9 | 336.2 |
| 1-Jul-05 | 124.3 | 261.0 |
| 2-Jul-05 | 94.0 | 199.4 |
| 3-Jul-05 | 81.6 | 165.6 |
| 4-Jul-05 | 74.7 | 150.3 |

| | Big Hole River LLC Bridge | Big Hole River Petersons Bridge |
|---|---|---|
| 29-Mar-06 | 61.0 | |
| 30-Mar-06 | 65.8 | |
| 31-Mar-06 | 71.8 | |
| 1-Apr-06 | 73.7 | 87.9 |
| 2-Apr-06 | 73.6 | 83.2 |
| 3-Apr-06 | 71.5 | 80.4 |
| 4-Apr-06 | 90.5 | 104.4 |
| 5-Apr-06 | 137.7 | 180.4 |
| 6-Apr-06 | 169.0 | 224.3 |
| 7-Apr-06 | 190.8 | 248.8 |
| 8-Apr-06 | 187.0 | 261.7 |
| 9-Apr-06 | 186.6 | 275.1 |
| 10-Apr-06 | 188.2 | 284.2 |
| 11-Apr-06 | 178.1 | 253.1 |
| 12-Apr-06 | 200.9 | 312.7 |
| 13-Apr-06 | 325.1 | 661.1 |
| 14-Apr-06 | 390.3 | 1078.0 |
| 15-Apr-06 | 375.2 | 1010.4 |
| 16-Apr-06 | 347.3 | 821.5 |
| 17-Apr-06 | 237.8 | 449.8 |
| 18-Apr-06 | 149.4 | 228.3 |
| 19-Apr-06 | 122.7 | 167.2 |
| 20-Apr-06 | 131.4 | 201.5 |
| 21-Apr-06 | 167.6 | 266.1 |
| 22-Apr-06 | 218.7 | 342.9 |
| 23-Apr-06 | 250.4 | 408.5 |
| 24-Apr-06 | 185.5 | 312.7 |
| 25-Apr-06 | 152.1 | 244.6 |
| 26-Apr-06 | 147.6 | 224.3 |
| 27-Apr-06 | 161.5 | 244.6 |
| 28-Apr-06 | 166.9 | 253.1 |
| 29-Apr-06 | 207.2 | 317.6 |
| 30-Apr-06 | 259.6 | 420.0 |
| 1-May-06 | 278.4 | 519.6 |
| 2-May-06 | 237.2 | 425.9 |
| 3-May-06 | 198.5 | 337.7 |
| 4-May-06 | 174.6 | 298.2 |
| 5-May-06 | 156.3 | 266.1 |
| 6-May-06 | 168.6 | 284.2 |
| 7-May-06 | 183.0 | 312.7 |
| 8-May-06 | 177.7 | 312.7 |
| 9-May-06 | 148.4 | 224.3 |
| 10-May-06 | 139.3 | 208.9 |
| 11-May-06 | 134.1 | 201.5 |
| 12-May-06 | 148.2 | 224.3 |
| 13-May-06 | 178.5 | 279.6 |
| 14-May-06 | 202.6 | 327.6 |
| 15-May-06 | 221.3 | 374.8 |
| 16-May-06 | 255.1 | 443.8 |
| 17-May-06 | 292.6 | 560.0 |
| 18-May-06 | 342.5 | 738.9 |
| 19-May-06 | 393.4 | 954.3 |
| 20-May-06 | 435.9 | 1199.3 |
| 21-May-06 | 454.8 | 1316.5 |
| 22-May-06 | 437.5 | 1147.9 |
| 23-May-06 | 413.8 | 972.8 |
| 24-May-06 | 375.4 | 779.6 |
| 25-May-06 | 347.3 | 683.9 |
| 26-May-06 | 326.8 | 602.2 |
| 27-May-06 | 332.5 | 661.1 |
| 28-May-06 | 352.2 | 755.1 |
| 29-May-06 | 333.9 | 638.6 |
| 30-May-06 | 278.4 | 462.1 |
| 31-May-06 | 215.9 | 317.6 |
| 1-Jun-06 | 150.8 | 228.3 |
| 2-Jun-06 | 132.8 | 197.8 |
| 3-Jun-06 | 154.4 | 240.5 |
| 4-Jun-06 | 212.1 | 402.7 |
| 5-Jun-06 | 248.3 | 539.6 |

# 2005 and 2006 Bighole River Stream flows (cfs) at Little Lake Creek Bridge (LLC) and Petersons Bridge

| | Big Hole River LLC Bridge | Big Hole River Petersons Bridge |
|---|---|---|
| 5-Jul-05 | 73.3 | 143.4 |
| 6-Jul-05 | 88.5 | 158.1 |
| 7-Jul-05 | 83.9 | 143.3 |
| 8-Jul-05 | 82.7 | 133.8 |
| 9-Jul-05 | 83.3 | 132.0 |
| 10-Jul-05 | 90.4 | 152.3 |
| 11-Jul-05 | 97.8 | 173.2 |
| 12-Jul-05 | 87.1 | 151.2 |
| 13-Jul-05 | 82.2 | 140.9 |
| 14-Jul-05 | 84.2 | 135.1 |
| 15-Jul-05 | 83.7 | 127.4 |
| 16-Jul-05 | 75.1 | 111.2 |
| 17-Jul-05 | 65.8 | 94.3 |
| 18-Jul-05 | 66.1 | 96.5 |
| 19-Jul-05 | 62.6 | 89.3 |
| 20-Jul-05 | 56.5 | 79.2 |
| 21-Jul-05 | 52.9 | 73.8 |
| 22-Jul-05 | 53.9 | 75.9 |
| 23-Jul-05 | 52.6 | 73.1 |
| 24-Jul-05 | 49.0 | 66.7 |
| 25-Jul-05 | 48.2 | 67.0 |
| 26-Jul-05 | 48.4 | 66.3 |
| 27-Jul-05 | 44.7 | 61.3 |
| 28-Jul-05 | 43.6 | 55.9 |
| 29-Jul-05 | 47.8 | 60.0 |
| 30-Jul-05 | 46.1 | 58.1 |
| 31-Jul-05 | 45.1 | 53.9 |
| 1-Aug-05 | 49.9 | 56.8 |
| 2-Aug-05 | 52.7 | 56.7 |
| 3-Aug-05 | 85.9 | 92.3 |
| 4-Aug-05 | 60.2 | 65.6 |
| 5-Aug-05 | 50.4 | 54.0 |
| 6-Aug-05 | 44.8 | 48.2 |
| 7-Aug-05 | 45.3 | 47.6 |
| 8-Aug-05 | 51.2 | 50.8 |
| 9-Aug-05 | 65.2 | 65.9 |
| 10-Aug-05 | 52.8 | 67.6 |
| 11-Aug-05 | 51.0 | 57.3 |
| 12-Aug-05 | 46.5 | 50.9 |
| 13-Aug-05 | 47.3 | 51.7 |
| 14-Aug-05 | 45.9 | 50.4 |
| 15-Aug-05 | 42.6 | 47.8 |
| 16-Aug-05 | 35.7 | 43.5 |
| 17-Aug-05 | 34.5 | 41.9 |
| 18-Aug-05 | 31.8 | 39.9 |
| 19-Aug-05 | 34.0 | 40.6 |
| 20-Aug-05 | 30.8 | 39.2 |
| 21-Aug-05 | 28.5 | 38.1 |
| 22-Aug-05 | 28.3 | 37.7 |
| 23-Aug-05 | 32.3 | 39.2 |
| 24-Aug-05 | 29.4 | 37.3 |
| 25-Aug-05 | 30.0 | 37.1 |
| 26-Aug-05 | 29.3 | 36.9 |
| 27-Aug-05 | 27.4 | 36.4 |
| 28-Aug-05 | 25.9 | 36.2 |
| 29-Aug-05 | 23.4 | 35.9 |
| 30-Aug-05 | 21.0 | 35.9 |
| 31-Aug-05 | 23.3 | 35.8 |
| 1-Sep-05 | 23.7 | 35.9 |
| 2-Sep-05 | 22.8 | 35.9 |
| 3-Sep-05 | 20.9 | 35.8 |
| 4-Sep-05 | 19.1 | 36.0 |
| 5-Sep-05 | 19.4 | 35.9 |
| 6-Sep-05 | 20.3 | 35.8 |
| 7-Sep-05 | 19.9 | 35.9 |
| 8-Sep-05 | 20.0 | 35.9 |
| 9-Sep-05 | 21.4 | 35.9 |
| 10-Sep-05 | 23.2 | 35.8 |
| 11-Sep-05 | 26.2 | 36.3 |

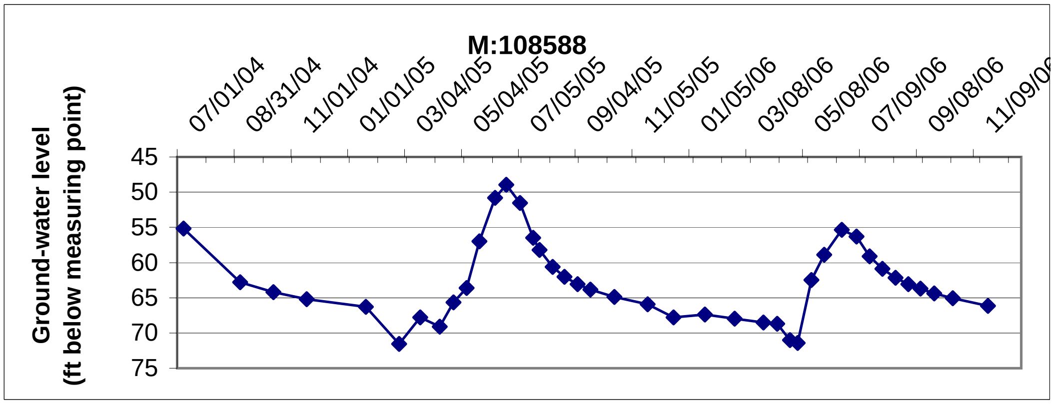
| | Big Hole River LLC Bridge | Big Hole River Petersons Bridge |
|---|---|---|
| 6-Jun-06 | 224.8 | 493.6 |
| 7-Jun-06 | 217.5 | 500.0 |
| 8-Jun-06 | 367.1 | 1158.1 |
| 9-Jun-06 | 489.3 | 1975.0 |
| 10-Jun-06 | 504.3 | 2043.0 |
| 11-Jun-06 | 403.2 | 1137.8 |
| 12-Jun-06 | 336.0 | 813.0 |
| 13-Jun-06 | 256.2 | 546.4 |
| 14-Jun-06 | 210.0 | 420.0 |
| 15-Jun-06 | 233.4 | 480.8 |
| 16-Jun-06 | 207.9 | 420.0 |
| 17-Jun-06 | 165.0 | 322.6 |
| 18-Jun-06 | 145.2 | 270.6 |
| 19-Jun-06 | 139.8 | 261.7 |
| 20-Jun-06 | 133.1 | 257.4 |
| 21-Jun-06 | 101.5 | 187.2 |
| 22-Jun-06 | 90.0 | 161.0 |
| 23-Jun-06 | 80.8 | 140.5 |
| 24-Jun-06 | 74.7 | 122.3 |
| 25-Jun-06 | 70.8 | 117.6 |
| 26-Jun-06 | 62.6 | 104.4 |
| 27-Jun-06 | 59.1 | 100.4 |
| 28-Jun-06 | 63.1 | 115.2 |
| 29-Jun-06 | 76.1 | 216.5 |
| 30-Jun-06 | 142.4 | 380.3 |
| 1-Jul-06 | 96.8 | 228.3 |
| 2-Jul-06 | 72.3 | 157.9 |
| 3-Jul-06 | 72.1 | 146.1 |
| 4-Jul-06 | 65.4 | 135.1 |
| 5-Jul-06 | 70.2 | 164.1 |
| 6-Jul-06 | 106.1 | 187.2 |
| 7-Jul-06 | 117.4 | 187.2 |
| 8-Jul-06 | 101.7 | 140.5 |
| 9-Jul-06 | 91.8 | 119.9 |
| 10-Jul-06 | 104.7 | 129.8 |
| 11-Jul-06 | 104.0 | 124.8 |
| 12-Jul-06 | 95.9 | 113.0 |
| 13-Jul-06 | 117.1 | 143.3 |
| 14-Jul-06 | 103.7 | 127.3 |
| 15-Jul-06 | 93.9 | 110.8 |
| 16-Jul-06 | 83.5 | 98.5 |
| 17-Jul-06 | 78.2 | 94.8 |
| 18-Jul-06 | 72.8 | 89.5 |
| 19-Jul-06 | 68.0 | 86.3 |
| 20-Jul-06 | 67.7 | 86.3 |
| 21-Jul-06 | 65.4 | 84.7 |
| 22-Jul-06 | 63.4 | 86.3 |
| 23-Jul-06 | 61.9 | 86.3 |
| 24-Jul-06 | 63.4 | 91.2 |
| 25-Jul-06 | 63.2 | 91.2 |
| 26-Jul-06 | 59.6 | 87.9 |
| 27-Jul-06 | 55.5 | 84.7 |
| 28-Jul-06 | 52.1 | 86.3 |
| 29-Jul-06 | 48.6 | 86.3 |
| 30-Jul-06 | 44.5 | 81.8 |
| 31-Jul-06 | 42.7 | 80.4 |
| 1-Aug-06 | 43.1 | 75.2 |
| 2-Aug-06 | 42.1 | 67.4 |
| 3-Aug-06 | 40.0 | 65.0 |
| 4-Aug-06 | 37.0 | 62.6 |
| 5-Aug-06 | 34.9 | 60.3 |
| 6-Aug-06 | 33.2 | 53.9 |
| 7-Aug-06 | 33.3 | 51.9 |
| 8-Aug-06 | 33.2 | 50.0 |
| 9-Aug-06 | 33.0 | 50.0 |
| 10-Aug-06 | 32.7 | 48.2 |
| 11-Aug-06 | 27.2 | 43.2 |
| 12-Aug-06 | 24.9 | 38.9 |
| 13-Aug-06 | 27.9 | 40.3 |

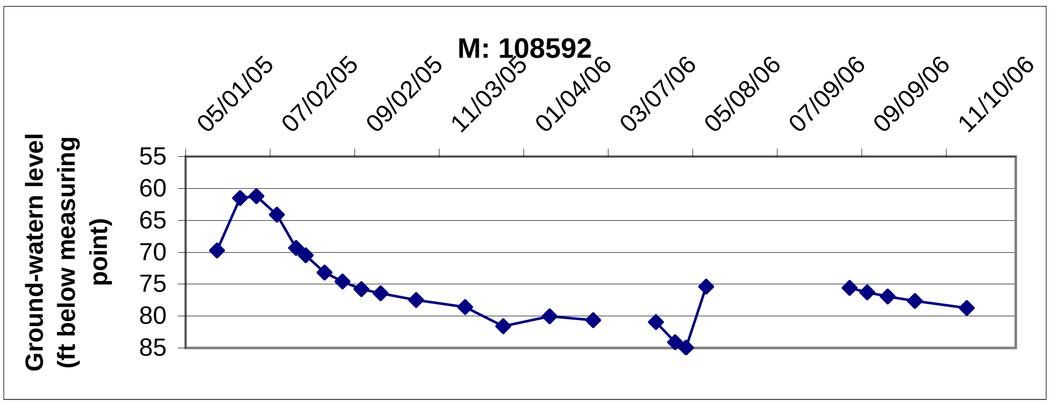
## 2005 and 2006 Bighole River Stream flows (cfs) at Little Lake Creek Bridge (LLC) and Petersons Bridge

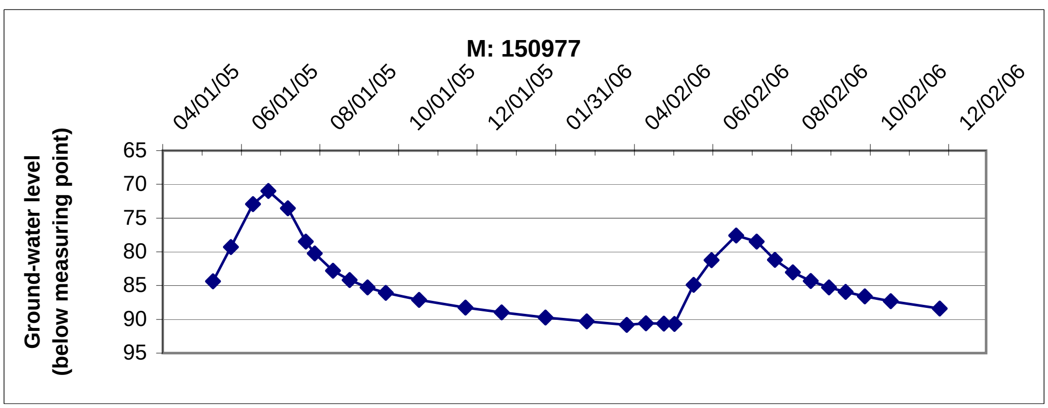
| | Big Hole River LLC Bridge | Big Hole River Petersons Bridge |
|---|---|---|
| 12-Sep-05 | 26.8 | 36.4 |
| 13-Sep-05 | 27.4 | 36.5 |
| 14-Sep-05 | 27.3 | 36.5 |
| 15-Sep-05 | 26.3 | 36.5 |
| 16-Sep-05 | 24.9 | 36.2 |
| 17-Sep-05 | 30.4 | 38.7 |
| 18-Sep-05 | 36.2 | 42.7 |
| 19-Sep-05 | 33.6 | 41.1 |
| 20-Sep-05 | 29.8 | 38.8 |
| 21-Sep-05 | 27.6 | 37.0 |
| 22-Sep-05 | 27.0 | 36.8 |
| 23-Sep-05 | 27.8 | 37.1 |
| 24-Sep-05 | 35.5 | 41.9 |
| 25-Sep-05 | 43.1 | 50.5 |
| 26-Sep-05 | 39.9 | 47.8 |
| 27-Sep-05 | 34.9 | 43.3 |
| 28-Sep-05 | 30.7 | 39.7 |
| 29-Sep-05 | 30.1 | 39.1 |
| 30-Sep-05 | 30.4 | 39.5 |
| 1-Oct-05 | 29.6 | 39.2 |
| 2-Oct-05 | 40.0 | 48.3 |
| 3-Oct-05 | 43.6 | 50.9 |
| 4-Oct-05 | 44.7 | 50.9 |
| 5-Oct-05 | 42.8 | 49.8 |
| 6-Oct-05 | 41.7 | 47.1 |
| 7-Oct-05 | 39.7 | 46.2 |
| 8-Oct-05 | 40.9 | 47.2 |
| 9-Oct-05 | 45.2 | 52.3 |
| 10-Oct-05 | 43.9 | 49.6 |
| 11-Oct-05 | 42.6 | 48.0 |
| 12-Oct-05 | 47.5 | 56.6 |
| 13-Oct-05 | 47.1 | 56.7 |
| 14-Oct-05 | 44.8 | 53.3 |
| 15-Oct-05 | 43.1 | 51.1 |
| 16-Oct-05 | 40.9 | 48.2 |
| 17-Oct-05 | 40.1 | 47.6 |
| 18-Oct-05 | 39.2 | 46.5 |
| 19-Oct-05 | 38.9 | 45.5 |
| 20-Oct-05 | 38.7 | 45.7 |
| 21-Oct-05 | 37.8 | 45.0 |
| 22-Oct-05 | 37.6 | 44.8 |
| 23-Oct-05 | 37.0 | 44.3 |
| 24-Oct-05 | 36.8 | 43.9 |
| 25-Oct-05 | 36.7 | 43.9 |
| 26-Oct-05 | 36.7 | 43.9 |
| 27-Oct-05 | 36.4 | 43.7 |
| 28-Oct-05 | 37.5 | 45.3 |
| 29-Oct-05 | 38.0 | 45.4 |
| 30-Oct-05 | 38.8 | 45.4 |
| 31-Oct-05 | 36.5 | 43.0 |
| 1-Nov-05 | 39.6 | 47.3 |
| 2-Nov-05 | 40.2 | 47.1 |

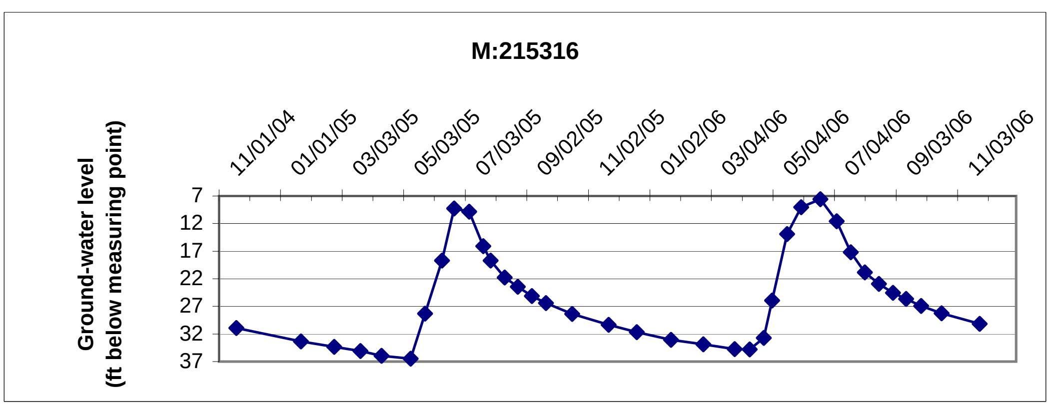
| | Big Hole River LLC Bridge | Big Hole River Petersons Bridge |
|---|---|---|
| 14-Aug-06 | 27.6 | 40.3 |
| 15-Aug-06 | 25.1 | 36.4 |
| 16-Aug-06 | 29.0 | 38.5 |
| 17-Aug-06 | 33.0 | 40.6 |
| 18-Aug-06 | 32.8 | 40.8 |
| 19-Aug-06 | 30.5 | 39.1 |
| 20-Aug-06 | 28.0 | 36.4 |
| 21-Aug-06 | 23.8 | 32.6 |
| 22-Aug-06 | 23.5 | 32.4 |
| 23-Aug-06 | 22.4 | 30.9 |
| 24-Aug-06 | 20.9 | 30.2 |
| 25-Aug-06 | 22.9 | 39.1 |
| 26-Aug-06 | 35.8 | 36.0 |
| 27-Aug-06 | 31.9 | 32.0 |
| 28-Aug-06 | 27.8 | 30.0 |
| 29-Aug-06 | 25.1 | 28.3 |
| 30-Aug-06 | 21.8 | 28.1 |
| 31-Aug-06 | 21.2 | 28.5 |
| 1-Sep-06 | 22.4 | 28.6 |
| 2-Sep-06 | 22.4 | 28.0 |
| 3-Sep-06 | 22.0 | 27.9 |
| 4-Sep-06 | 20.9 | 27.9 |
| 5-Sep-06 | 20.6 | 27.9 |
| 6-Sep-06 | 20.7 | 28.0 |
| 7-Sep-06 | 21.2 | 28.2 |
| 8-Sep-06 | 22.9 | 28.3 |
| 9-Sep-06 | 23.7 | 27.9 |
| 10-Sep-06 | 23.9 | 27.7 |
| 11-Sep-06 | 22.2 | 27.7 |
| 12-Sep-06 | 20.6 | 27.9 |
| 13-Sep-06 | 19.4 | 27.9 |
| 14-Sep-06 | 18.9 | 29.6 |
| 15-Sep-06 | 23.5 | 29.7 |
| 16-Sep-06 | 30.1 | 28.9 |
| 17-Sep-06 | 30.3 | 28.7 |
| 18-Sep-06 | 28.6 | 29.7 |
| 19-Sep-06 | 28.1 | 31.0 |
| 20-Sep-06 | 31.1 | 31.8 |
| 21-Sep-06 | 33.5 | 30.9 |
| 22-Sep-06 | 35.7 | 30.9 |
| 23-Sep-06 | 36.0 | 30.4 |
| 24-Sep-06 | 32.6 | 29.8 |
| 25-Sep-06 | 31.1 | 28.9 |
| 26-Sep-06 | 29.8 | 28.6 |
| 27-Sep-06 | 29.1 | 28.3 |
| 28-Sep-06 | 28.2 | 34.2 |
| 29-Sep-06 | 27.7 | 33.0 |
| 30-Sep-06 | 27.0 | 37.1 |
| 1-Oct-06 | 26.6 | 41.2 |
| 2-Oct-06 | 26.2 | 54.4 |
| 3-Oct-06 | 27.2 | 103.2 |
| 4-Oct-06 | 27.9 | 93.2 |
| 5-Oct-06 | 30.1 | 73.8 |
| 6-Oct-06 | 36.2 | 69.1 |
| 7-Oct-06 | 69.2 | 64.5 |
| 8-Oct-06 | 60.7 | 58.8 |
| 9-Oct-06 | 48.8 | 56.3 |
| 10-Oct-06 | 47.2 | 54.1 |
| 11-Oct-06 | 44.0 | 58.4 |
| 12-Oct-06 | 40.4 | 65.3 |
| 13-Oct-06 | 40.2 | 63.6 |
| 14-Oct-06 | 40.1 | 62.7 |
| 15-Oct-06 | 39.9 | 66.4 |
| 16-Oct-06 | 43.6 | 71.1 |
| 17-Oct-06 | 50.1 | 63.9 |
| 18-Oct-06 | 48.2 | 57.4 |

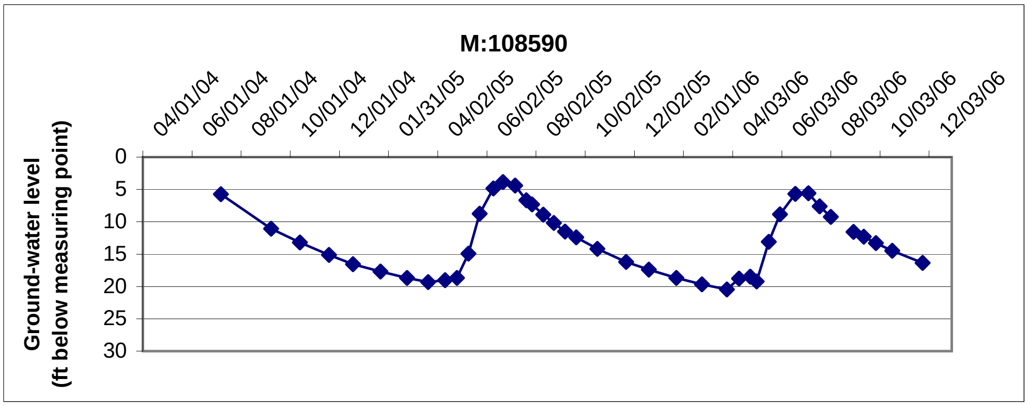
# Appendix C
Ground-water hydrographs

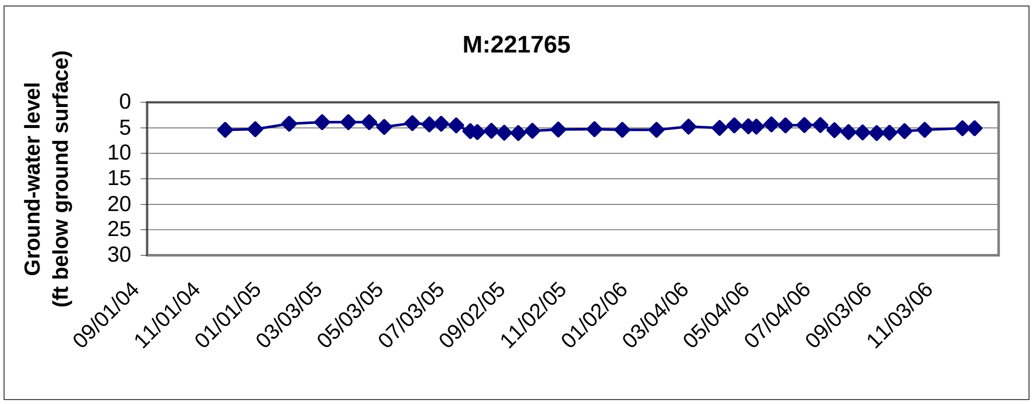

M:108588
Ground-water level
(ft below measuring point)
07/01/04
08/31/04
11/01/04
01/01/05
03/04/05
05/04/05
07/05/05
09/04/05
11/05/05
01/05/06
03/08/06
05/08/06
07/09/06
09/08/06
45
50
55
60
65
70
75

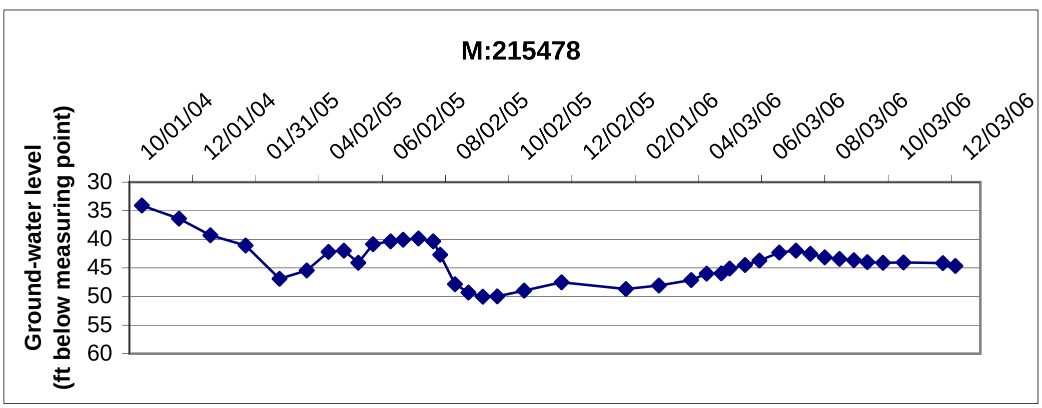

M: 108592
Ground-watern level
(ft below measuring
point)
05/01/05
07/02/05
09/02/05
11/03/05
01/04/06
03/07/06
05/08/06
07/09/06
09/09/06
11/10/06
55
60
65
70
75
80
85

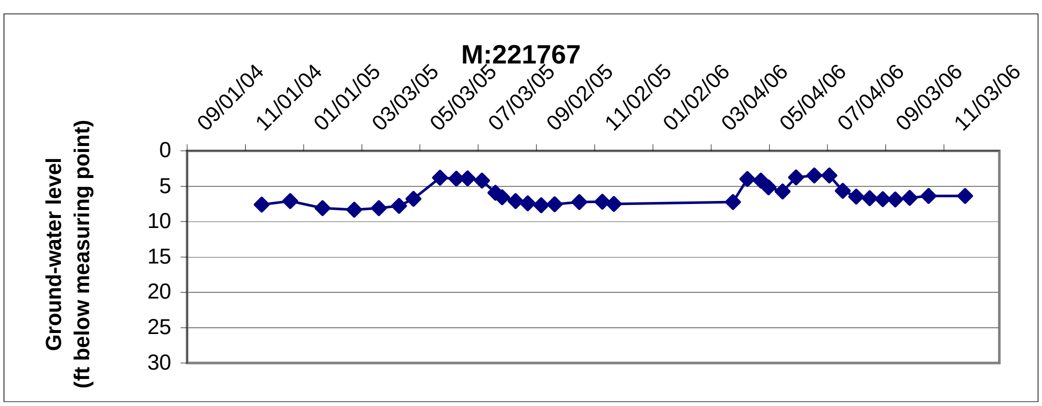

M: 150977
Ground-water level
(below measuring point)
04/01/05
06/01/05
08/01/05
10/01/05
12/01/05
01/31/06
04/02/06
06/02/06
08/02/06
10/02/06
12/02/06
65
70
75
80
85
90
95

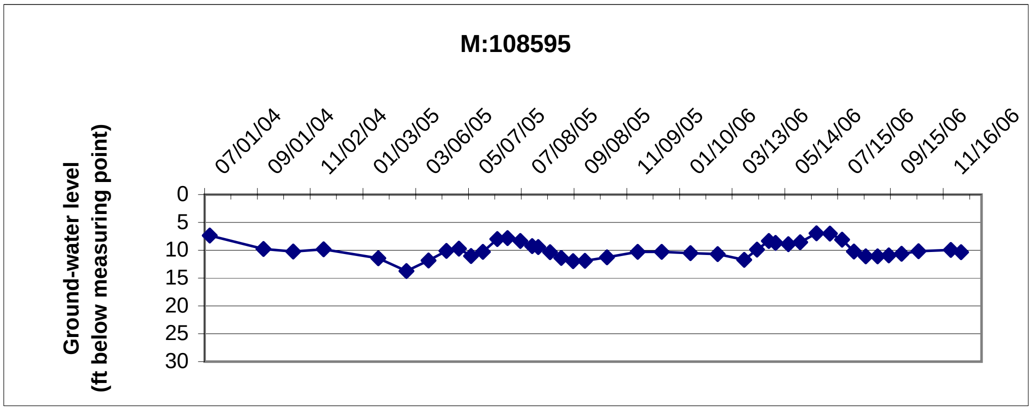

M:215316
Ground-water level
(ft below measuring point)
11/01/04
01/01/05
03/03/05
05/03/05
07/03/05
09/02/05
11/02/05
01/02/06
03/04/06
05/04/06
07/04/06
09/03/06
11/03/06
7
12
17
22
27
32
37


M:108590
04/01/04
06/01/04
08/01/04
10/01/04
12/01/04
01/31/05
04/02/05
06/02/05
08/02/05
10/02/05
12/02/05
02/01/06
04/03/06
06/03/06
08/03/06
10/03/06
12/03/06
0
5
10
15
20
25
30
Ground-water level
(ft below measuring point)

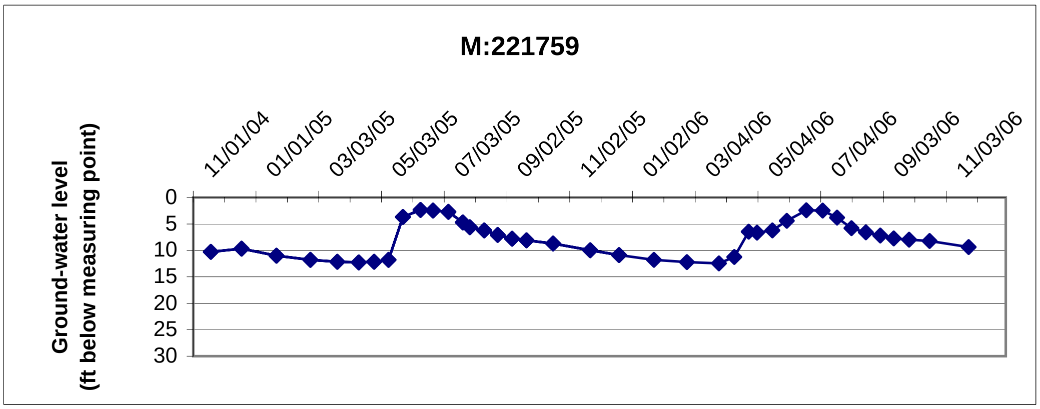

M:221765
0
5
10
15
20
25
30
Ground-water level
(ft below ground surface)
09/01/04
11/01/04
01/01/05
03/03/05
05/03/05
07/03/05
09/02/05
11/02/05
01/02/06
03/04/06
05/04/06
07/04/06
09/03/06
11/03/06


M:215478
10/01/04
12/01/04
01/31/05
04/02/05
06/02/05
08/02/05
10/02/05
12/02/05
02/01/06
04/03/06
06/03/06
08/03/06
10/03/06
12/03/06
30
35
40
45
50
55
60
Ground-water level
(ft below measuring point)

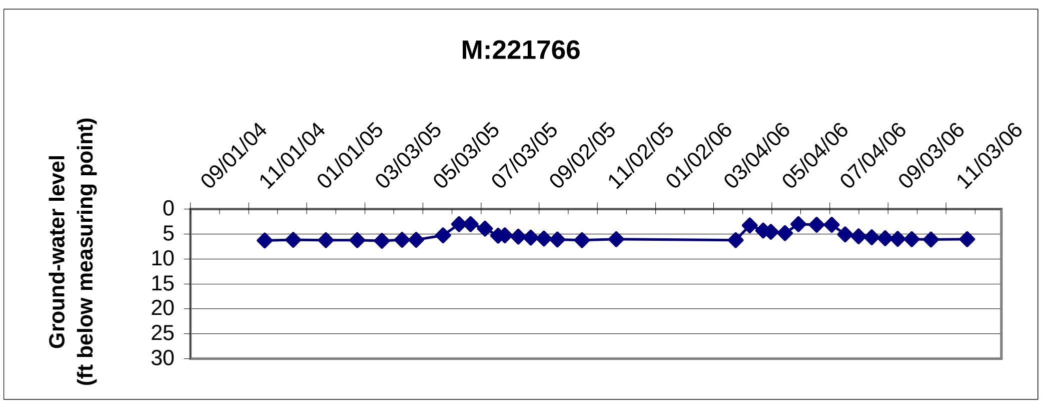

M:221767
09/01/04
11/01/04
01/01/05
03/03/05
05/03/05
07/03/05
09/02/05
11/02/05
01/02/06
03/04/06
05/04/06
07/04/06
09/03/06
11/03/06
0
5
10
15
20
25
30
Ground-water level
(ft below measuring point)



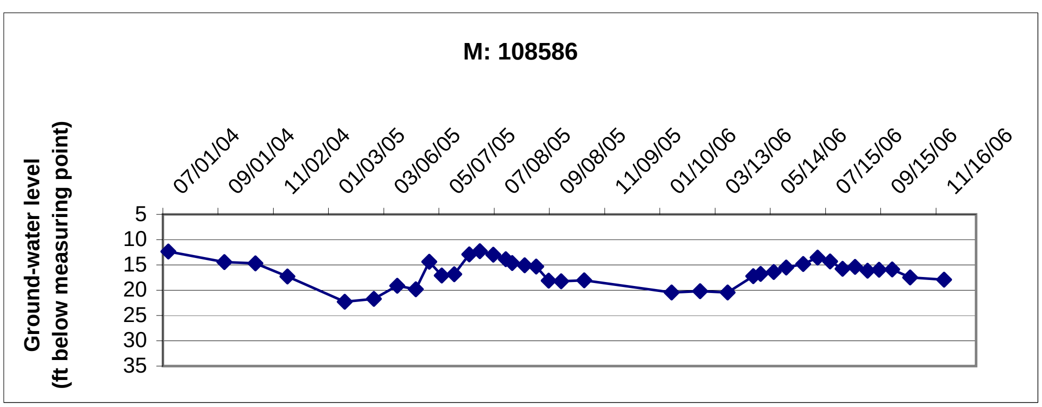
M:108595
Ground-water level
(ft below measuring point)
0
5
10
15
20
25
30
07/01/04
09/01/04
11/02/04
01/03/05
03/06/05
05/07/05
07/08/05
09/08/05
11/09/05
01/10/06
03/13/06
05/14/06
07/15/06
09/15/06
11/16/06

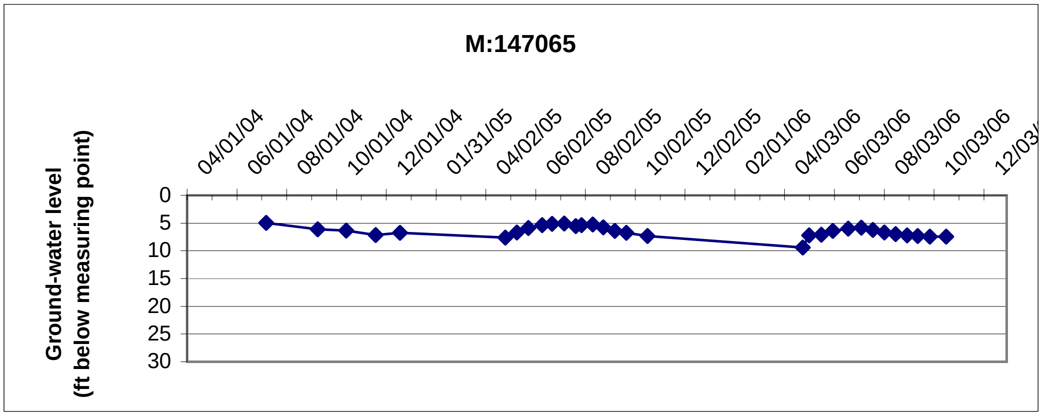
M:221759
Ground-water level
(ft below measuring point)
0
5
10
15
20
25
30
11/01/04
01/01/05
03/03/05
05/03/05
07/03/05
09/02/05
11/02/05
01/02/06
03/04/06
05/04/06
07/04/06
09/03/06
11/03/06

M:221766
Ground-water level
(ft below measuring point)
0
5
10
15
20
25
30
09/01/04
11/01/04
01/01/05
03/03/05
05/03/05
07/03/05
09/02/05
11/02/05
01/02/06
03/04/06
05/04/06
07/04/06
09/03/06
11/03/06

M: 108586
Ground-water level
(ft below measuring point)
5
10
15
20
25
30
35
07/01/04
09/01/04
11/02/04
01/03/05
03/06/05
05/07/05
07/08/05
09/08/05
11/09/05
01/10/06
03/13/06
05/14/06
07/15/06
09/15/06
11/16/06


M:147065
Ground-water level
(ft below measuring point)
0
5
10
15
20
25
30
04/01/04
06/01/04
08/01/04
10/01/04
12/01/04
01/31/05
04/02/05
06/02/05
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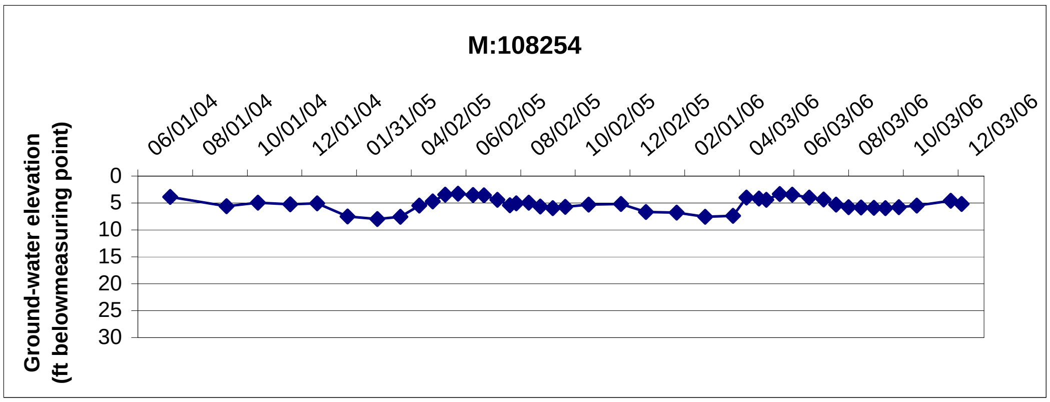
04/03/06
06/03/06
08/03/06
10/03/06


M:108254
Ground-water elevation
(ft belowmeasuring point)
0
5
10
15
20
25
30
06/01/04
08/01/04
10/01/04
12/01/04
01/31/05
04/02/05
06/02/05
08/02/05
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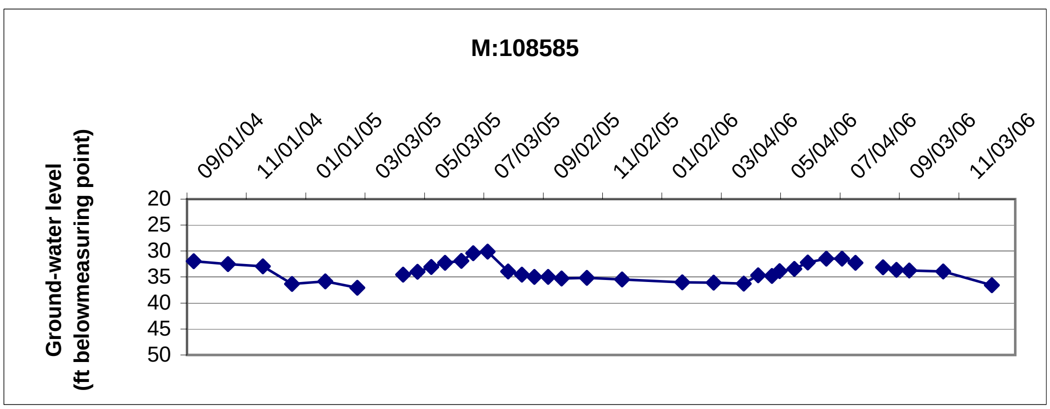
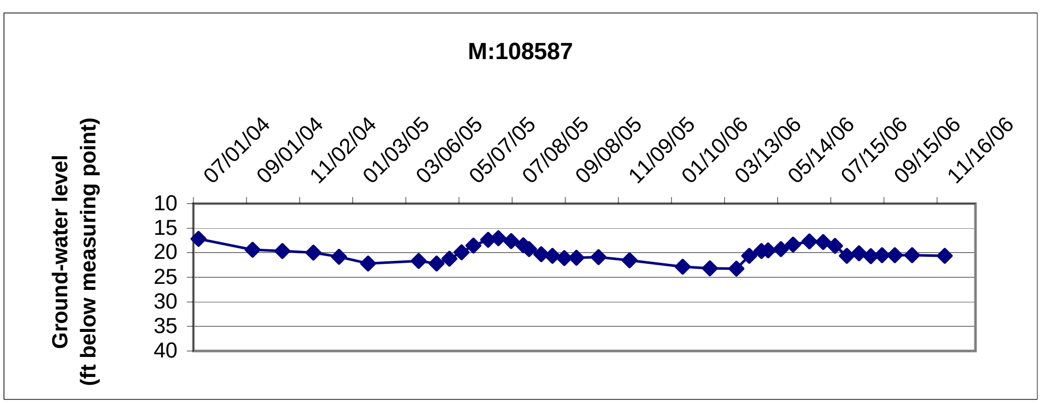
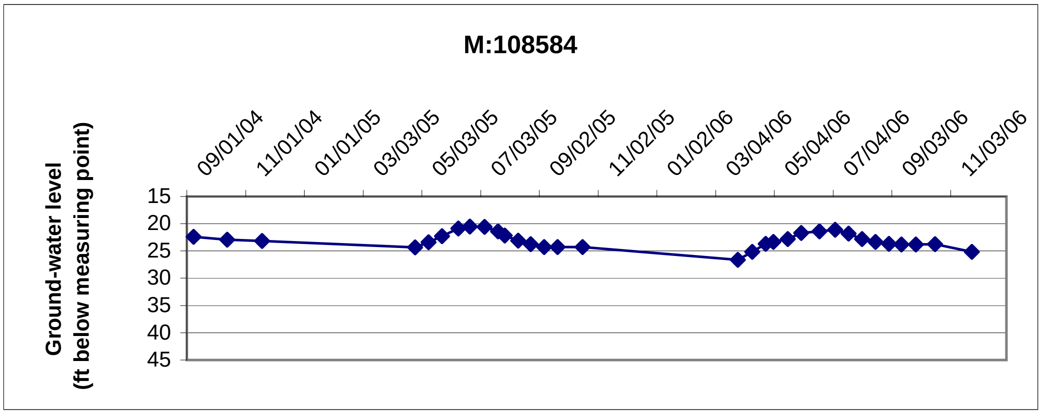
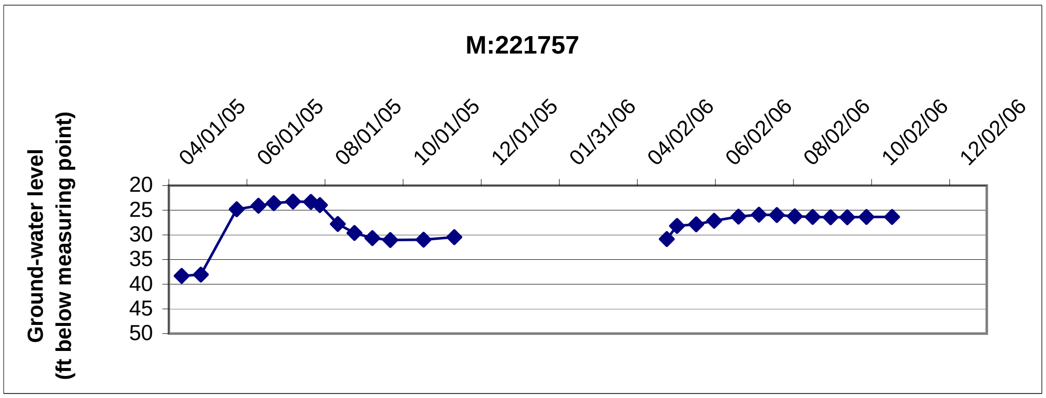
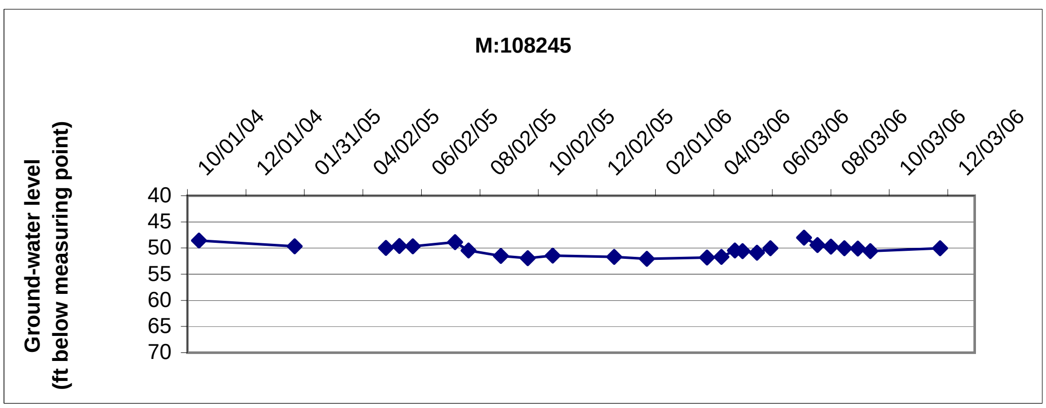
04/03/06
06/03/06
08/03/06
10/03/06
12/03/06


M:108585
Ground-water level
(ft belowmeasuring point)
20
25
30
35
40
45
50
09/01/04
11/01/04
01/01/05
03/03/05
05/03/05
07/03/05
09/02/05
11/02/05
01/02/06
03/04/06
05/04/06
07/04/06
09/03/06
11/03/06


M:108587
Ground-water level
(ft below measuring point)
10
15
20
25
30
35
40
07/01/04
09/01/04
11/02/04
01/03/05
03/06/05
05/07/05
07/08/05
09/08/05
11/09/05
01/10/06
03/13/06
05/14/06
07/15/06
09/15/06
11/16/06


M:108584
Ground-water level
(ft below measuring point)
09/01/04
11/01/04
01/01/05
03/03/05
05/03/05
07/03/05
09/02/05
11/02/05
01/02/06
03/04/06
05/04/06
07/04/06
09/03/06
11/03/06
15
20
25
30
35
40
45


M:221757
Ground-water level
(ft below measuring point)
04/01/05
06/01/05
08/01/05
10/01/05
12/01/05
01/31/06
04/02/06
06/02/06
08/02/06
10/02/06
12/02/06
20
25
30
35
40
45
50


M:108245
Ground-water level
(ft below measuring point)
10/01/04
12/01/04
01/31/05
04/02/05
06/02/05
08/02/05
10/02/05
12/02/05
02/01/06
04/03/06
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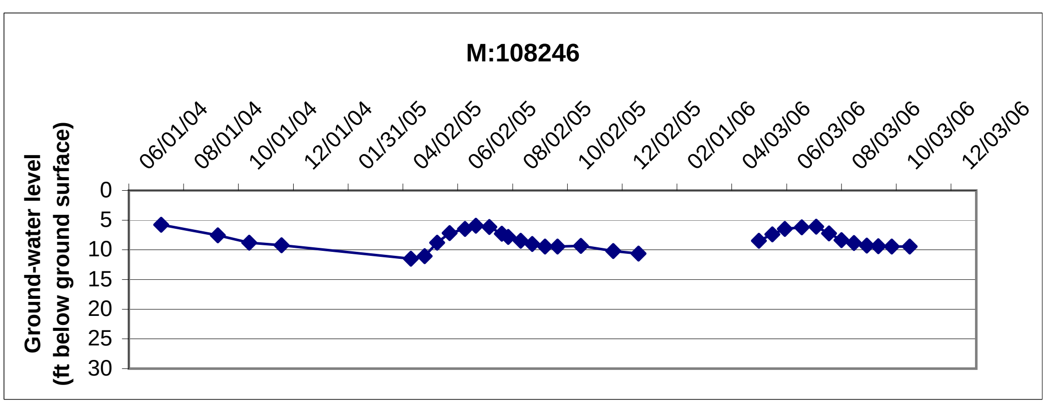
12/03/06
40
45
50
55
60
65
70


M:108246
Ground-water level
(ft below ground surface)
06/01/04
08/01/04
10/01/04
12/01/04
01/31/05
04/02/05
06/02/05
08/02/05
10/02/05
12/02/05
02/01/06
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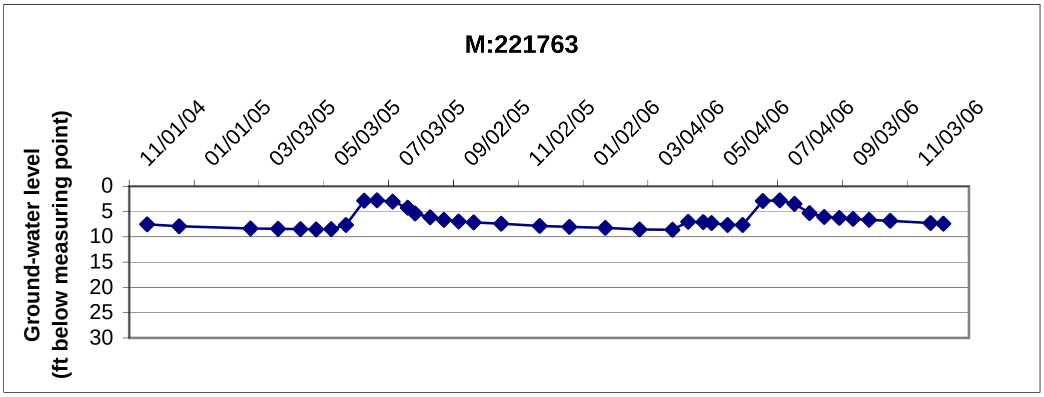
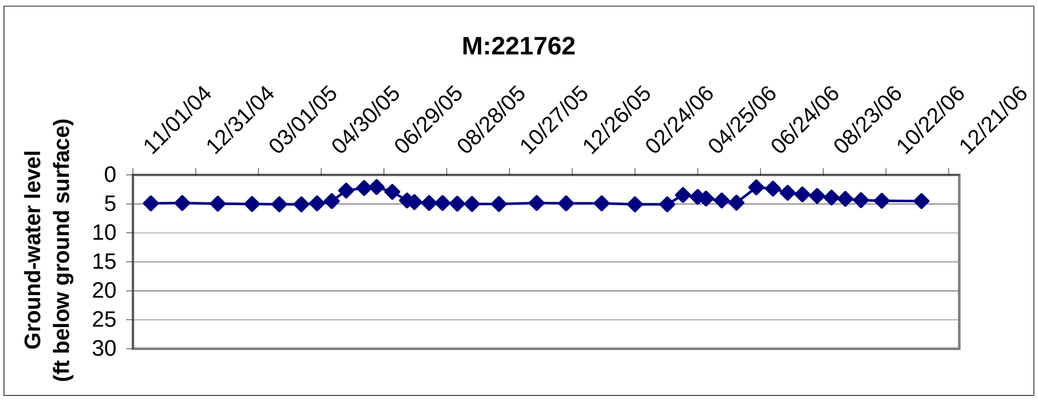
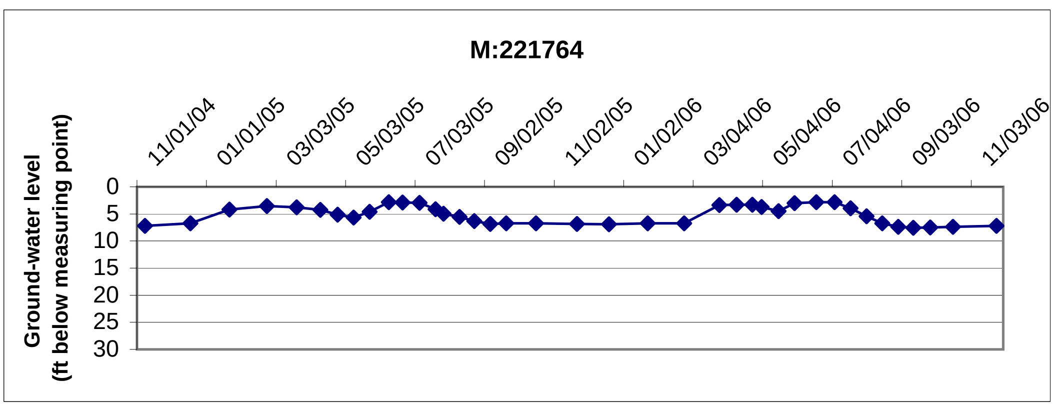
12/03/06
0
5
10
15
20
25
30


M:221763
Ground-water level
(ft below measuring point)
11/01/04
01/01/05
03/03/05
05/03/05
07/03/05
09/02/05
11/02/05
01/02/06
03/04/06
05/04/06
07/04/06
09/03/06
11/03/06
0
5
10
15
20
25
30


M:221762
Ground-water level
(ft below ground surface)
11/01/04
12/31/04
03/01/05
04/30/05
06/29/05
08/28/05
10/27/05
12/26/05
02/24/06
04/25/06
06/24/06
08/23/06
10/22/06
12/21/06
0
5
10
15
20
25
30


M:221764
Ground-water level
(ft below measuring point)
11/01/04
01/01/05
03/03/05
05/03/05
07/03/05
09/02/05
11/02/05
01/02/06
03/04/06
05/04/06
07/04/06
09/03/06
11/03/06
0
5
10
15
20
25
30

# Appendix D

Ground-water analyses

Ground-Water Information Center Water Quality Report
**Report Date:** 8/6/2008

**Site Name:** JOHNSON BROS INC
Compare to Water Quality Standards

## Location Information

| | | | |
|---|---|---|---|
| Sample Id/Site Id: | 2001Q1431 / 108595 | Sample Date: | 4/17/2001 6:30:00 PM |
| Location (TRS): | 05S 15W 17 BABA | Agency/Sampler: | MBMG / MGR |
| Latitude/Longitude: | 45° 24' 15" N 113° 29' 7" W | Field Number: | 108595 |
| Datum: | NAD27 | Lab Date: | 5/21/2001 |
| Altitude: | 6439.52 | Lab/Analyst: | MBMG / JMC |
| County/State: | BEAVERHEAD / MT | Sample Method/Handling: | PUMPED / 4220 |
| Site Type: | WELL | Procedure Type: | DISSOLVED |
| Geology: | 111SNGR | Total Depth (ft): | 43 |
| USGS 7.5' Quad: | FOX GULCH | SWL-MP (ft): | 8.06 |
| PWS Id: | | Depth Water Enters (ft): | 31 |
| Project: | GWAAMON, MEM59, BIGHOLE3 | | |

## Major Ion Results

| | mg/L | meq/L | | mg/L | meq/L |
|---|---|---|---|---|---|
| Calcium (Ca) | 12.500 | 0.624 | Bicarbonate ($HCO_3$) | 103.000 | 1.688 |
| Magnesium (Mg) | 3.930 | 0.323 | Carbonate ($CO_3$) | 0.000 | 0.000 |
| Sodium (Na) | 14.300 | 0.622 | Chloride (Cl) | 4.390 | 0.124 |
| Potassium (K) | 3.840 | 0.098 | Sulfate ($SO_4$) | 2.810 | 0.059 |
| Iron (Fe) | 2.330 | 0.125 | Nitrate (as N) | <.5 P | 0.000 |
| Manganese (Mn) | 1.100 | 0.040 | Fluoride (F) | 0.181 | 0.010 |
| Silica ($SiO_2$) | 59.600 | | Orthophosphate ($OPO_4$) | <.05 | 0.000 |
| **Total Cations** | | 1.835 | **Total Anions** | | 1.880 |

## Trace Element Results (µg/L)

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Aluminum (Al): | <30 | Cesium (Cs): | NR | Molybdenum (Mo): | <10 | Strontium (Sr): | 90.100 |
| Antimony (Sb): | <2 | Chromium (Cr): | <2 | Nickel (Ni): | 2.750 | Thallium (Tl): | <5 |
| Arsenic (As): | 10.800 | Cobalt (Co): | <2 | Niobium (Nb): | NR | Thorium (Th): | NR |
| Barium (Ba): | 61.800 | Copper (Cu): | <2 | Neodymium (Nd): | NR | Tin (Sn): | NR |
| Beryllium (Be): | <2 | Gallium (Ga): | NR | Palladium (Pd): | NR | Titanium (Ti): | <1 |
| Boron (B): | <30 | Lanthanum (La): | NR | Praseodymium (Pr): | NR | Tungsten (W): | NR |
| Bromide (Br): | <50 | Lead (Pb): | <2 | Rubidium (Rb): | NR | Uranium (U): | NR |
| Cadmium (Cd): | <2 | Lithium (Li): | 5.000 | Silver (Ag): | <1 | Vanadium (V): | <5 |
| Cerium (Ce): | NR | Mercury (Hg): | NR | Selenium (Se): | <1 | Zinc (Zn): | 4.360 |
| | | | | | | Zirconiuim (Zr): | <2 |

## Field Chemistry and Other Analytical Results

| | | | | | |
|---|---|---|---|---|---|
| **Total Dissolved Solids (mg/L): | 155.170 | Field Hardness as $CaCO_3$ (mg/L): | NR | Ammonia (mg/L): | NR |
| **Sum of Diss. Constituents (mg/L): | 207.430 | Hardness as $CaCO_3$: | 47.390 | T.P. Hydrocarbons (µg/L): | NR |
| Field Conductivity (µmhos): | 178 | Field Alkalinity as $CaCO_3$ (mg/L): | 86 | PCP (µg/L): | NR |
| Lab Conductivity (µmhos): | 194 | Akalinity as $CaCO_3$ (mg/L): | 84.48 | Phosphate, TD (mg/L as P): | 0.165 |

| | | | | | |
|---|---|---|---|---|---|
| Field pH: | 6.79 | Ryznar Stability Index: | 10.093 | Field Nitrate (mg/L): | NR |
| Lab pH: | 6.76 | Sodium Adsorption Ratio: | 0.885 | Field Dissolved $O_2$ (mg/L): | 5.980 |
| Water Temp (°C): | 5.4 | Langlier Saturation Index: | -1.666 | Field Chloride (mg/L): | NR |
| Air Temp (°C): | NR | Nitrite (mg/L as N): | NR | Field Redox (mV): | NR |
| | | Hydroxide (mg/L as OH): | NR | | |

**Notes**

Sample Condition: CLEAR

Field Remarks:

Lab Remarks:

Explanation: **mg/L** = milligrams per Liter; **µg/L** = micrograms per Liter; **ft** = feet; **NR** = No Reading in GWIC

Qualifiers: **A** = Hydride atomic absorption; **E** = Estimated due to interference; **H** = Exceeded holding time; **K** = Na+K combined; **N** = Spiked sample recovery not within control limits; **P** = Preserved sample; **S** = Method of standard additions; * = Duplicate analysis not within control limits; ** = Sum of Dissolved Constituents is the sum of major cations (Na, Ca, K, Mg, Mn, Fe) and anions ($HCO_3$, $CO_3$, $SO_4$, Cl, $SiO_2$, $NO_3$, F) in mg/L. Total Dissolved Solids is reported as equivalent weight of evaporation residue.

Disclaimer

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Ground-Water Information Center Water Quality Report
**Report Date:** 8/6/2008

**Site Name:** HIRSCHY DICK
Compare to Water Quality Standards

## Location Information

| | | | |
|---|---|---|---|
| Sample Id/Site Id: | 2007Q0624 / 179403 | Sample Date: | 10/11/2006 10:27:00 AM |
| Location (TRS): | 05S 15W 03 BCAD | Agency/Sampler: | MBMG / JPF |
| Latitude/Longitude: | 45° 25' 41" N 113° 26' 45" W | Field Number: | 179403 |
| Datum: | NAD27 | Lab Date: | 11/27/2006 |
| Altitude: | 6327.6 | Lab/Analyst: | MBMG / WO |
| County/State: | BEAVERHEAD / MT | Sample Method/Handling: | / 2200 |
| Site Type: | WELL | Procedure Type: | DISSOLVED |
| Geology: | 120SNGR | Total Depth (ft): | 60 |
| USGS 7.5' Quad: | | SWL-MP (ft): | NR |
| PWS Id: | | Depth Water Enters (ft): | 55 |
| Project: | BIGHOLE3 | | |

## Major Ion Results

| | mg/L | meq/L | | mg/L | meq/L |
|---|---|---|---|---|---|
| Calcium (Ca) | NR | 0.000 | Bicarbonate ($HCO_3$) | NR | 0.000 |
| Magnesium (Mg) | NR | 0.000 | Carbonate ($CO_3$) | NR | 0.000 |
| Sodium (Na) | NR | 0.000 | Chloride (Cl) | NR | 0.000 |
| Potassium (K) | NR | 0.000 | Sulfate ($SO_4$) | NR | 0.000 |
| Iron (Fe) | 1.110 | 0.060 | Nitrate (as N) | <0.5 P | 0.000 |
| Manganese (Mn) | NR | 0.000 | Fluoride (F) | NR | 0.000 |
| Silica ($SiO_2$) | NR | | Orthophosphate ($OPO_4$) | NR | 0.000 |
| **Total Cations** | | 0.060 | **Total Anions** | | 0.000 |

## Trace Element Results (µg/L)

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Aluminum (Al): | NR | Cesium (Cs): | NR | Molybdenum (Mo): | NR | Strontium (Sr): | NR |
| Antimony (Sb): | NR | Chromium (Cr): | NR | Nickel (Ni): | NR | Thallium (Tl): | NR |
| Arsenic (As): | <1 | Cobalt (Co): | NR | Niobium (Nb): | NR | Thorium (Th): | NR |
| Barium (Ba): | NR | Copper (Cu): | NR | Neodymium (Nd): | NR | Tin (Sn): | NR |
| Beryllium (Be): | NR | Gallium (Ga): | NR | Palladium (Pd): | NR | Titanium (Ti): | NR |
| Boron (B): | NR | Lanthanum (La): | NR | Praseodymium (Pr): | NR | Tungsten (W): | NR |
| Bromide (Br): | NR | Lead (Pb): | NR | Rubidium (Rb): | NR | Uranium (U): | NR |
| Cadmium (Cd): | NR | Lithium (Li): | NR | Silver (Ag): | NR | Vanadium (V): | NR |
| Cerium (Ce): | NR | Mercury (Hg): | NR | Selenium (Se): | NR | Zinc (Zn): | NR |
| | | | | | | Zirconiuim (Zr): | NR |

## Field Chemistry and Other Analytical Results

| | | | | | |
|---|---|---|---|---|---|
| **Total Dissolved Solids (mg/L): | NR | Field Hardness as $CaCO_3$ (mg/L): | NR | Ammonia (mg/L): | NR |
| **Sum of Diss. Constituents (mg/L): | NR | Hardness as $CaCO_3$: | NR | T.P. Hydrocarbons (µg/L): | NR |
| Field Conductivity (µmhos): | 161.9 | Field Alkalinity as $CaCO_3$ (mg/L): | NR | PCP (µg/L): | NR |
| Lab Conductivity (µmhos): | NR | Akalinity as $CaCO_3$ (mg/L): | NR | Phosphate, TD (mg/L as P): | NR |

| | | | | | |
|---|---|---|---|---|---|
| Field pH: | 7.96 | Ryznar Stability Index: | NR | Field Nitrate (mg/L): | NR |
| Lab pH: | NR | Sodium Adsorption Ratio: | NR | Field Dissolved $O_2$ (mg/L): | NR |
| Water Temp (°C): | 7 | Langlier Saturation Index: | NR | Field Chloride (mg/L): | NR |
| Air Temp (°C): | NR | Nitrite (mg/L as N): | NR | Field Redox (mV): | NR |
| | | Hydroxide (mg/L as OH): | NR | | |

**Notes**

Sample Condition:

Field Remarks: YIELD ABOUT 15GPM

Lab Remarks:

Explanation: **mg/L** = milligrams per Liter; **µg/L** = micrograms per Liter; **ft** = feet; **NR** = No Reading in GWIC

Qualifiers: **A** = Hydride atomic absorption; **E** = Estimated due to interference; **H** = Exceeded holding time; **K** = Na+K combined; **N** = Spiked sample recovery not within control limits; **P** = Preserved sample; **S** = Method of standard additions; ***** = Duplicate analysis not within control limits; ****** = Sum of Dissolved Constituents is the sum of major cations (Na, Ca, K, Mg, Mn, Fe) and anions ($HCO_3$, $CO_3$, $SO_4$, Cl, $SiO_2$, $NO_3$, F) in mg/L. Total Dissolved Solids is reported as equivalent weight of evaporation residue.

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Ground-Water Information Center Water Quality Report
**Report Date:** 8/6/2008

**Site Name:** PETERSON BROS CATTLE
Compare to Water Quality Standards

## Location Information

| | | | |
|---|---|---|---|
| Sample Id/Site Id: | 2007Q0702 / 108585 | Sample Date: | 10/23/2006 3:15:00 PM |
| Location (TRS): | 05S 15W 05 BDAD | Agency/Sampler: | MBMG / GNA |
| Latitude/Longitude: | 45° 25' 42" N 113° 28' 50" W | Field Number: | 108585 |
| Datum: | NAD27 | Lab Date: | 11/27/2006 |
| Altitude: | 6372.58 | Lab/Analyst: | MBMG / WO |
| County/State: | BEAVERHEAD / MT | Sample Method/Handling: | / |
| Site Type: | WELL | Procedure Type: | DISSOLVED |
| Geology: | 111ALVM | Total Depth (ft): | 112 |
| USGS 7.5' Quad: | FOX GULCH 7 1/2 | SWL-MP (ft): | NR |
| PWS Id: | | Depth Water Enters (ft): | 100 |
| Project: | BIGHOLE, BIGHOLE3 | | |

## Major Ion Results

| | mg/L | meq/L | | mg/L | meq/L |
|---|---|---|---|---|---|
| Calcium (Ca) | NR | 0.000 | Bicarbonate ($HCO_3$) | NR | 0.000 |
| Magnesium (Mg) | NR | 0.000 | Carbonate ($CO_3$) | NR | 0.000 |
| Sodium (Na) | NR | 0.000 | Chloride (Cl) | NR | 0.000 |
| Potassium (K) | NR | 0.000 | Sulfate ($SO_4$) | NR | 0.000 |
| Iron (Fe) | 0.719 | 0.039 | Nitrate (as N) | 0.951 P | 0.068 |
| Manganese (Mn) | NR | 0.000 | Fluoride (F) | NR | 0.000 |
| Silica ($SiO_2$) | NR | | Orthophosphate ($OPO_4$) | NR | 0.000 |
| **Total Cations** | | 0.039 | **Total Anions** | | 0.068 |

## Trace Element Results (µg/L)

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Aluminum (Al): | NR | Cesium (Cs): | NR | Molybdenum (Mo): | NR | Strontium (Sr): | NR |
| Antimony (Sb): | NR | Chromium (Cr): | NR | Nickel (Ni): | NR | Thallium (Tl): | NR |
| Arsenic (As): | <1 | Cobalt (Co): | NR | Niobium (Nb): | NR | Thorium (Th): | NR |
| Barium (Ba): | NR | Copper (Cu): | NR | Neodymium (Nd): | NR | Tin (Sn): | NR |
| Beryllium (Be): | NR | Gallium (Ga): | NR | Palladium (Pd): | NR | Titanium (Ti): | NR |
| Boron (B): | NR | Lanthanum (La): | NR | Praseodymium (Pr): | NR | Tungsten (W): | NR |
| Bromide (Br): | NR | Lead (Pb): | NR | Rubidium (Rb): | NR | Uranium (U): | NR |
| Cadmium (Cd): | NR | Lithium (Li): | NR | Silver (Ag): | NR | Vanadium (V): | NR |
| Cerium (Ce): | NR | Mercury (Hg): | NR | Selenium (Se): | NR | Zinc (Zn): | NR |
| | | | | | | Zirconiuim (Zr): | NR |

## Field Chemistry and Other Analytical Results

| | | | | | |
|---|---|---|---|---|---|
| **Total Dissolved Solids (mg/L): | NR | Field Hardness as $CaCO_3$ (mg/L): | NR | Ammonia (mg/L): | NR |
| **Sum of Diss. Constituents (mg/L): | NR | Hardness as $CaCO_3$: | NR | T.P. Hydrocarbons (µg/L): | NR |
| Field Conductivity (µmhos): | 110.9 | Field Alkalinity as $CaCO_3$ (mg/L): | NR | PCP (µg/L): | NR |
| Lab Conductivity (µmhos): | NR | Akalinity as $CaCO_3$ (mg/L): | NR | Phosphate, TD (mg/L as P): | NR |
| Field pH: | 6.64 | Ryznar Stability Index: | NR | Field Nitrate (mg/L): | NR |

| | | | | | |
|---|---|---|---|---|---|
| Lab pH: | NR | Sodium Adsorption Ratio: | NR | Field Dissolved $O_2$ (mg/L): | NR |
| Water Temp (°C): | 7.6 | Langlier Saturation Index: | NR | Field Chloride (mg/L): | NR |
| Air Temp (°C): | NR | Nitrite (mg/L as N): | NR | Field Redox (mV): | NR |
| | | Hydroxide (mg/L as OH): | NR | | |

**Notes**

Sample Condition: CLEAR

Field Remarks:

Lab Remarks:

Explanation: **mg/L** = milligrams per Liter; **µg/L** = micrograms per Liter; **ft** = feet; **NR** = No Reading in GWIC

Qualifiers: **A** = Hydride atomic absorption; **E** = Estimated due to interference; **H** = Exceeded holding time; **K** = Na+K combined; **N** = Spiked sample recovery not within control limits; **P** = Preserved sample; **S** = Method of standard additions; ***** = Duplicate analysis not within control limits; ****** = Sum of Dissolved Constituents is the sum of major cations (Na, Ca, K, Mg, Mn, Fe) and anions ($HCO_3$, $CO_3$, $SO_4$, Cl, $SiO_2$, $NO_3$, F) in mg/L. Total Dissolved Solids is reported as equivalent weight of evaporation residue.

Disclaimer

Ground-Water Information Center Water Quality Report
**Report Date:** 8/6/2008

**Site Name:** JOHNSON JOE
Compare to Water Quality Standards

## Location Information

| | | | |
|---|---|---|---|
| Sample Id/Site Id: | 2007Q0637 / 215478 | Sample Date: | 10/5/2006 2:20:00 PM |
| Location (TRS): | 05S 15W 08 CDCA | Agency/Sampler: | MBMG / GNA |
| Latitude/Longitude: | 45° 24' 20" N 113° 29' 1" W | Field Number: | 215478 |
| Datum: | NAD27 | Lab Date: | 11/27/2006 |
| Altitude: | 6444.65 | Lab/Analyst: | MBMG / WO |
| County/State: | BEAVERHEAD / MT | Sample Method/Handling: | / 2200 |
| Site Type: | WELL | Procedure Type: | DISSOLVED |
| Geology: | 111ALVM | Total Depth (ft): | 78 |
| USGS 7.5' Quad: | | SWL-MP (ft): | 44.14 |
| PWS Id: | | Depth Water Enters (ft): | 78 |
| Project: | BIGHOLE3 | | |

## Major Ion Results

| | mg/L | meq/L | | mg/L | meq/L |
|---|---|---|---|---|---|
| Calcium (Ca) | NR | 0.000 | Bicarbonate ($HCO_3$) | NR | 0.000 |
| Magnesium (Mg) | NR | 0.000 | Carbonate ($CO_3$) | NR | 0.000 |
| Sodium (Na) | NR | 0.000 | Chloride (Cl) | NR | 0.000 |
| Potassium (K) | NR | 0.000 | Sulfate ($SO_4$) | NR | 0.000 |
| Iron (Fe) | 7.780 | 0.418 | Nitrate (as N) | <0.5 P | 0.000 |
| Manganese (Mn) | NR | 0.000 | Fluoride (F) | NR | 0.000 |
| Silica ($SiO_2$) | NR | | Orthophosphate ($OPO_4$) | NR | 0.000 |
| **Total Cations** | | 0.418 | **Total Anions** | | 0.000 |

## Trace Element Results (µg/L)

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Aluminum (Al): | NR | Cesium (Cs): | NR | Molybdenum (Mo): | NR | Strontium (Sr): | NR |
| Antimony (Sb): | NR | Chromium (Cr): | NR | Nickel (Ni): | NR | Thallium (Tl): | NR |
| Arsenic (As): | 16.600 | Cobalt (Co): | NR | Niobium (Nb): | NR | Thorium (Th): | NR |
| Barium (Ba): | NR | Copper (Cu): | NR | Neodymium (Nd): | NR | Tin (Sn): | NR |
| Beryllium (Be): | NR | Gallium (Ga): | NR | Palladium (Pd): | NR | Titanium (Ti): | NR |
| Boron (B): | NR | Lanthanum (La): | NR | Praseodymium (Pr): | NR | Tungsten (W): | NR |
| Bromide (Br): | NR | Lead (Pb): | NR | Rubidium (Rb): | NR | Uranium (U): | NR |
| Cadmium (Cd): | NR | Lithium (Li): | NR | Silver (Ag): | NR | Vanadium (V): | NR |
| Cerium (Ce): | NR | Mercury (Hg): | NR | Selenium (Se): | NR | Zinc (Zn): | NR |
| | | | | | | Zirconiuim (Zr): | NR |

## Field Chemistry and Other Analytical Results

| | | | | | |
|---|---|---|---|---|---|
| **Total Dissolved Solids (mg/L): | NR | Field Hardness as $CaCO_3$ (mg/L): | NR | Ammonia (mg/L): | NR |
| **Sum of Diss. Constituents (mg/L): | NR | Hardness as $CaCO_3$: | NR | T.P. Hydrocarbons (µg/L): | NR |
| Field Conductivity (µmhos): | NR | Field Alkalinity as $CaCO_3$ (mg/L): | NR | PCP (µg/L): | NR |
| Lab Conductivity (µmhos): | NR | Akalinity as $CaCO_3$ (mg/L): | NR | Phosphate, TD (mg/L as P): | NR |
| Field pH: | NR | Ryznar Stability Index: | NR | Field Nitrate (mg/L): | NR |

| | | | | | |
|---|---|---|---|---|---|
| Lab pH: | NR | Sodium Adsorption Ratio: | NR | Field Dissolved $O_2$ (mg/L): | NR |
| Water Temp (°C): | NR | Langlier Saturation Index: | NR | Field Chloride (mg/L): | NR |
| Air Temp (°C): | NR | Nitrite (mg/L as N): | NR | Field Redox (mV): | NR |
| | | Hydroxide (mg/L as OH): | NR | | |

**Notes**

| | |
|---|---|
| Sample Condition: | CLEAR |
| Field Remarks: | |
| Lab Remarks: | |

Explanation: **mg/L** = milligrams per Liter; **µg/L** = micrograms per Liter; **ft** = feet; **NR** = No Reading in GWIC

Qualifiers: **A** = Hydride atomic absorption; **E** = Estimated due to interference; **H** = Exceeded holding time; **K** = Na+K combined; **N** = Spiked sample recovery not within control limits; **P** = Preserved sample; **S** = Method of standard additions; ***** = Duplicate analysis not within control limits; ****** = Sum of Dissolved Constituents is the sum of major cations (Na, Ca, K, Mg, Mn, Fe) and anions ($HCO_3$, $CO_3$, $SO_4$, Cl, $SiO_2$, $NO_3$, F) in mg/L. Total Dissolved Solids is reported as equivalent weight of evaporation residue.

Ground-Water Information Center Water Quality Report

**Report Date:** 8/6/2008

**Site Name:** JOHNSON BROS INC

Compare to Water Quality Standards

## Location Information

| | | | |
|---|---|---|---|
| Sample Id/Site Id: | 2007Q0623 / 108595 | Sample Date: | 10/11/2006 3:16:00 PM |
| Location (TRS): | 05S 15W 17 BABA | Agency/Sampler: | MBMG / GNA |
| Latitude/Longitude: | 45° 24' 15" N 113° 29' 7" W | Field Number: | 108595 |
| Datum: | NAD27 | Lab Date: | 11/27/2006 |
| Altitude: | 6439.52 | Lab/Analyst: | MBMG / WO |
| County/State: | BEAVERHEAD / MT | Sample Method/Handling: | GRAB / 4230 |
| Site Type: | WELL | Procedure Type: | DISSOLVED |
| Geology: | 111SNGR | Total Depth (ft): | 43 |
| USGS 7.5' Quad: | FOX GULCH | SWL-MP (ft): | NR |
| PWS Id: | | Depth Water Enters (ft): | 31 |
| Project: | GWAAMON, MEM59, BIGHOLE3 | | |

## Major Ion Results

| | mg/L | meq/L | | mg/L | meq/L |
|---|---|---|---|---|---|
| Calcium (Ca) | 14.900 | 0.744 | Bicarbonate ($HCO_3$) | 101.100 | 1.657 |
| Magnesium (Mg) | 4.520 | 0.372 | Carbonate ($CO_3$) | 0.000 | 0.000 |
| Sodium (Na) | 15.300 | 0.666 | Chloride (Cl) | 5.400 | 0.152 |
| Potassium (K) | 4.370 | 0.112 | Sulfate ($SO_4$) | <2.5 | 0.000 |
| Iron (Fe) | 1.230 | 0.066 | Nitrate (as N) | <0.5 P | 0.000 |
| Manganese (Mn) | 1.300 | 0.047 | Fluoride (F) | 0.240 | 0.013 |
| Silica ($SiO_2$) | 58.500 | | Orthophosphate ($OPO_4$) | <0.05 | 0.000 |
| **Total Cations** | | 2.009 | **Total Anions** | | 1.822 |

## Trace Element Results (µg/L)

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Aluminum (Al): | <30 | Cesium (Cs): | NR | Molybdenum (Mo): | <10 | Strontium (Sr): | 116.000 |
| Antimony (Sb): | <2 | Chromium (Cr): | <2 | Nickel (Ni): | <2 | Thallium (Tl): | <5 |
| Arsenic (As): | 9.620 | Cobalt (Co): | <2 | Niobium (Nb): | NR | Thorium (Th): | NR |
| Barium (Ba): | 57.000 | Copper (Cu): | <2 | Neodymium (Nd): | NR | Tin (Sn): | NR |
| Beryllium (Be): | <2 | Gallium (Ga): | NR | Palladium (Pd): | NR | Titanium (Ti): | <1 |
| Boron (B): | <30 | Lanthanum (La): | NR | Praseodymium (Pr): | NR | Tungsten (W): | NR |
| Bromide (Br): | <50 | Lead (Pb): | <2 | Rubidium (Rb): | NR | Uranium (U): | <1 |
| Cadmium (Cd): | <1 | Lithium (Li): | 5.850 | Silver (Ag): | <1 | Vanadium (V): | <5 |
| Cerium (Ce): | NR | Mercury (Hg): | NR | Selenium (Se): | <1 | Zinc (Zn): | <2 |
| | | | | | | Zirconiuim (Zr): | <2 |

## Field Chemistry and Other Analytical Results

| | | | | | |
|---|---|---|---|---|---|
| **Total Dissolved Solids (mg/L): | 154.170 | Field Hardness as $CaCO_3$ (mg/L): | NR | Ammonia (mg/L): | NR |
| **Sum of Diss. Constituents (mg/L): | 205.420 | Hardness as $CaCO_3$: | 55.810 | T.P. Hydrocarbons (µg/L): | NR |
| Field Conductivity (µmhos): | 196.6 | Field Alkalinity as $CaCO_3$ (mg/L): | NR | PCP (µg/L): | NR |
| Lab Conductivity (µmhos): | 194 | Akalinity as $CaCO_3$ (mg/L): | 82.84 | Phosphate, TD (mg/L as P): | 0.131 |

| | | | | | |
|---|---|---|---|---|---|
| Field pH: | 7.42 | Ryznar Stability Index: | 10.457 | Field Nitrate (mg/L): | NR |
| Lab pH: | 6.26 | Sodium Adsorption Ratio: | 0.874 | Field Dissolved $O_2$ (mg/L): | NR |
| Water Temp (°C): | 7.7 | Langlier Saturation Index: | -2.099 | Field Chloride (mg/L): | NR |
| Air Temp (°C): | NR | Nitrite (mg/L as N): | NR | Field Redox (mV): | NR |
| | | Hydroxide (mg/L as OH): | NR | | |

**Notes**

Sample Condition: CLEAR

Field Remarks: YIELD ABOUT 12 GPM

Lab Remarks:

Explanation: **mg/L** = milligrams per Liter; **µg/L** = micrograms per Liter; **ft** = feet; **NR** = No Reading in GWIC

Qualifiers: **A** = Hydride atomic absorption; **E** = Estimated due to interference; **H** = Exceeded holding time; **K** = Na+K combined; **N** = Spiked sample recovery not within control limits; **P** = Preserved sample; **S** = Method of standard additions; ***** = Duplicate analysis not within control limits; ****** = Sum of Dissolved Constituents is the sum of major cations (Na, Ca, K, Mg, Mn, Fe) and anions ($HCO_3$, $CO_3$, $SO_4$, Cl, $SiO_2$, $NO_3$, F) in mg/L. Total Dissolved Solids is reported as equivalent weight of evaporation residue.

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