DEERE & AULT
CONSULTANTS, INC.

February 11, 2011

Mr. Karl Ohlsen
Carlson, Hammond & Paddock, LLC
1700 Lincoln Street, Suite 3900
Denver, Colorado 80203-4539

**Re: DP-3 and DP-4 Well Depletion Locations for Deerwood Service Company Case No. 05CW23; D&A Job No. CG-0430.001.00**

Dear Mr. Ohlsen:

This letter report summarizes our scope of work, data review and analysis of groundwater hydrology and geology for depletion locations from water supply wells DP-3 and DP-4 at the Deerwood Park development in Routt County.

## ***SCOPE OF WORK***

As outlined in our proposal dated September 27, 2010 this study of depletion locations consisted of the following scope of work.

### ***Tasks 1 through 4 - Review of Existing Data***

For Task 1 we reviewed the existing information related to Case No. 05CW23 including:

- J. Craig Green's Engineering Report dated February 16, 2006
- Laramide Environmental, LLC's January 10, 2006 engineering report
- The proposed draft decree dated January 14, 2010 by Carlson, Hammond, & Paddock for 05CW23
- The April 8, 2009 letter to the CWCB regarding a proposed mitigation plan for Case No. 05CW23
- The June 15, 2010 letter by Lytle Water Solutions, LLC to Holland and Hart summarizing the issues related to Deerwood Service Company's plan for augmentation in Case No. 05CW23 prepared on behalf of Peabody Energy/Twentymile Coal Company
- The decree explaining Twentymile Coal Company's water rights in Case No. W-1502-78.

For Task 2 we reviewed information related to Deerwood Service Company's Wells DP-3 and DP-4 including well logs, permits, decrees, and pump tests. This includes the following:

- The Adrian Brown Consultants, Inc. (ABC) report on the "*Deerwood Park Water Supply Evaluation*," prepared for John Adams, dated September 21, 1994

- ABC's Technical Memorandum entitled, "*Creek Ranch Water Supply Evaluation*," prepared by Adrian Brown Consultants for the Routt County Board of Commissioners, dated April 22, 1999
- A letter report from Laramide Environmental, LLC to Brent Romick and Wes Adams entitled "*DP-4 pumping capacity*" dated January 17, 2007
- A letter report from ABC to Terry Audesirk entitled "*Deerwood Water Supply System Well Rehabilitation*" dated February 20, 2009

For Tasks 3 and 4 we reviewed pertinent hydrogeologic and geologic reports and maps to develop the framework for the depletion location study. These reports included:

- *Geohydrologic Evaluation of the Upper Part of The Mesaverde Group, Northwestern Colorado* (Robson and Stewart, 1990)
- *Geologic Map of the Northernmost Gore Range & Southernmost Park Range, Grand, Jackson & Routt Counties, Colorado* (Snyder, 1980)
- *Geologic Map of Craig 1° x 2° Quadrangle, Colorado* (Tweto, 1976)
- *Geologic Map of Colorado* (Tweto, 1979)
- *A Summary of Stratigraphy, Coal Resources, and Coal-Bed Methane Potential of Northwest Colorado* (Brownfield et al., 2000)
- *Stratigraphy of the Upper Cretaceous Mancos Shale (Upper Part) and the Mesaverde Group in the Southern Part of the Uinta and Piceance Basins, Utah and Colorado* (Hettinger and Kirschbaum, 2002)
- *Geologic Map and Coal Sections of the Sawmill Mountain Quadrangle, Rio Blanco County, Colorado* (Reheis, 1984)

In addition to the specific references listed above, Task 4 also involved inventory and evaluation of digital data in a GIS (Geographic Information System) including 7.5-minute topographic images, aerial photography and digital elevation models.

Following our review of the relevant documentation listed above, a thorough inventory was created within the GIS. The inventoried data was analyzed within the GIS in order to estimate the probable locations of well depletions caused by pumping wells DP-3 and DP-4. The bulk of the analysis was focused on well DP-4 due to its relative importance as a water supply well.

***<u>Task 5 - Depletion Location Report</u>***

Based on the review and analysis of the data cited above, we wrote this report to summarize our findings and opinions.

## ***INTRODUCTION***

The Deerwood Service Company wells DP-3 and DP-4 are located in south-central Routt County in Section 20 of Township 5 North, Range 85 West approximately 12 miles southwest of Steamboat Springs (**Figure 1**). The site is located in the Wyoming Basin physiographic province of Colorado. The wells are located in the upper intermittent tributaries of Whetstone Creek, which is tributary to Trout Creek. Trout Creek is tributary to the Yampa River at a point approximately seven miles north of the site. The site is characterized by hogback topography forming north-south trending ridges and valleys. The topography is controlled by the differential weathering and erosion of tilted alternating sequences of more resistant sandstone (ridges) and less resistant shale (valleys).

## ***GEOLOGY***

The site geology not only controls the appearance of the topography, but also the occurrence and flow of groundwater. The site geology consists of alternating sequences of sandstone and shale which dip to the west and have been cut by faulting as shown on the geologic map in **Figure 2**. The mapping on **Figure 2** was derived from several of the aforementioned geologic references (Robson and Stewart, 1990; Snyder, 1980; Tweto, 1976) and digitized into the GIS. The oldest rocks at the site are mapped on the eastern edge of the map as the Dakota, Morrison and Sundance Formations (KJds). These formations consist primarily of Jurassic to Cretaceous age sandstones and claystones and are undivided for presentation purposes. The next overlying unit is the Cretaceous age Mancos Shale (Km), which consists primarily of thick shale with minor interbedded sandstone lenses. The Mancos Shale is approximately 5,000 feet thick (Tweto, 1976; Reheis, 1984). The next younger unit on top of the Mancos is the Cretaceous age Iles Formation. The Iles Formation is approximately 1,500 feet thick (Tweto, 1976; Reheis, 1984) and is subdivided into the upper Trout Creek Sandstone Member (Kit) and the Lower Member (Kil) on **Figure 2**. The Lower Member consists primarily of shale, sandy shale and interbedded and intertongueing sandstone. The Trout Creek Sandstone Member is a prominent marker bed in the region, consisting of massive fine grained sandstone up to 150 feet thick in the study area (Robson and Stewart, 1990). Above the Iles Formation is the Cretaceous age Williams Fork Formation, which consists of 1,100 to 2,000 feet of interbedded sandstone and shale with abundant coal beds that are mined in the region (Robson and Stewart, 1990; Brownfield et al., 2000). The Williams Fork Formation is subdivided into the Upper Member (Kwu), the Twenty Mile Sandstone Member (Kwt) and the Middle & Lower Members, undivided (Kwl). Locally, Tertiary age volcanic basalt flows (Tbb) and the sedimentary beds of the Browns Park Formation (Tbp) outcrop in the area but do not significantly impact the project.

### ***Structural Geology***

The site is situated on the eastern limb of the Twenty Mile Syncline. A syncline is a downward folded sequence of rocks that forms a subsurface basin. The axis of the Twenty Mile Syncline is approximately three to four miles west-southwest of the site. The axis defines the line where the beds are nearly horizontal and the two opposite limbs meet. Because the site is on the eastern limb of the syncline, the rocks strike approximately north-south and dip west-southwest approximately 10° to 30° towards the axis. This structure is well defined and mapped based on drilling of water wells and coal investigation borings in the Yampa Basin (Robson and Stewart, 1990; Brownfield et al., 2000). The structure of the syncline is mapped by recognizing and measuring the elevation of the prominent Trout Creek Sandstone and Twenty Mile Sandstone beds in the drilled borings. A resulting structure contour map of the top of the Trout Creek Sandstone was created by Robson and Stewart (1990), digitized into the GIS and presented on **Figure 2** as heavy red lines. The subsurface geometry of the structure of the rocks is presented in two geologic cross-sections on **Figure 3**.

Two faults have also been mapped in the vicinity of the site (**Figure 2**). These faults trend roughly northwest-southeast and show normal down-to-the-northeast offset. Normal faulting occurs as a result of extensional tectonic forces. The first fault of note defines the Whetstone Creek valley. This fault exhibits down-to-the-northeast offset with a right lateral strike slip offset component. The second fault near the site is situated west of the site and exhibits down-to-the-northeast offset along most of its length, and reverse offset in the vicinity of Trout Creek (**Figure 2**). Reverse faulting occurs when compressional forces reactivate a normal fault and push a downthrown block back upwards along the fault plane (see cross-section A-A' on **Figure 3**).

In addition to these two faults, it is likely that smaller, less continuous faults are present where small valleys cut across the hogbacks at various angles. Several of these valleys can be seen best on **Figure 1** in the vicinity of well DP-4. Such faulting is common in geologic terrain where relatively brittle rocks have been folded. In this type of terrain, the minor faulting represents flexural breaks where folding is most prominent. The structural geometry of the rocks can change depending on the offset on these minor faults, and if the faults cross each other the result will be a fault-bound block of rock. Because of the predominantly extensional forces in the region, resulting in larger scale normal and strike-slip faulting, it is likely that these smaller faults also exhibit normal and strike-slip offset. Also in an extensional environment, dominated by normal faulting, large landslides of fault-bound blocks can occur between faults. This type of mass movement is usually along weak, steepened bedding planes, such as within shale beds.

***Hydrogeology***

The hydrogeology in the region consists of two primary types of aquifers: 1) unconfined alluvial aquifers associated with the major rivers and streams and 2) confined to partially confined bedrock aquifers. The alluvial aquifers consist primarily of sand and gravel that has been eroded and deposited by the adjacent river. They are generally recharged by the adjacent river and by precipitation infiltration. Typically the alluvial aquifer holds water because the underlying bedrock has a much lower permeability than the unconsolidated sand and gravel comprising the alluvium.

The bedrock aquifers are controlled by the structural geology discussed above. The principal bedrock aquifers in the region are the Twenty Mile Sandstone and Trout Creek Sandstone (Robson and Stewart, 1990), however other minor aquifers exist within the smaller sandstone beds of the bedrock formations. The principal aquifers are tapped by many wells in the region and are confined by overlying shale beds that have much lower permeability than the sandstone. The aquifers are generally recharged by precipitation where the rock units outcrop at the surface. In these areas the aquifers can be partially confined if the aquifer is not completely saturated. In general, these aquifers are not hydraulically connected to the unconfined alluvial aquifers except where the sandstone beds subcrop below the river alluvium. When this occurs, depending on the relative head difference within each aquifer, one aquifer will be recharged by the other with the higher hydraulic head. Because these areas are small and infrequent, the amount of recharge and the extent of the hydraulic connection are relatively small. Based on the geometry of the syncline, when the sandstone aquifers are recharged, the water typically flows down gradient in a direction parallel to the dip of the beds. In the study area this means that the recharge of the sandstone aquifers generally flows west-southwest along the dip of the rocks towards the axis of the syncline where it collects.

The faulting in the region will also control the flow of groundwater within the bedrock aquifers. Generally, groundwater flow is inhibited across a fault plane and enhanced along it. However, in instances where relatively plastic shale is present, a fault can be filled with a clay gouge and result in a clayey smear along the plane. This situation will further inhibit flow across the plane and likely decrease the flow along the plane as well. Where faults intersect, groundwater flow along those planes will be inhibited by the cross-cutting fault. This situation is typical of fault-bounded blocks and results in a relatively isolated aquifer that is characterized by a much smaller recharge area. Wells drilled into sandstone beds bounded by faults will have no connection to surface water features and will have a finite amount of water to extract. At this stage of the investigation, it is possible, but not precisely known if such fault-bounded blocks exist in the study area.

## ***DEERWOOD SERVICE COMPANY WELLS***

Prior to 1994 two wells (DP-1 and DP-2) were drilled and installed by a dowser in the Mancos Shale (ABC, 1994). DP-1 was drilled 450 feet deep and did not encounter water. The second well was drilled to a depth of 180 feet and produced only 0.5 gpm (gallons per minute). Subsequently, Adrian Brown Consultants, Inc. (ABC) conducted a water supply evaluation at the site. During ABC's 1994 project, a seep/spring study revealed that approximately 60 gpm of water discharged from the springs. This amount of water was deemed an insufficient water supply for the Deerwood Park development, so two more wells were drilled. These wells are known as DP-3 and DP-4.

Well DP-3 was drilled to a depth of 460 feet into the Mancos Shale and encountered a water-bearing sandstone unit from 390 to 442 feet deep. Although the well was screened from 400 to 440 feet across this interval, a 3/8-inch gravel pack allows water to enter the well from 22 to 440 feet (see well construction documents in **Appendix A**). The well initially produced approximately 20 gpm.

DP-4 was drilled to a depth of 460 feet and encountered sandy shale interbedded with water-bearing fractured sandstone at depth intervals of 200-220, 301-329 and 404-419 feet. These sandstone beds can be seen in outcrop on the aerial photos, so the outcrop pattern was traced and is depicted on **Figure 2** as brown lines within the Lower Member of the Iles Formation (Kil). Although the well was screened in 20-foot intervals in the vicinity of these three sandstone intervals (200' to 220', 300' to 320' and 400' to 420'), 8/12 silica sand was placed as a filter pack from 103 to 460 feet deep, thus allowing groundwater to enter the well from a 317-foot interval from 103 to 420 feet (see well construction documents in **Appendix A**). The well initially produced artesian flows of approximately 60 gpm, and subsequently stabilized at 5 gpm, which equated to an artesian head of 12 feet and a maximum yield of about 160 gpm (ABC, 2009). The initial artesian flows illustrate the confined nature of this aquifer at the time of drilling.

A pumping test was performed by ABC in well DP-4 after it was installed to estimate the capacity of the well. It was pumped at approximately 150 gpm for five days and exhibited a drawdown of 350 feet at the end of the test. This results in a specific capacity of about 0.4 gpm/foot of drawdown. Based on the recovery data from the pumping test, ABC estimated the transmissivity to be approximately 2,000 gpd/ft. Although the storage coefficient could not be calculated from the test, ABC estimated it to be approximately $1x10^{-4}$, a generally accepted value for confined aquifers. ABC indicated that the pumping of well DP-4 would have no effect on nearby wells for two reasons: 1) nearby Iles Formation wells are too far from well DP-4 and 2) one nearby well is screened in the overlying alluvium.

In 1999 ABC performed another water supply evaluation at the site to verify the 1994 results. A four-day pumping test was performed on well DP-4. The well was pumped at a rate of 100 to 122 gpm for the duration of the test, yielding approximately 1.9 acre-feet of water, the equivalent to 70 percent of the total amount pumped from the well in 1998 (ABC, 1999). Water levels were recorded throughout the duration of the test in well DP-3, and two nearby wells referred to as the Lorenze well (well 194895 on **Figure 2**) and the Van Der Bund well (well 85603 on **Figure 2**). Additionally, flow measurements were taken during the pump test from seeps and springs near the well. The locations of these surface water features (SW-1, SW-15 and SW-16) are within the outcrop of the Mancos Shale as shown on **Figure 2**.

The only well or seep/spring to show negative water level change during the aquifer test was well DP-3 (ABC, 1999). Therefore, the aquifer characteristics for the aquifer at well DP-4 were estimated by using the time-drawdown data from well DP-3. The data were analyzed using the Cooper-Jacob method (Cooper & Jacob, 1946) and the results indicate that the transmissivity of the aquifer is 75,000 gpd/ft and that the storage coefficient is $5x10^{-4}$. The transmissivity estimate is 73,000 gpd/ft higher than the 1994 estimate (2,000 gpd/ft) and the storage coefficient confirms the 1994 estimate and conclusion that the aquifer is confined.

The 1999 ABC study estimates the total storage in the Iles aquifer to be 9,000 acre-feet assuming a porosity of 0.05 and an aquifer thickness of 220 feet. They also estimate the recharge by precipitation to the aquifer to be approximately 237 acre-feet per year. The estimate used the EPA HELP model (version 3.04), assumed a recharge area of approximately 1.3 square miles, steady-state infiltration of 3.24 inches (14 percent of average annual precipitation of about 24 inches), an average of 26 percent slopes and a soil type of silty-sandy loam.

In February of 2009, Adrian Brown Consultants rehabilitated well DP-4 after the pump failed from an apparent lightening strike. In their letter report, ABC states that the original groundwater level was 12 feet above the ground surface and the original well yield as approximately 160 gpm. At the time of the rehabilitation, the groundwater level was measured as 38 feet below the ground surface or a total drop in head of 50 feet between 1994 and 2009 (15 years). Based on the new water level ABC estimated the new maximum well yield to be approximately 140 gpm. The reduction in well yield was primarily attributed to a plugged well screen because the specific capacity of the well had decreased from 0.4 gpm/foot of drawdown to 0.1 gpm/foot of drawdown, a reduction of 75 percent (ABC, 2009). Therefore ABC rehabilitated the well by a 24-hour acid treatment and subsequent scrubbing of the screens. Approximately 750 gallons of the acidic water and solid waste was bailed from the well after approximately 300 minutes equating to a rate of about 2.5 gpm. During the bailing, the water level dropped about six feet, which equates to a rehabilitated specific capacity of 0.4 gpm/foot of drawdown, the same capacity as calculated in 1994. ABC then replaced the motor and pump set at a capacity of approximately 100 gpm.

## ***REVIEW OF 2006 LARAMIDE STREAM DEPLETION STUDY***

In 2006, Laramide Environmental, LLC (Laramide) performed an evaluation of stream depletions from pumping wells DP-3 and DP-4 and irrigation return-flows. This study assumed that DP-3 and DP-4 are both within the Iles Formation aquifer. Laramide used the Glover method (Glover, 1974 and 1977) to estimate stream depletions based on the distance from the wells to Trout Creek and to Whetstone Creek, the aquifer transmissivity and the storativity (a.k.a. storage coefficient). The assumptions of the Glover method include the following:

1. The aquifer is homogeneous and isotropic
2. A well is screened across the entire thickness of the aquifer
3. The streambed penetrates the entire thickness of the aquifer

The Glover methodology can be applied to an infinite aquifer scenario where boundary conditions do not affect the result. The infinite aquifer assumption was employed by Laramide. Laramide states that the assumptions listed above do not apply to the hydrogeology present at the site, which is more analogous to Denver Basin hydrogeology, and therefore the estimates for stream depletion are conservative (Laramide, 2006).

The aquifer characteristics used for the stream depletion study are those estimated by ABC in their 1999 study: transmissivity = 75,000 gpd/ft (which equals 10,027 $ft^2$/day); and storativity = 0.0005. Transmissivity (T) equals the product of hydraulic conductivity (K) and saturated thickness (b) (T=Kb). Laramide assumed the saturated thickness of the aquifer to be 220 feet. This assumption appears to be from the top of the upper screened interval to the bottom of the lower screened interval. They then calculate the hydraulic conductivity (K=T/b) to be 46 feet/day. These aquifer characteristics were used for both wells DP-3 and DP-4. The shortest distance to Trout Creek from wells DP-3 and DP-4 is 7,100 feet and 5,700 feet, respectively. The shortest distance to Whetstone Creek from wells DP-3 and DP-4 is 1,200 feet and 4,700 feet, respectively. Using these distances, Laramide assigns the depletion location on Trout Creek to be from a point approximately 5,000 feet upstream of the confluence of Whetstone Creek down to said confluence. The depletion factors estimated by Laramide are presented on pages 3-5 in their 2006 report.

For reasons outlined below, Deere and Ault disagree with the conclusions presented in the 2006 Laramide Stream Depletion Study.

***<u>SUMMARY OF LYTLE WATER SOLUTIONS REPORT</u>***

In a letter report to Holland & Hart, LLP dated On June 15, 2010, Bruce Lytle of Lytle Water Solutions (Lytle), provided a letter report to Holland & Hart, LLP in support of Peabody Energy/Twentymile Coal Company's objection to Deerwood Service Company's application in Case No. 05CW23. Lytle's letter report provided an analysis and critique of the J. Craig Green and Laramide engineering analyses and the proposed decree circulated by Deerwood Service Company in that case. Peabody Energy owns several water rights in the Trout Creek basin as shown on **Figure 2**; however the one water right that Deerwood has the potential of injuring is the one on Trout Creek Ditch No. 2. This water right is approximately 1,400 feet upstream of the Whetstone Creek/Trout Creek Confluence, within the depletion location reach determined by Laramide (2006). The three primary areas of concern listed by Lytle are:

1. Lack of understanding of the geologic/hydrogeologic framework between the proposed water supply wells and the local stream systems,
2. The associated determination of depletive effects, and
3. The proposed augmentation sources.

Regarding the first issue, Lytle expressed concern about the geologic contacts between the Iles Formation sandstone beds and the alluvium or channel of both Trout Creek and Whetstone Creek.

He also highlights potential difference in saturated thickness of the aquifer depending on where the well was screened and which assumptions are used to calculate saturated thickness in the vicinity of well DP-4. Finally he notes a problem with using the same aquifer parameters for wells DP-3 and DP-4 in the depletions analysis. He recommended the following information be collected and analyzed to help properly understand the geologic setting and thereby support Deerwood Service Company's plan for augmentation:

1. Geologic logs for wells DP-3 and DP-4
2. Well construction details of well DP-3 and DP-4
3. Pumping test data from the 1999 aquifer test
4. A geologic cross-section showing the geologic and hydrogeologic relationships between the Iles Formation and adjacent stream systems

Regarding the determination of depletive effects, Lytle raises concerns about the applicability of the Glover method to the site conditions. This issue is closely related to the first issue because if the hydrogeology is not properly understood, the Glover method cannot be properly applied. Further, Lytle states that Laramide's conclusion that the "calculated well impacts on streamflow represent a conservative, maximum-depletion scenario" is flawed because the monthly depletion values may be incorrect, which is not necessarily conservative.

Lytle's concerns about augmentation sources are that the sources have relatively junior priority dates, that the water supply does not incorporate future supplies, that the augmentation sources are not currently operable and that Deerwood cannot deliver the augmentation sources to Trout Creek any further upstream than the confluence with Whetstone Creek. Regarding the first issue, Lytle argues that the junior priority dates of the augmentation sources may be out of priority for a majority of the year, therefore preventing augmentation from occurring. Lytle also states that the engineering done by J. Craig Green (2006) does not include future in-priority water supplies. Further, the physical supplies that do exist are in the Deerwood Pond and Whetstone Reservoir, the latter of which does not currently contain any storage for Deerwood. Finally, the releases from these ponds can only augment Trout Creek at the confluence with Whetstone Creek, and not any further upstream where their depletion locations are located.

## ***DEERE & AULT ANALYSIS***

The data review for this investigation was performed with the goal of identifying the stream depletion locations from Deerwood Service Company's wells DP-3 and DP-4. The discussion of the site hydrogeology will be evaluated in terms of hydraulic connections between possible depletion locations and wells DP-3 and DP-4. Evidence will also be cited from the various studies included in the review.

### ***Geological Data Analysis***

The geology at the site directly controls the depletion locations from pumping wells DP-3 and DP-4. The cross-sections shown in **Figure 3**, along with the fact that the Mancos Shale and the shale within the Lower Iles Formation have intrinsic low permeability, support the concept that the aquifers encountered by wells DP-3 and DP-4 are confined. To confirm this observation, the aerial extent of the aquifers was evaluated. The sandstone aquifers encountered in well DP-4 were observed in outcrop on aerial photography. These beds were traced using the aerial image to the fault defining the Whetstone Creek valley and south to Oak Creek. As shown on the geologic map (**Figure 2**) and in the geologic cross-sections (**Figure 3**), the water bearing sandstone beds encountered by the two wells do not intersect the streams or alluvium of Trout Creek or Whetstone Creek. Further, well DP-4 experienced a net drop in total head of 50 feet in the 15 years since it was installed (ABC, 2009). This evidence indicates a strong likelihood that both wells DP-3 and DP-4 are non-tributary wells. However, the beds do intersect the fault defining the Whetstone Creek valley as well as the fault further to the west.

While neither the exact location of the Whetstone valley fault, nor the normal offset on the fault is precisely known, the fault will act as a barrier to groundwater flow across it. Therefore, no hydraulic connection exists between the water-bearing sandstone beds and Whetstone Creek. Depending on the nature and geometry of the fault plane, it is possible that the groundwater in the water-bearing sandstone beds can migrate along the fault plane and be in hydraulic connection with Trout Creek at its intersection with the alluvium, which is at a point approximately 2,540 feet upstream of the confluence between Trout Creek and Whetstone Creek (**Figure 4**). Therefore this is a possible depletion location (location 1) for both wells DP-3 and DP-4. This is supported by the fact that the location where the fault likely subcrops below the Trout Creek alluvium is at an elevation of approximately 6,760 feet and therefore down gradient from both wells DP-3 and DP-4. For well DP-4, this depletion location has a hydraulic length of approximately 8,500 feet and a difference in hydraulic head of 202 feet giving a hydraulic gradient of 0.024 towards Trout Creek. For well DP-3, this depletion location has a hydraulic length of approximately 8,200 feet and a difference in hydraulic head of 247 feet giving a hydraulic gradient of 0.030 towards Trout Creek.

Conversely, the fault could be made up of clay gouge material and likely has smeared the shale beds across the fault plane. The fault exhibits approximately 1,800 feet of right lateral strike-slip offset within the Iles Formation and approximately 3,600 feet of right lateral strike-slip offset within the Mancos Shale (**Figure 4**). Thus, it is also possible that the fault does not allow water to flow along it, indicating that the water-bearing sandstone beds may not be in hydraulic connection with Trout Creek. If this fault is not a hydraulic connection, then the likelihood that the two wells are non-tributary wells increases.

For well DP-4 another possible depletion location (location 2) is where the western fault subcrops below the Trout Creek alluvium. This occurs approximately 10,500 feet upstream of the confluence of Trout Creek with Whetstone Creek (**Figure 4**). Cross-section A-A' on **Figure 3** shows that the sandstone aquifers encountered in well DP-4 likely intersect this fault at depths ranging from about 1,600 to 1,800 feet deep. Again, if this fault is relatively open and conductive, groundwater from within the sandstone beds may be hydraulically connected along this fault to the Trout Creek alluvium. As shown on **Figure 4** the approximate elevation of the subcropping fault beneath the Trout Creek alluvium is 6,860 feet, which is about 102 feet lower than the water level in well DP-4. This fault has a lower likelihood of a hydraulic connection because it exhibits reverse motion, it exhibits about 160 feet of offset and it is up to 1,800 feet long. Because this fault exhibits reverse motion and approximately 160-feet of offset, the plane is less likely to be open, and more likely to smear shale beds. Additionally, it is more likely to smear shale beds within both the Iles Formation and the overlying Williams Fork Formation because there are approximately 1,600 to 1,800 feet along the fault between the Trout Creek alluvium and where the fault cuts the Lower Iles sandstone aquifers. This depletion location has a hydraulic length of approximately 7,400 feet and a difference in hydraulic head of 102 feet giving a hydraulic gradient of 0.014 towards Trout Creek.

Because the DP-4 sandstone aquifer beds were able to be traced south to Oak Creek and likely do subcrop below the Oak Creek alluvium, this becomes another possible depletion location (location 3). The location is approximately 2.5 miles south of well DP-4 where Oak Creek cuts through the Lower Iles Formation hogback (**Figure 4**). This subcrop location is at an elevation of approximately 7,160 feet. Compared to the water level in well DP-4 (6,962 feet), the location is up gradient and should therefore be treated as a recharge site for the sandstone aquifers of DP-4 assuming the sandstone beds are continuous between the sites and that no cross-cutting faults inhibit the recharge. For well DP-4, this depletion location has a hydraulic length of approximately 13,200 feet and a difference in hydraulic head of 198 feet giving a hydraulic gradient of 0.015 towards well DP-4. This is not a depletion location for well DP-3.

A recharge analysis for the Iles sandstone aquifers encountered by well DP-4 was performed for the Oak Creek location using the data in the GIS. The dip of the beds at the location was assumed to be 30°, so that the subcrop length in cross-section could be calculated as the sandstone bed thickness divided by sin(30°). This equates to subcrop lengths twice as long as the thickness of the beds. The likely extent of the alluvial aquifer adjacent to Oak Creek was digitized using aerial photography and DEM topographic mapping. Then, the area was calculated of the subcropping areas within the Oak Creek alluvium in square feet. Next, 18 samples of lower Iles Formation sandstone beds tested by Robson & Stewart (1990) using a gas permeameter were tabulated in **Table 1**. The average permeability of these 18 samples is approximately $4x10^{-2}$ ft/day. This value was raised by one order of magnitude ($4x10^{-1}$ ft/day) to account for the fracturing within the sandstone. The data used for this analysis is shown in the table below:

| Kil Sandstone Unit | Bed Thickness (ft) | Subcrop Length (ft) | Subcrop Area under Oak Creek Alluvium ($ft^2$) |
|---|---|---|---|
| Kil 3 (upper bed) | 20 | 40 | 13,520 |
| Kil 2 (middle bed) | 28 | 56 | 21,046 |
| Kil 1 (lower bed) | 15 | 30 | 19,144 |
| | | ***Total*** | ***53,170*** |
| Hydraulic Conductivity, K = 0.4 ft/day (after Robson & Stewart, 1990) | | | |

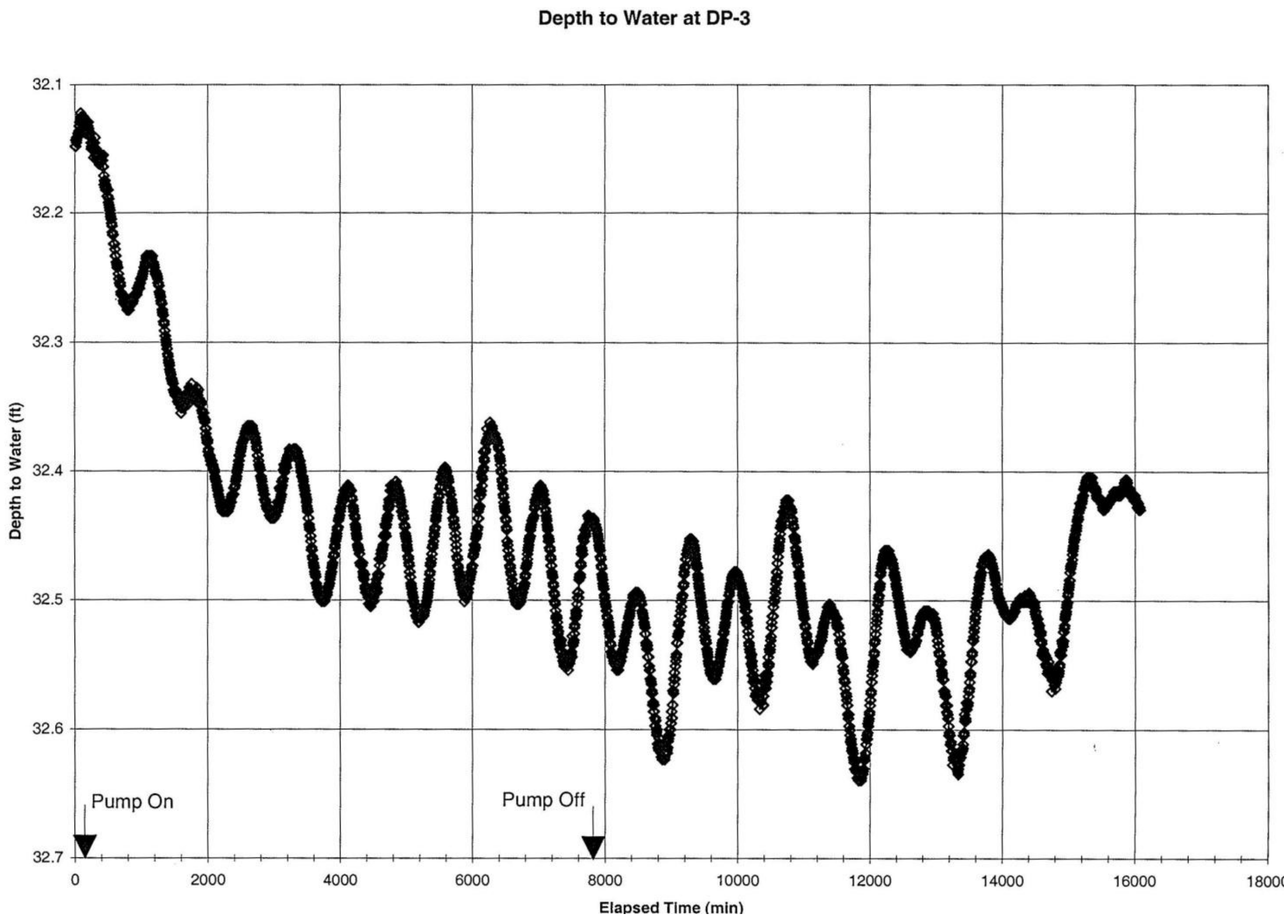
Using Darcy's Law (Q = KiA), assuming the hydraulic gradient, i, is equal to one, the recharge potential from the Oak Creek alluvial aquifer to the Lower Iles sandstone aquifers was estimated at approximately 0.25 cubic feet per second (cfs). If well DP-4 pumps at a constant rate of 80 gpm, this equates to approximately 0.18 cfs, which is 0.07 cfs lower than the estimated potential recharge from the Oak Creek alluvium into the Lower Iles sandstone aquifers. This suggests that the aquifers are likely recharged at a constant rate, and since none of the variables can change due to pumping from the well, this location is not a likely depletion location.

In summary, the preliminary evidence suggests that wells DP-3 and DP-4 are likely either non-tributary wells or that they are tributary to depletion location 1 (**Figure 4**). If they are tributary to location 1, the location is approximately 1,100 feet upstream of Twentymile Coal's Trout Creek Ditch No. 2 diversion location (**Figure 4**). **Figure 5** shows the configuration of the water supply infrastructure in the vicinity of Trout Creek Ditch No. 2, including depletion location 1, Whetstone Ditch and the approximate areas irrigated by Trout Creek Ditch No. 2, which were obtained from the decree in Case No. W-1502-78.

***ABC 1999 Pumping Test Analysis***

All the data collected from the ABC pumping tests (ABC, 1994 & 1999) suggest that the Iles Formation aquifers encountered by well DP-4 are confined. The fact that none of the surface water features (springs & seeps) or the nearby wells experienced changes in flows or water levels during the 1999 ABC pumping test suggests that the features are not in hydraulic connection with the water-bearing sandstone beds encountered in well DP-4. The Van Der Bund well (well 85603 on **Figure 4**, located about 1,750 feet south of DP-4 is completed in the shallow alluvium (40 feet deep) and showed no change in water level during the test. This illustrates that the shallow alluvial aquifer defining the tributary above Deerwood pond is not in hydraulic connection with well DP-4. The Lorenze well (well 194895 on **Figure 4**), also completed within the Lower Member of the Iles Formation, is 255 feet deep and approximately 3,040 feet south of well DP-4. Nonetheless, it also did not experience a water level change during the DP-4 pumping test. The Lorenze well encountered only one water-bearing sandstone layer, 35 feet thick at a depth of 210 feet. The well is approximately 160 feet higher in elevation, so the water-bearing sandstone is approximately 150 feet above the highest water-bearing sandstone bed in well DP-4. This fact confirms that the two wells are not in hydraulic connection and also suggests that the shale beds in between the water-bearing sandstone beds in the Iles Formation have a permeability low enough to confine the sandstone beds and inhibit water flowing between sandstone beds.

Well DP-3 and the three surface water features are located within the outcrop/subcrop of the Mancos Shale (**Figures 2** & **4**). The Mancos Shale is older than the Iles Formation, so it is under the Iles Formation (**Figure 3**). The thick shale beds in the Mancos Shale have a very low permeability, which suggests that any well or spring within the Mancos Shale is not hydraulically connected to the Iles Formation aquifers. The 1999 ABC pumping test confirms that the surface water features are not connected to the aquifers in well DP-4. However, ABC actually used time-drawdown data from well DP-3 to estimate the transmissivity and storativity of the Iles aquifers. The perceived drawdown in well DP-3 can be recognized after about 8 hours and stabilized after 33 hours as shown in the time-drawdown graph for DP-3 below.




The total magnitude of the drawdown is approximately 0.2 feet (2 inches). ABC (1999) therefore concludes that there is a hydraulic connection between the two wells. This directly contradicts the evidence that the surface water features are hydraulically disconnected from the Iles aquifers as well as the logic that the low permeability Mancos Shale acts as an aquitard below the Iles Formation and above the water-bearing sandstone bed encountered in well DP-3. There are two likely explanations for this contradiction.

The first is that the Whetstone valley fault is hydraulically connected to the water-bearing sandstone aquifers in both wells DP-3 and DP-4. While well DP-3 is approximately 3,480 feet from well DP-4, the hydraulic length along the Iles sandstone beds and the fault is approximately 9,070 feet. It seems unlikely that such a small magnitude of drawdown would occur so quickly along such a long hydraulic length, but the plot above clearly shows a difference in water level, however small.

The second explanation is that there is no hydraulic connection between the two wells, along the fault or not, and the perceived drawdown data simply represents diurnal recharge fluctuations. The absence of static water level data on the well DP-3 time-drawdown curve prior to the pumping test does not allow an antecedent water level to have been established at the well. The oscillating nature of the time-drawdown curve for well DP-3 during the test suggests that the diurnal recharge events discussed by ABC (1999) are occurring. However, the magnitude of these events appears to be erratic. Further, the well did not experience any recovery after the pumping at well DP-4 was stopped. Therefore, the absence of antecedent water level data in well DP-3, the relatively small time period of data collection (the duration of the test), the small magnitude of drawdown (2 inches) and the absence of any water level recovery in well DP-3 after pumping ceased may not actually constitute a response to pumping well DP-4.

If the first explanation is true, then the transmissivity and storativity values calculated by ABC (1999) may be real, but likely represent all water-bearing sandstone aquifers in both wells and the transmissibility of the fault. If the second explanation is true, then the two wells are likely non-tributary wells and aquifer parameters calculated by ABC (1999) are wrong and do not represent the Iles Formation aquifer parameters. To best test these hypotheses, a new monitoring well would need to be installed within the Trout Creek alluvium close to depletion location 1, be equipped with a pressure transducer and record water level data prior to new pumping tests performed at wells DP-3 and DP-4.

A more accurate estimate of the aquifer transmissivity in the vicinity of each well could probably have been obtained from analysis of the recovery data after the pump was turned off. Once the well bore filled up, which typically happens quickly, the recovery of the depressed groundwater surface in the aquifer can be measured in the well. Because the pumping test imparted a large stress on the aquifer, the magnitude of the recovery would probably be sufficient to estimate the transmissivity of the aquifers encountered at each well. In fact, ABC (1994) used the recovery data from the DP-4 pumping test to estimate the transmissivity of the Iles sandstone aquifers. This analysis resulted in a transmissivity value of 2,000 gpd/ft, which is much smaller than the 75,000 gpd/ft estimated by ABC in the 1999 DP-4 pumping test. Therefore, the 1994 estimate of transmissivity is probably more representative of the Iles aquifers encountered by well DP-4. No recovery data is available for well DP-3 from the 1994 pumping test or from the 1999 pumping test. The time-drawdown curve for well DP-3 presented above clearly shows that the groundwater level in the well did not experience any recovery even after approximately 133 hours since the pump was shut off. Therefore the transmissivity of the sandstone aquifer in well DP-3 remains unknown.

***<u>Depletions Study Analysis</u>***

The depletion study performed by Laramide in 2006 has several flaws. The most significant problem is the way Laramide used the Glover method within a confined bedrock aquifer hydrogeologic environment. Laramide explicitly states that none of the Glover assumptions apply to the confined nature of the Iles aquifer. Again, the assumptions of the Glover method include the following:

1. The aquifer is homogeneous and isotropic
2. A well is screened across the entire thickness of the aquifer
3. The streambed penetrates the entire thickness of the aquifer

As discussed in the geologic review, the Iles aquifer is not homogeneous or isotropic because it contains interbedded sandstone and shale; well DP-4 has three separate 20-foot screened intervals and does not penetrate the full thickness of the Iles Formation; and no streambed, Trout Creek or Whetstone Creek, penetrates the full thickness of the aquifer.

The analytical solution developed by Glover (1977) requires calculation of what is referred to as the aquifer constant, $\alpha$:

$$\alpha = \frac{KD}{V}$$

Where:

K = hydraulic conductivity in feet per day
D = aquifer saturated thickness in feet (also referred to as b in some texts)
V = volume of water that will drain from a unit volume of the aquifer if the pressure is dropped one foot, a dimensionless term (also referred to as specific yield (Sy), which is the unconfined equivalent to the storage coefficient in a confined aquifer)

The Glover solution also requires these terms:

W = distance from boundary of the aquifer running parallel to the stream back to the stream
x = distance to the stream from the edge of the well

The Laramide study does not use the term W because it employs the infinite aquifer solution in the Glover method. The values used by Laramide for the term x are not correct because our geologic analysis shows that the Iles sandstone aquifers are not in direct hydraulic connection to Trout Creek or Whetstone Creek via subcrop due to the faulting and the confining shale layers. To use Laramide's values for the term x, the value of transmissivity would have to be an average value representing all the shale and sandstone beds in the lower Iles Formation between the well and the creek weighted by thickness. Such a value would likely be very small.

Because Laramide uses the ABC (1999) pumping test data, it is possible that the value for transmissivity (KD in the above equation) is wrong. In fact, the transmissivity estimate from the ABC (1994) pumping test may be more representative. Similarly, the value of 220 feet for saturated thickness (D or b) used would make K different. Based on the well log for DP-4, the value for saturated thickness should be the aggregate thickness of the water-bearing sandstone beds or 63 feet. If the ABC (1994) value for transmissivity (2,000 gpd/ft or 267 $ft^2$/day) and the lower value of saturated thickness is used, the value for hydraulic conductivity would be about 4.2 feet/day, an order of magnitude less that the 46 feet/day used by Laramide (2006). If the transmissivity of the shale layers is included in the estimate, the resulting value for hydraulic conductivity would be significantly smaller.

Finally, Glover's method assumes an unconfined alluvial aquifer situation where V is the specific yield (Sy). Specific yield is defined as the ratio of the volume of water that can drain from a unit volume (porosity) of unconfined aquifer by gravity (Driscoll, 2003). In confined aquifers the term is known as the storage coefficient, which has typical values of $10^{-3}$ to $10^{-5}$ (Driscoll, 2003). Water pumped from confined aquifers is released from storage by expansion of the water and by compression of the aquifer. The pressure in the aquifer is reduced during pumping, but the aquifer is not dewatered in the vicinity of the well like it is in an unconfined aquifer (Driscoll, 2003). The term V used by Laramide (2006) in Glover's equation represents the storage coefficient in the Iles confined aquifers. It is very small (0.0005), so the value for $\alpha$ becomes large and the depletion effect is faster. However, because the aquifer is not draining in the vicinity of the creek, this value may not be applicable to the Glover solution.

## ***CONCLUSIONS***

The geologic framework presented within this study shows that the hydrogeology of the site is complicated, but can be understood. Because the aquifers in question are confined, it also demonstrates that the hydraulic connection between the wells and the local stream systems is not immediately apparent. Therefore, the possibility that wells DP-3 and DP-4 are non-tributary wells appears likely. However, the geologic framework also allows multiple hypotheses to be formulated for the location of tributary well depletions. In order of decreasing likelihood, the possible well depletion locations, if any occur, are as follows:

1) At a point on Trout Creek where the Whetstone valley fault likely subcrops below the Trout Creek alluvium approximately 2,540 feet upstream of the confluence with Whetstone Creek. The hydraulic gradient is approximately 0.024 from well DP-4 towards Trout Creek. The hydraulic gradient is approximately 0.030 from well DP-3 towards Trout Creek.

2) At a point on Trout Creek where the western fault likely subcrops below the Trout Creek alluvium approximately 10,500 feet upstream of the confluence with Whetstone Creek. The hydraulic gradient is approximately 0.014 from well DP-4 towards Trout Creek. Well DP-3 is not connected to this fault.

3) At a point on Oak Creek where the sandstone aquifers likely subcrop below the alluvium of Oak Creek approximately 2.5 miles south of the site. The hydraulic gradient is approximately 0.014 from Oak Creek towards well DP-4. This is not a depletion location for well DP-3

These possible depletion locations are shown on **Figure 4**.

The likelihood of the locations 1 and 2 being depleted is much higher than that of location 3 for several reasons. The first is that the both faults subcrop below the Trout Creek alluvium and intersect the sandstone aquifers encountered by well DP-4, while only the Whetstone valley fault intersects the sandstone in well DP-3. Second is the concept that groundwater typically flows along a fault. Third, the points have steeper hydraulic gradients and are much closer than the Oak Creek location. Finally, the recharge supplied by Oak Creek likely recharges the sandstone aquifers at a constant rate that wouldn't change due to pumping.

For well DP-4, location 1 is more likely than location 2 because the western fault has a higher probability of having smeared shale along its plane due to large offset (~160 feet), a long length (1,600 to 1,800 feet) and the fact that it exhibits reverse motion. Additionally, the hydraulic gradient is much steeper between well DP-4 and Trout Creek via the Whetstone valley fault.

Based on this reasoning, wells DP-3 and DP-4 may be non-tributary wells, or if they are tributary, they are most likely tributary to depletion location 1. While these two hypotheses have the highest likelihood, further research may need to be conducted to confirm or refute them. Therefore, we propose changing the depletion location for both wells DP-3 and DP-4 to the point where the Whetstone valley fault likely subcrops beneath the Trout Creek alluvium, approximately 2,540 feet upstream of the confluence of Trout Creek and Whetstone Creek.

Regarding the aquifer testing, we do agree that the storage coefficient (storativity) is on the order of $10^{-4}$ because it is a realistic value for confined aquifers. We also agree with Lytle that Laramide's argument that the "calculated well impacts on streamflow represent a conservative, maximum-depletion scenario" is not necessarily conservative if it is incorrect. In our opinion we believe that argument to be incorrect. We do not believe that the Glover method, as used by Laramide, is appropriate for a confined aquifer situation as clearly exists at the Deerwood Park wells DP-3 and DP-4. We are uncomfortable with using the drawdown data from well DP-3 to estimate the transmissivity of the Iles aquifers encountered in well DP-4 because the geology shows that the two wells are in different geologic units, that they are separated by a relatively thick sequence of low permeability shale and that the time-drawdown data from well DP-3 may only represent diurnal recharge events. However, if a true response in well DP-3 to pumping well DP-4 exists, the drawdown in well DP-3 supports our opinion of the new depletion location. We also do not agree with the 220-foot saturated thickness value. It is likely much closer to the aggregate thickness of the three water-bearing sandstone aquifers encountered by well DP-4 or 63 feet. Similarly, the saturated thickness of well DP-3 is 52 feet, which is the thickness of the water-bearing sandstone aquifer in the Mancos Shale. We also do not agree with the way Laramide measured the distances to the creeks, primarily because the aquifers are confined and are not hydraulically connected to the creeks through the rocks themselves. If Laramide's distances to Trout Creek are used, a value of transmissivity representing all the shale and sandstone between the well and the creek should be used. We propose using the hydraulic distances used for the hydraulic gradient estimates presented in this study.

If the proposed depletion location is used for further depletions analyses, the Trout Creek Ditch No. 2 water rights owned by Peabody Energy/Twentymile Coal Company could be injured because the diversion is approximately 1,000 feet downstream of the proposed depletion location. The Trout Creek Ditch No. 2 water right is decreed is in the amount of 1.66 cfs. There are several alternatives that can mitigate this injury once the magnitude of the injury is calculated.

First, Deerwood Service Company could purchase water rights upstream of the proposed depletion location and use them as augmentation sources. The water rights would likely have to be changed for augmentation use. An adequate supply (flow rate) would have to be acquired to account for any transit losses in the delivery of the water to the Trout Creek Ditch No. 2 headgate.

A second alternative may be for Deerwood Service Company to purchase a portion of the Trout Creek No. 2 water right to offset the potential depletion flow rate.

A third alternative would be that Deerwood Service could release water from Deerwood Pond or Whetstone Reservoir into Whetstone Creek, build a diversion structure from Whetstone creek into Trout Creek Ditch no. 2 to satisfy any potential Trout Creek diversion reductions due to depletions caused from DP-3 and dP-4. At such time as Peabody Energy/Twentymile Coal Company begins to use its Trout Creek Ditch No. 2 for storage at Energy Fuels reservoir No. 2 per the Decree in Case No. W-1502-78, the Deerwood Service Company water stored in Deerwood Pond or Whetstone Reservoir could be released to Whetstone Creek and delivered to the Trout Creek confluence to replace Trout Creek potential diversion reductions due to well depletions from DP-3 and DP-4. The Deerwood Pond and Whetstone Reservoir water rights may have to be changed to add augmentation use to allow this alternative to work.

Please call if you have any questions or comments.

Sincerely,

DEERE & AULT CONSULTANTS, INC.

V. G. deWolfe

Michael J Ballantine

Victor G. deWolfe, P.G., EIT
Geological Engineer

Michael J. Ballantine, P.E.
Principal, Project Manager

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# TABLES

**Table 1.**
**Lower Iles Formation Sandstone Laboratory Test Data**

| Sample ID | Location (Township/Range-Section Q160 Q40 Q10)* | Hydraulic Conductivity, K (feet/day)* | Porosity (%)* | Grain-size distribution (% finer) by Sieve Size (mm)* | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | 1.0 | 0.5 | 0.25 | 0.125 | 0.0625 |
| Kio-1** | 4/85-8CAA | 3.8E-04 | 14 | 100 | 97.6 | 89.0 | 42.9 | 10.2 |
| Kio-2 | 4/85-19ADA | 1.5E-03 | 14 | 100 | 96.8 | 87.0 | 41.1 | 10.5 |
| Kio-3 | 4/85-19ADA | 8.3E-03 | 16 | 100 | 98.2 | 72.0 | 24.7 | 9.2 |
| Kio-4 | 4/85-30ACC | 1.4E-03 | 14 | 100 | 96.3 | 72.8 | 21.3 | 5.8 |
| Kio-5 | 4/85-31BAD | 1.5E-03 | 17 | 100 | 98.3 | 85.3 | 33.6 | 7.5 |
| Kio-6 | 4/85-31BBD | 7.7E-03 | 18 | 100 | 97.7 | 91.5 | 49.8 | 11.6 |
| Kio-7 | 4/86-22ACD | 7.3E-04 | 14 | 100 | 96.4 | 88.5 | 72.0 | 14.2 |
| Kio-8 | 4/86-23ACC | 2.2E-02 | 19 | 100 | 99.8 | 91.2 | 20.0 | 3.9 |
| Kio-9 | 4/86-23BAB | 8.8E-04 | 17 | 100 | 99.3 | 77.7 | 24.6 | 5.2 |
| Kio-10 | 4/86-28CCD | 2.8E-02 | 20 | 100 | 99.5 | 76.7 | 24.7 | 8.4 |
| Kio-11 | 4/87-10ACC | 1.8E-01 | 20 | 100 | 99.1 | 84.9 | 21.3 | 7.8 |
| Kio-12 | 4/87-34DBA | 2.7E-03 | 20 | 100 | 96.5 | 89.2 | 55.6 | 12.5 |
| Kio-13** | 5/85-20CAB | 2.1E-01 | 22 | 100 | 99.0 | 64.7 | 11.1 | 4.5 |
| Kio-14 | 5/86-1BAD | 1.3E-04 | 11 | 100 | 98.9 | 92.5 | 29.2 | 9.9 |
| Kio-15 | 5/88-25DAA | 2.3E-01 | 25 | 100 | 98.3 | 92.8 | 35.6 | 8.9 |
| Kio-16 | 6/86-23BCC | 8.3E-03 | 20 | 100 | 99.1 | 94.0 | 43.6 | 15.0 |
| Kio-17 | 6/86-25BAA | 8.0E-03 | 21 | 100 | 98.5 | 94.6 | 82.8 | 15.5 |
| Kio-18 | 6/86-25DBA | 5.8E-05 | 6.6 | 100 | 96.9 | 87.8 | 72.2 | 24.9 |
| | **Average=** | **4.0E-02** | | | | | | |

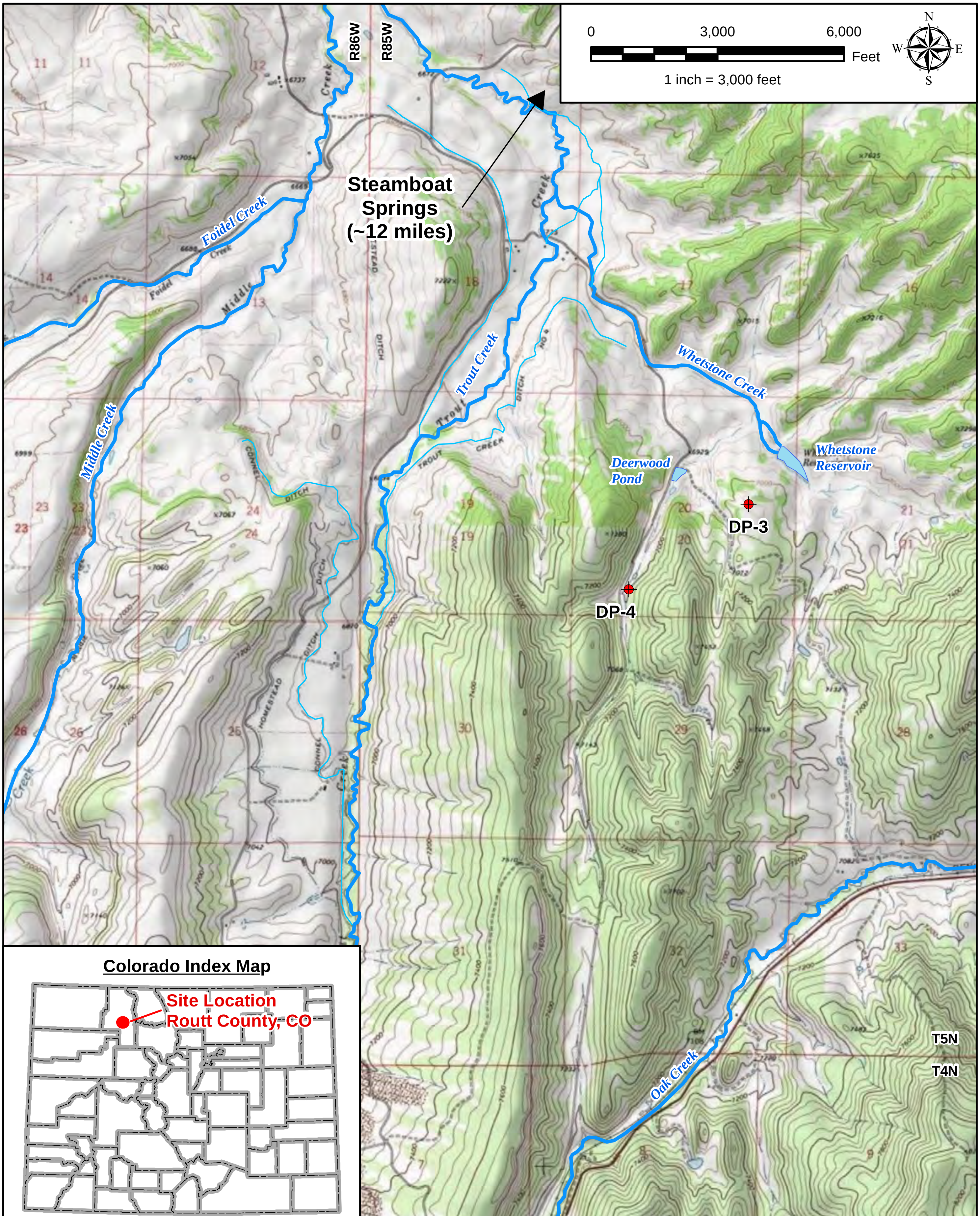
* Data is from gas permeameter tests performed on hand samples of the Tow Creek Sandstone (Kio) from the Lower Iles Formation by Robson and Stewart (1990) page 62.

** Samples Kio-1 and Kio-13 are the closest to the study area. Kio-13 was taken from approximately 1,700 feet north of well DP-4 and Kio-1 was taken from approximtely 300 feet south of Oak Creek where it crosses the Iles Formation.

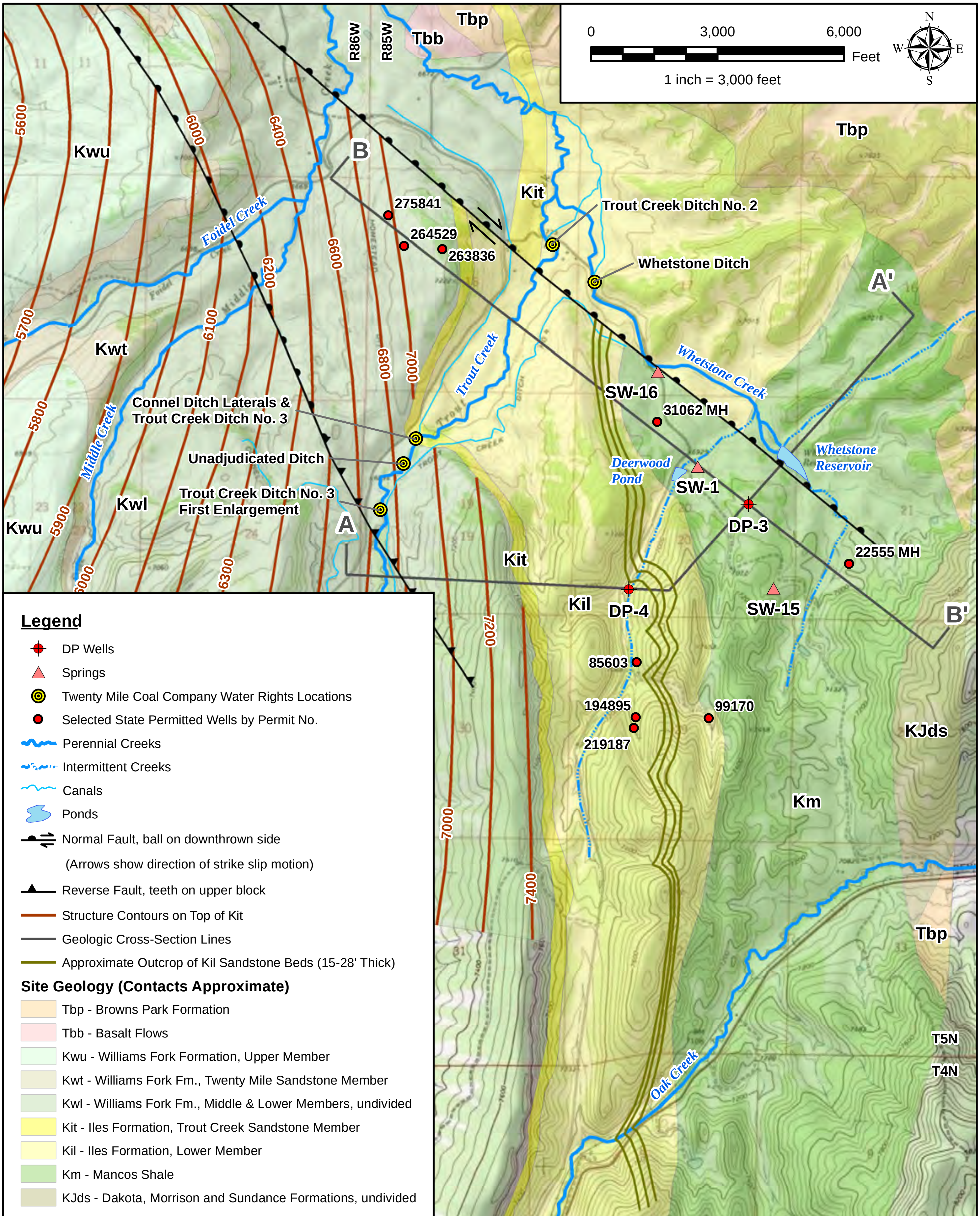
Section Quartering Key

| | |
|---|---|
| B | A |
| C | D |

# FIGURES




| | | |
|---|---|---|
| DEERE & AULT CONSULTANTS, INC. | **DEERWOOD SERVICE COMPANY**<br>**Location Map** | Figure No.<br>**1** |
| | Job No: 0430.001.00 / Scale: 1:36,000 | |




DEERE & AULT
CONSULTANTS, INC.

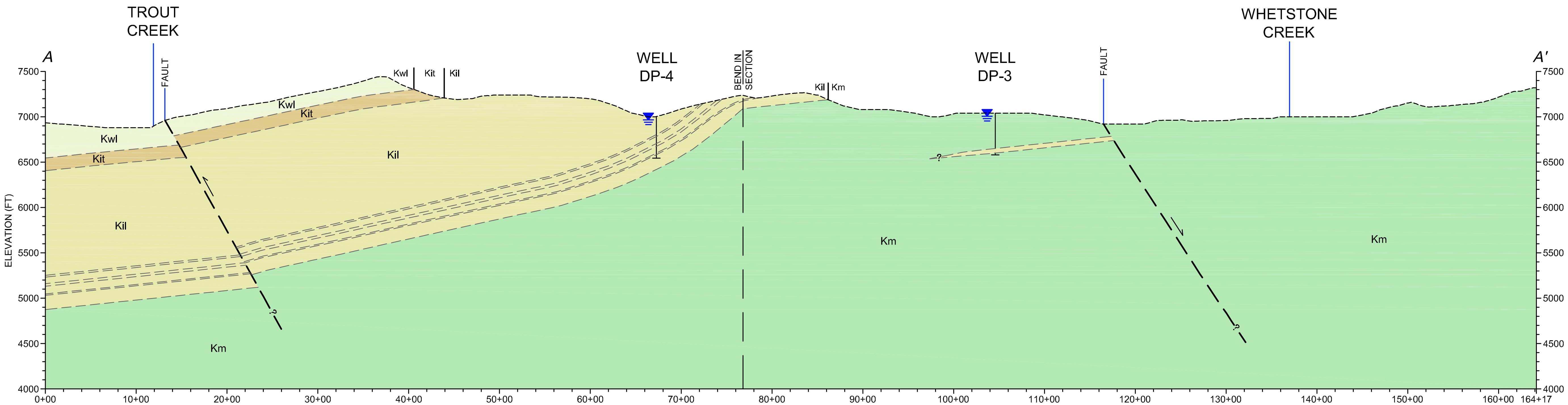
**DEERWOOD SERVICE COMPANY**

**Site Geologic Map**

| Job No: | 0430.001.00 | Scale: | 1:36,000 |
|---|---|---|---|

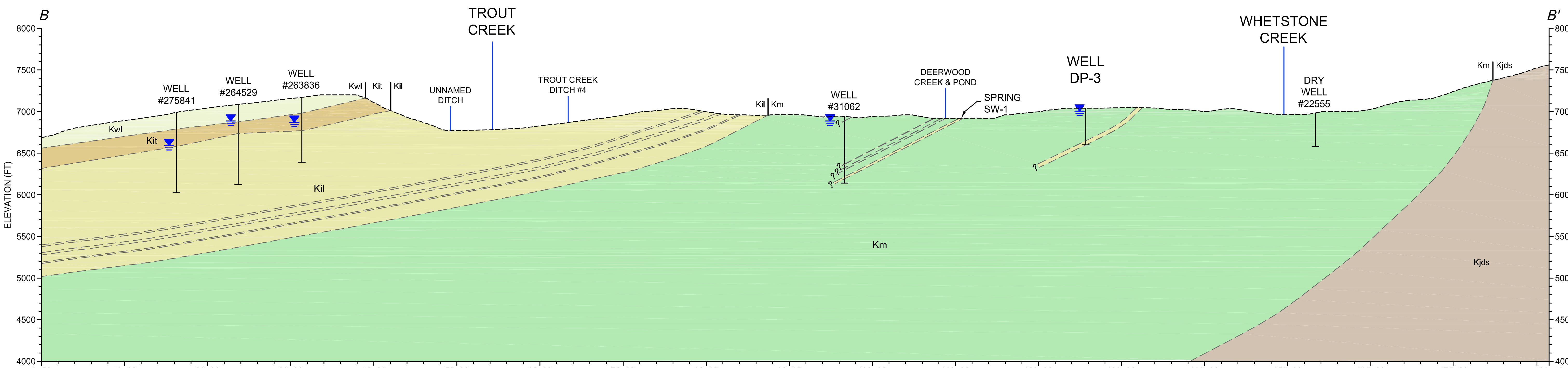
Figure No.

**2**




*CROSS SECTION A-A'*

0 600 1200
Scale In Feet




*CROSS SECTION B-B'*

0 600 1200
Scale In Feet

LEGEND:

- Kwl — WILLIAMS FORK FORMATION, LOWER MEMBER
- Kit — ILES FORMATION, TROUT CREEK SANDSTONE MEMBER
- Kil — ILES FORMATION, LOWER MEMBER: SHALE WITH SANDSTONE INTERBEDS
- Km — MANCOS SHALE: SHALE WITH MINOR SANDSTONE INTERBEDS
- Kjds — DAKOTA, MORRISION, AND SUNDANCE FORMATIONS UNDIVIDED
- GEOLOGIC CONTACTS, APPROXIMATELY LOCATED (? WHERE QUERIED)
- GEOLOGIC FAULTS SHOWING RELATIVE MOTION, APPROXIMATELY LOCATED (? WHERE QUERIED)
- WELL SHOWING ID, DEPTH AND APPROXIMATE GROUNDWATER LEVEL

JOB NO. 0430.001.00

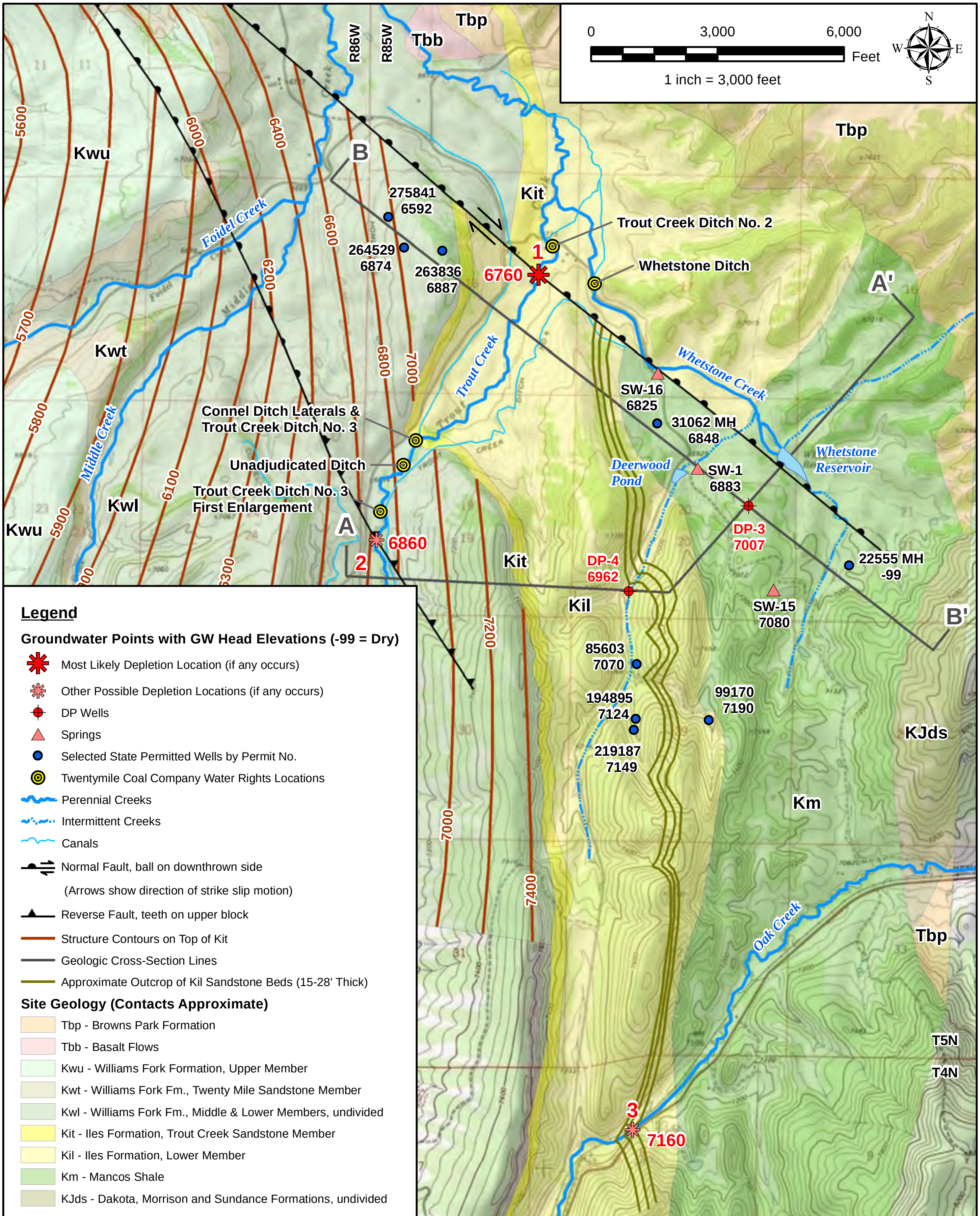
**DEEREWOOD SERVICE COMPANY**

**Geologic Cross Sections**

DEERE & AULT CONSULTANTS, INC.

| | |
|---|---|
| FIGURE NO. | 3 |
| DATE: 1-12-11 | SCALE: AS NOTED |

Wednesday, January 12, 2011 9:08:39 AM DRAWING: P:\0430 Deerewood Service Company\GIS\CAD\Deerewood.DWG




DEERE & AULT CONSULTANTS, INC.

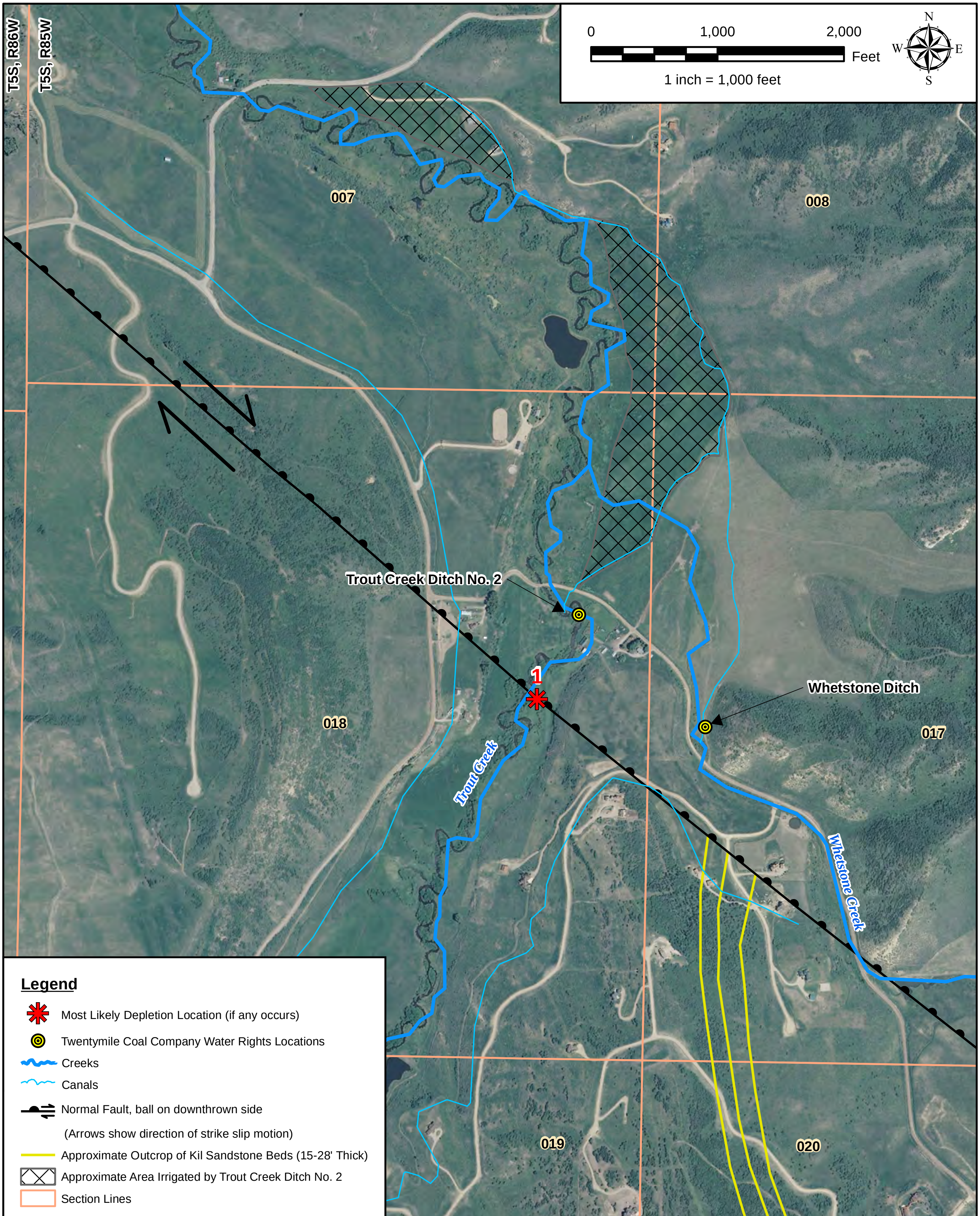
**DEERWOOD SERVICE COMPANY**

**Groundwater Head Map**

| | | | |
|---|---|---|---|
| Job No: | 0430.001.00 | Scale: | 1:36,000 |

Figure No.

**4**




DEERE & AULT CONSULTANTS, INC.

| DEERWOOD SERVICE COMPANY<br>Trout Creek Ditch No. 2 Map | | Figure No.<br>5 |
|---|---|---|
| Job No: 0430.001.00 | Scale: 1:12,000 | |

# APPENDIX A
## DP-3 AND DP-4 WELL CONSTRUCTION DETAILS

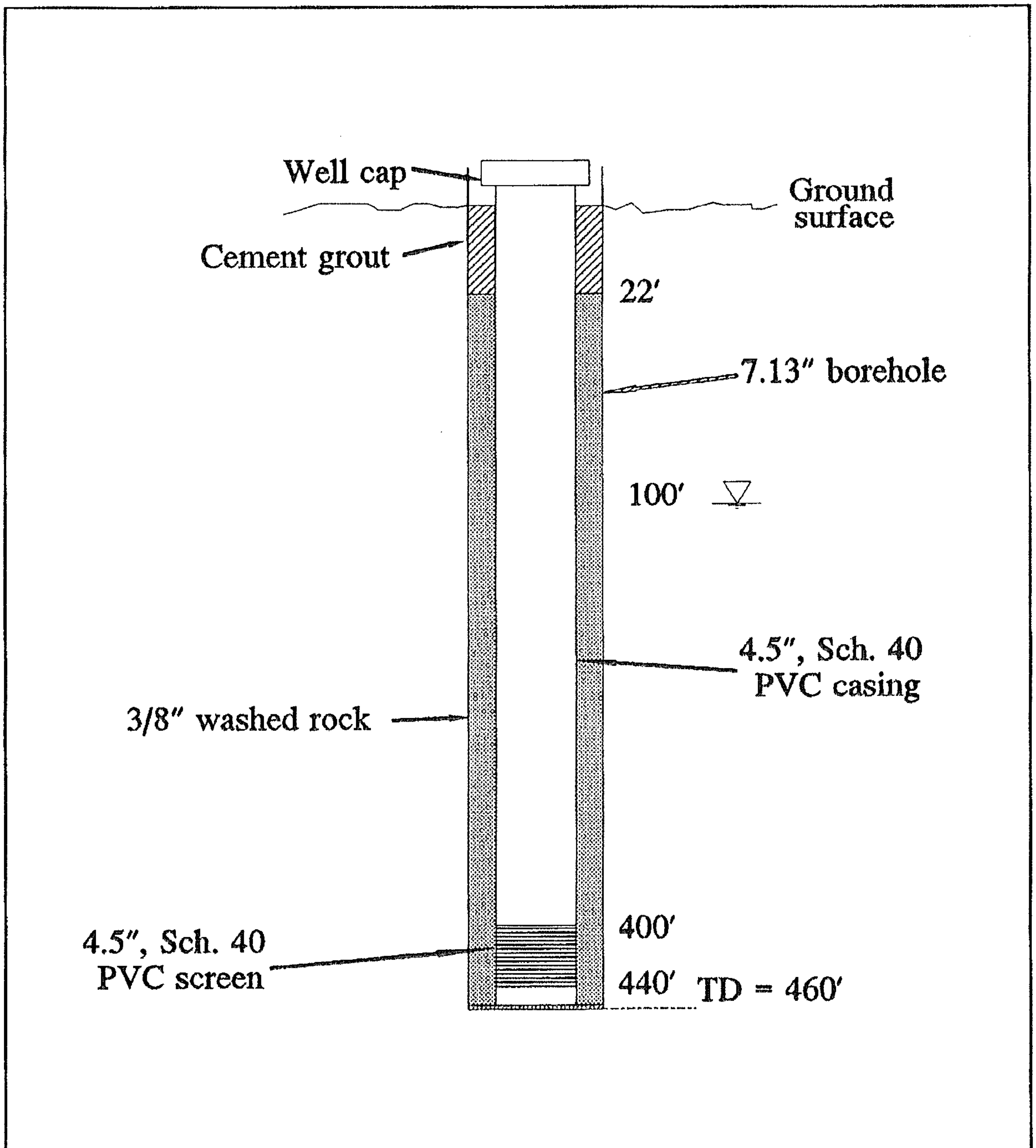



**Figure 2**: Well DP-3 completion diagram.

FORM NO. GWS-31 11/90

# WELL CONSTRUCTION AND TEST REPORT
## STATE OF COLORADO, OFFICE OF THE STATE ENGINEER

For Office Use only

RECEIVED
JUL 27 '94
WATER RESOURCES STATE ENGINEER COLO.

1. WELL PERMIT NUMBER ~~MH 22556~~ ~~44332-F~~ 56801-F

2. OWNER NAME(S) Rummick ASS. John Adams
Mailing Address Po Box 770247
City, St. Zip Steamboat Springs Co 80477
Phone ( )

3. WELL LOCATION AS DRILLED: SE 1/4 ____ 1/4, Sec. 20 Twp. 5 N, Range 85 W
DISTANCES FROM SEC. LINES:
____ ft. from ____ Sec. line, and ____ ft. from ____ Sec. line. OR
(north or south) (east or west)
SUBDIVISION: ____ LOT ____ BLOCK ____ FILING(UNIT) ____
STREET ADDRESS AT WELL LOCATION:

4. GROUND SURFACE ELEVATION ____ ft. DRILLING METHOD Rotary AiR
DATE COMPLETED May 24 1994. TOTAL DEPTH 460 ft. DEPTH COMPLETED 460 ft.

5. GEOLOGIC LOG:

| Depth | Description of Material (Type, Size, Color, Water Location) |
|---|---|
| 0-3 | TS |
| 3-86 | Brown Sandy shale |
| 86-157 | Grey sandy shale |
| 157-243 | Grey Shale |
| 243-321 | Grey sandy shale |
| 321-390 | Grey shale |
| 390-442 | Grey SS |
| 442-460 | Grey shale |
| | Water 400-440 |

DP-3 Geologic Log:
000 - 003 feet: Toposoil
003 - 086 feet: Brown Sandy Shale
086 - 157 feet: Grey Sandy Shale
157 - 243 feet: Grey Shale
243 - 321 feet: Grey Sandy Shale
321 - 390 feet: Grey Shale
390 - 442 feet: Grey Sandstone
442 - 460 feet: Grey Shale

Water: 400 - 440 feet

REMARKS:

6. HOLE DIAM. (in.)

| HOLE DIAM. (in.) | From (ft) | To (ft) |
|---|---|---|
| 12 1/4 | 0 | 20 |
| 7 7/8 | 20 | 460 |

7. PLAIN CASING

| OD (in) | Kind | Wall Size | From(ft) | To(ft) |
|---|---|---|---|---|
| 8 5/8 | Steel | .250 | +1 | 19 |
| 4 1/2 | PVC | sch 40 | +1 | 400 |
| 4 1/2 | PVC | sch 40 | 440 | 460 |

PERF. CASING: Screen Slot Size:

| OD (in) | Kind | Wall Size | From(ft) | To(ft) |
|---|---|---|---|---|
| 4 1/2 | PVC | sch 40 | 400 | 440 |

8. FILTER PACK:
Material washed Rock
Size 3/8
Interval 22 - 460

9. PACKER PLACEMENT:
Type
Depth

10. GROUTING RECORD:

| Material | Amount | Density | Interval | Placement |
|---|---|---|---|---|
| Cement | 4 | 6-1 | 0-19 | poured |
| Cement | 3 | 6-1 | 8-22 | |

11. DISINFECTION: Type HTH Amt. Used 3 oz

12. WELL TEST DATA: ☐ Check box if Test Data is submitted on Supplemental Form.
TESTING METHOD Bailer
Static Level 35 ft. Date/Time measured May 24 1994, Production Rate 14 gpm.
Pumping level 240 ft. Date/Time measured May 24 1994, Test length (hrs.) 2 HRS
Remarks

13. I have read the statements made herein and know the contents thereof, and that they are true to my knowledge. [Pursuant to Section 24-4-104 (13)(a) C.R.S., the making of false statements herein constitutes perjury in the second degree and is punishable as a class 1 misdemeanor.]

CONTRACTOR Western American Drilling Phone (303) 824-9641 Lic. No. 1213
Mailing Address 96157 E. Hwy 40 Craig Co 81625

| Name/Title (Please type or print) | Signature | Date |
|---|---|---|
| Dan Pankey Driller | Dan Pankey | June 8 1994 |

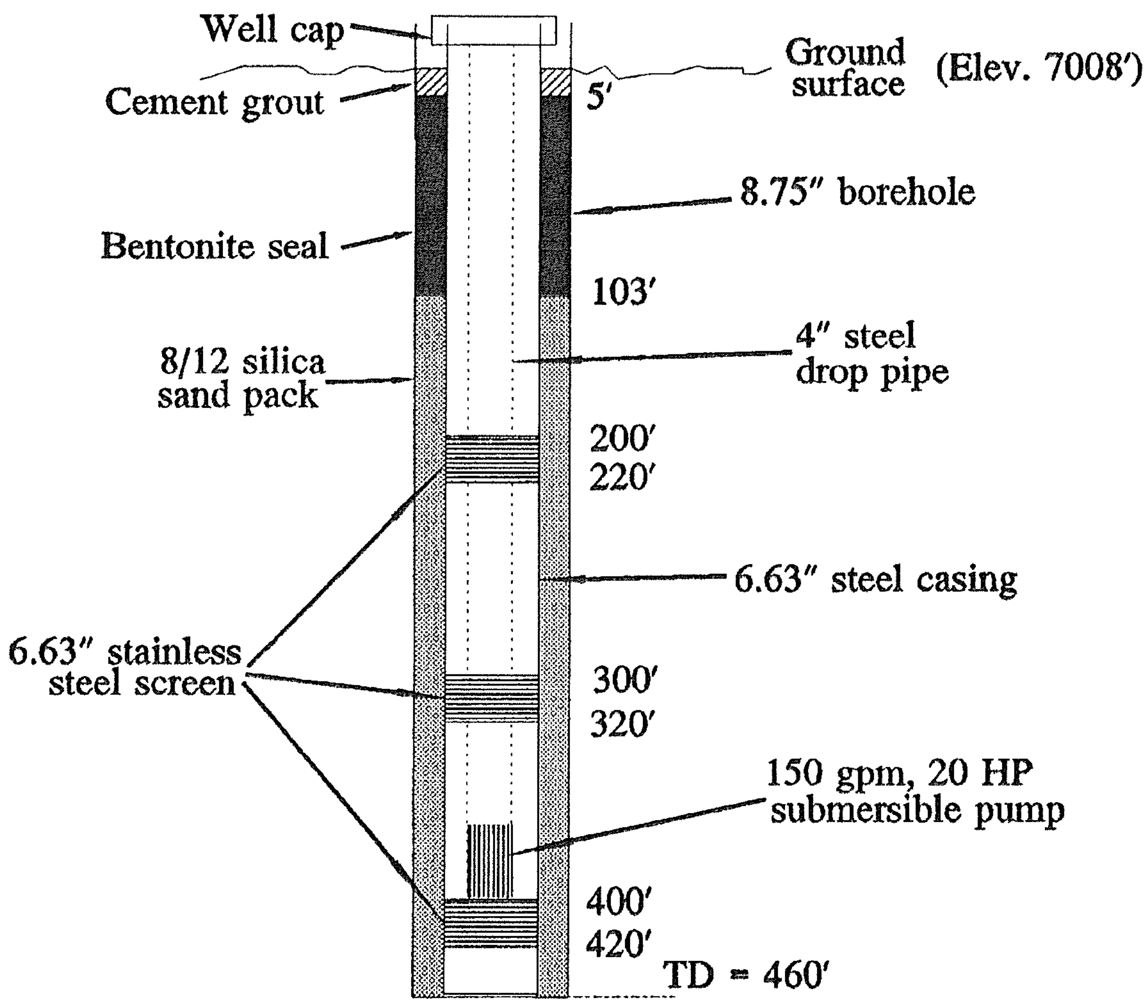



**Figure 3**: Well DP-4 completion diagram.

# WELL CONSTRUCTION AND TEST REPORT
STATE OF COLORADO, OFFICE OF THE STATE ENGINEER

BIG WELL (DP #4)

WELL PERMIT NUMBER: MH-22854

NAME(S): JOHN R. ADAMS S-TRUST-1991
Mailing Address: P.O. Box 773457
City, St. Zip: Steamboat Springs Co 80477
Phone (303) 879-7310

WELL LOCATION AS DRILLED: SE 1/4 SW 1/4, Sec. 20 Twp. 5 N, Range 85 W

DISTANCES FROM SEC. LINES:
632 ft. from SOUTH (north or south) Sec. line, and 1374 ft. from WEST (east or west) Sec. line. OR

SUBDIVISION: DEERWOOD PARK LOT 18 BLOCK 1 FILING(UNIT) 1

STREET ADDRESS AT WELL LOCATION: N/A

GROUND SURFACE ELEVATION 7008.4 ft. DRILLING METHOD Rotary Air

DATE COMPLETED MAY 31, 1994. TOTAL DEPTH 460 ft. DEPTH COMPLETED 460 ft.

## GEOLOGIC LOG:

Depth / Description of Material (Type, Size, Color, Water Location)

-200 - Grey Sandy Shale
-220 - Grey SS
-301 - Grey Sandy Shale
-327 - Grey SS
-404 - Grey Sandy Shale
-419 - Grey SS
- Grey Sandy Shale

Water 432'

DP-4 Geologic Log from Adrian Brown:

| | | |
|---|---|---|
| 000 - 200 feet: | Grey Sandy Shale | |
| 200 - 220 feet: | Grey Sandstone | water |
| 220 - 301 feet: | Grey Sandy Shale | |
| 301 - 329 feet: | Grey Sandstone | water |
| 329 - 404 feet: | Grey Sandy Shale | |
| 404 - 419 feet: | Grey Sandstone | water |
| 419 - 460 feet: | Grey Sandy Shale | |

REMARKS:

## 6. HOLE DIAM. (in.)

| HOLE DIAM. (in.) | From (ft) | To (ft) |
|---|---|---|
| 12 1/4 | 0 | 19 |
| 8 3/4 | 19 | 460 |

## 7. PLAIN CASING

| OD (in) | Kind | Wall Size | From(ft) | To(ft) |
|---|---|---|---|---|
| 10" | Steel | .250 | +1 | 19 |
| 6 5/8 | Steel | .250 | +1 | 200 |
| | | | 220 | 300 |
| | | | 320 | 400 |
| | | | ~~420~~ | ~~460~~ |

PERF. CASING: Screen Slot Size: .20

| OD (in) | Kind | Wall Size | From(ft) | To(ft) |
|---|---|---|---|---|
| 6 5/8 | Stainless | sch 40 | 200 | 220 |
| " | " | " | 300 | 320 |
| " | " | | 400 | 420 |

## 8. FILTER PACK:
Material: Silica Sand
Size: 8-12
Interval: 103-460

## 9. PACKER PLACEMENT:
Type:
Depth:

## 10. GROUTING RECORD:

| Material | Amount | Density | Interval | Placement |
|---|---|---|---|---|
| Cement | 7 SKS | 6-1 | 0-20' | poured |
| Pellets | 10 buckets | | 5-103' | poured |
| Cement | 1 SK | 6, | 1-5 | poured |

DISINFECTION: Type HTH Amt. Used 4 oz

WELL TEST DATA: ☐ Check box if Test Data is submitted on Supplemental Form.

TESTING METHOD: Flowing

Static Level: Flowing ft. Date/Time measured: May 29 1994, Production Rate 30 gpm.

Pumping level: Flowing ft. Date/Time measured: May 29 1994, Test length (hrs.) 24 HRS

Remarks:

I have read the statements made herein and know the contents thereof, and that they are true to my knowledge. [Pursuant to Section 24-4-104 (13)(a) C.R.S., the making of false statements herein constitutes perjury in the second degree and is punishable as a class 1 misdemeanor.]

CONTRACTOR: Western Associates Drilling Phone (303) 824-4641 Lic. No. 1203

Mailing Address: 96197 E. Hwy 40 Craig Co 81625

Name/Title (Please type or print) | Signature | Date