Climax Molybdenum
A Freeport-McMoRan Company

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Highway 91 - Fremont Pass
Climax, CO 80429
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Sent by Certified Mail

May 4, 2012

Mr. Eric Scott
Environmental Protection Specialist
Division of Reclamation, Mining and Safety
Department of Natural Resources
1313 Sherman St. Room 215
Denver, Colorado 80203

RE: Conceptual Hydrogeological Model and Proposed New Groundwater Monitoring Well Locations, Climax Mine, Permit No. M-1977-493, Technical Revision 18 - Water Quality Monitoring Plan

Dear Mr. Scott,

Attached please find the April 27, 2012 letter-report from ARCADIS to Climax Molybdenum Company, Climax Mine that describes the conceptual hydrogeological model for the site and recommended new groundwater monitoring well locations. The report was prepared in accordance with the Climax Water Quality Monitoring Plan, included in the Environmental Protection Plan (Technical Revision 18), that stated Climax would conduct a hydrological characterization prior to the 2012 field season to better assess the locations of new monitoring and point of compliance wells.

Climax is prepared to begin scheduling the well construction for the upcoming field season upon your approval of the recommended well locations. Please contact me at 719-486-7584 if you would like to discuss the findings in the report.

Sincerely,

Raymond Lazuk
Environmental Manager

attachment

RECEIVED
MAY 08 2012
Division of Reclamation, Mining & Safety

ARCADIS
Infrastructure · Water · Environment · Buildings

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ENVIRONMENT

Raymond Lazuk
Environmental Manager
Climax Molybdenum Company, Climax Mine
Fremont Pass, Highway 91
Climax, Colorado 80429

Subject
Hydrogeologic Conceptual Model and Proposed Groundwater Monitoring and Compliance Locations at Climax Mine

Date
April 27, 2012

Contact
Paul Williams

Phone
303 231 9115 x 125

Email
paul.williams
@arcadis-us.com

ARCADIS reference
CO001682.0001

Dear Mr. Lazuk:

This letter report was prepared at the request of Climax Molybdenum Company – Climax Mine (Climax) to develop a hydrogeologic conceptual model of the Climax Mine as described in the December 15, 2011 TR-18 adequacy review response letter and Water Quality Monitoring Plan from Climax to the Division of Reclamation, Mining and Safety (DRMS). In those documents, Climax indicated to DRMS that they would develop a hydrogeologic conceptual model of the site to support and justify additional wells recommended by DRMS.

Based on site visits and review of historical documents and monitoring data, ARCADIS U.S. Inc. (ARCADIS) has developed a preliminary hydrogeologic conceptual model of critical areas within the mine site boundaries and identified potential locations for new groundwater wells. A discussion of the data and the interpretations for each of the three drainages within the mine boundary are provided in this correspondence.

The Climax property boundary and the three watershed boundaries are shown on **Figure 1.** A list of tables and figures included with this correspondence is provided at the end of the document.

Arkansas River Drainage

The drainage for the Arkansas River (Arkansas drainage) is located south of the Climax Mine on the eastern side of the Continental Divide. The boundaries of the Arkansas drainage immediately adjacent to the site are shown on **Figure 2**. Within the Arkansas drainage, Climax maintains water management facilities related to dewatering of the open pit and underground workings (5-Shaft Pump Station), interception and collection of impacted seepage and surface water (Storke Wastewater Pump Station), and water supply for industrial use and potable treatment (Arkansas Well).

There are two groundwater wells within the Arkansas drainage that Climax utilizes to monitor water levels and water quality (**Figure 2**):

- 5-Shaft Monitoring Well (S5MW2): used to monitor the potentiometric surface adjacent to 5-Shaft on the east side of the Mosquito Fault
- Arkansas Monitoring Well (ARWell): used to monitor alluvial groundwater south of Arkansas Pond (also a current POC well)

A third well is located at the foot of the Arkansas Pond (Arkansas Well); however, it is essentially a wet well used for water supply.

Hydrogeology

As shown on **Figure 1**, there is a limited extent of alluvium mapped though the site (Colorado Geological Survey 2003). The unconsolidated material overlying bedrock in the Arkansas drainage is predominantly Pinedale till (Late Pleistocene). There are no site-specific aquifer parameter data available for the Pinedale till; however, glacial tills are typically poorly sorted with a relatively high percentage of clay and silt. It is likely that the Pinedale till exhibits hydraulic conductivity values on the order of 10^{-4} centimeters per second (cm/sec) or lower (Fetter 1980). Residual mine rock materials are stored at the surface in limited areas on the Climax property east of Highway 91; percolation testing conducted in 1967 indicated that these residual materials exhibited a hydraulic conductivity of 2.8×10^{-2} cm/sec and a horizontal hydraulic gradient of 0.02 (Woodward Clyde 1991), as shown on **Figure 3** and **Table 1**. In addition, there are reclaimed gravel pits (west of Highway 91) and alluvial sands and gravels, which are generally limited to above Storke Yard and downgradient of the Arkansas Pond (**Figure 1**).

One of the dominant geologic features in the Arkansas drainage is the Mosquito Fault, which is a normal fault that trends 10 degrees east of north (N10°E) starting south of Leadville and extending north to Mayflower Creek. The width of the Mosquito Fault varies, and it should be envisioned as a fault zone rather than a continuous thin fault plane. The fault does appear to be quite thin in outcrop in the open pit; however, it was inferred to be 300 feet wide during advancement of the Phillipson Tunnel in 1930 and has been documented to be 700 feet wide in other locations. Within the Arkansas drainage, the Mosquito Fault crosses through the Storke area, just east of Highway 91. Bedrock east of the fault is Precambrian Silver Plume Granite and Precambrian Idaho Springs schists and gneisses; bedrock west of the fault is Paleozoic sedimentary rock of the Minturn and Maroon formations (**Figure 3**). The rock mass west of the fault has been down-dropped thousands of feet. In the vicinity of Climax Mine, the fault dips at 70° and the strike is to the northeast. The Mosquito Fault is generally assumed to be a barrier to east-west bedrock groundwater flow due to fault gouge. However, there is some evidence to suggest that the Mosquito fault transmits water relatively well along strike through brecciated zones within the fault zone.[1]

Figures 3 and **4** depict conceptual cross-sections of the Arkansas drainage along the drainage axis and perpendicular to the drainage axis, respectively. The conceptual cross-section on **Figure 3** is transect A – A' on **Figure 1**; the conceptual cross section on **Figure 4** is transect H – H'.

The 5-Shaft Pump Station controls the level of water in the underground workings, the open pit, and the collapsed block cave zone on the eastern side of the Mosquito Fault. Climax and DRMS have agreed previously that if the water level is kept below the elevation of the Mosquito Fault subcrop, impacted groundwater will not move west across the fault; S5MW2 was installed adjacent to 5-Shaft to monitor the water level on the east side of the fault.

The Precambrian rock mass east of the Mosquito Fault is igneous and metamorphic and likely to have a low bulk transmissivity as a whole, except in the vicinity of the open pit. It is likely that the majority of the movement through undisturbed Precambrian rock is through fracture flow, and the storativity is probably quite low. Packer testing completed in these units at the Henderson Mill indicated bulk hydraulic conductivity values of 3.6×10^{-5} cm/sec. Hydrogeologic data from the Paleozoic units are discussed in further detail in the following sections of the report.

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[1] Data compiled from the driving of an adit (Phillipson Tunnel) to the east across the fault zone in 1930 indicated flow began after the adit penetrated an 18 inch gouge seam into shattered granite on June 15, 1930. Flow slowly increased to 200 gallons per minute (gpm) in mid-August and then a step increase to 500 gpm occurred after crossing a single water bearing fracture. Flows from the adit reached 750 gpm on October 2, 1930 and then tapered off to 475 gpm over the next three months. The Phillipson Tunnel produced over 117 million gallons of water between the August 1 and December 31, 1930.

However, the sedimentary units are generally more transmissive than the undisturbed Precambrian units east of the Mosquito Fault.

The predominant movement of water in the Arkansas drainage is surface runoff and westerly groundwater discharge through the Pinedale till. Other than runoff from the lower half of Ceresco Ridge and the Storke Yard in the vicinity of 5-Shaft, the majority of surface runoff reports to the East Fork Arkansas River and Arkansas Pond. It is likely that groundwater from the till upgradient of the Arkansas Pond also discharges to the pond. Shallow groundwater flow is inferred with the contours provided on **Figure 2.**

Points of Compliance and Internal Monitoring Locations

In addition to the existing ARWell point of compliance (POC) to monitor shallow groundwater, ARCADIS agrees with the DRMS recommendation that Climax construct a bedrock monitoring well adjacent to ARWell to monitor the bedrock and serve as an additional POC location (**Figure 5**).

ARCADIS also agrees with the DRMS recommendation for a shallow/deep well pair on the western side of the Mosquito Fault and upgradient of the Arkansas Pond as an internal location for monitoring groundwater quality downgradient of 5-Shaft and the Storke Yard. This monitoring location will confirm the ability of the Mosquito Fault to act as a groundwater barrier, and further characterize the hydrologic and chemical characteristics of the Pinedale till and underlying bedrock (**Figure 5**).

Eagle River Drainage

The drainage for the East Fork Eagle River (Eagle drainage) is on the west edge of the site downgradient of 1 Dam, on the western side of the Continental Divide **(Figure 6).** Climax operates active water management facilities within the Eagle drainage. These facilities include storage of process water (Robinson Lake), collection and transport of impacted seepage (Tim's Pond, Warren's Pump Station, and the Robinson Lake Seepage Collection system and cutoff wall), and interception of surface runoff (Chalk Mountain Interceptor) above mine facilities. Unimpacted runoff in the Chalk Mountain Interceptor system is directed either to the Eagle Park Reservoir (a reclaimed oxide tailings storage facility [TSF] that was later sold to private interests) or to the East Fork Eagle River. A small amount of seepage from the Eagle Park Reservoir dam (4 Dam) also is collected and pumped up to Robinson Lake.

There are six wells within the Eagle drainage (**Figure 6**):

- Eagle Valley Monitoring Well (EVMW): older well used historically to monitor alluvial groundwater upgradient of the Eagle Park Reservoir and downgradient of the Robinson Lake Seepage Collection system
- EVMW-1S and EVMW-1D: a new shallow/deep well pair constructed in 2011 approximately 20 feet upgradient of EVMW to replace EVMW and monitor alluvial and bedrock groundwater downgradient of the cutoff wall
- EVMW-2: a new deep well constructed in 2011 between the north abutment of 1 Dam and Eagle Park Reservoir to monitor bedrock groundwater
- EVMW-3S and EVMW-3D: a new shallow/deep well pair constructed in 2011 near the site boundary adjacent to the East Fork Pumping Station upgradient of the Eagle River to monitor alluvial and bedrock groundwater and provide a property boundary POC location in the Eagle drainage

Hydrogeology

The unconsolidated material overlying bedrock in the Eagle drainage is predominantly the low hydraulic conductivity Pinedale till (Late Pleistocene), although there may be some alluvium present. In addition, there is a former gravel quarry above Eagle Park Reservoir used to provide material to construct 4 Dam (**Figure 1**).

Bedrock in the Eagle drainage is predominantly the Minturn Formation (Middle Pennsylvanian), intruded by Tertiary quartz monzonite. Field packer tests conducted in the Minturn Formation indicate an average hydraulic conductivity of 4.6×10^{-4} cm/sec and ranges from 0 to 2.8×10^{-3} cm/sec, generally decreasing with depth (Kumar 1994, as quoted in Tetra Tech 2011). **Figures 7** and **8** depict conceptual cross-sections of the Eagle drainage along the drainage axis and perpendicular to the drainage axis, respectively. The conceptual cross-section on **Figure 7** is transect C – C' on **Figure 1**; the conceptual cross section on **Figure 8** is transect D – D'.

Recovery data recorded during development of the new EVMW wells suggests that the till at EVMW-1S is the most transmissive unit, yielding about 1.5 gpm during development. EVMW-1D, EVMW-3S and EVMW-3D yielded approximately 0.15 gpm during development. EVMW-2 yielded about 0.5 gpm from a screened interval that is 145 feet in length.

Accordingly, the predominant movement of groundwater in the Eagle drainage is westerly through the Pinedale till and other unconsolidated strata, as shown by the inferred shallow groundwater contours provided on **Figure 6.** Water levels in the well pair EVMW-1S and -1D indicate the potential existence of an upward gradient from bedrock to till (**Figure 8**), but well casing elevation surveys and monitoring will be required to confirm this observation. Given the steep topography and the contrast in transmissivity between the bedrock and alluvium, it is likely that groundwater in the bedrock discharges to the till and alluvium along the axis of the drainage, as suggested on **Figure 7**. Shallow bedrock flow direction is inferred by the shallow groundwater contours provided on **Figure 6**.

Points of Compliance and Internal Monitoring Locations

The new well pair EVMW-3S and EVMW-3D is near the downgradient site boundary and is currently being used as a boundary POC location. DRMS requested an additional POC location upgradient of Eagle Park Reservoir. Based on the site conceptual hydrogeology, and available site access, a proposed new POC location is shown on **Figure 9**. If sufficient saturated unconsolidated material exists in the area, a shallow and deep well pair would be constructed. However, reconnaissance of the area suggests that the POC location is likely to only encounter groundwater in the bedrock, and therefore only a bedrock POC well is envisioned. Also, the topography of the drainage below the existing EVMW-1S/D location is challenging, and final siting of the wells will be dependent upon where a drilling rig can access.

New wells EVMW-1S, EVMW-1D, and EVMW-2 provide good internal groundwater monitoring locations to detect potential changes in groundwater quality upgradient of the new proposed POC well. In addition, a continuation of the ongoing seeps and springs monitoring program surrounding the gravel pit area above Eagle Park Reservoir is encouraged to help characterize shallow groundwater quality and detect potential changes in water quality.

McNulty Gulch (Tenmile Creek Drainage)

McNulty Gulch is a small sub-basin within the drainage of Tenmile Creek (Tenmile drainage) located directly east of Robinson TSF near the center of the site. It is also immediately downgradient of the McNulty Overburden Storage Facility (OSF). Most surface water from the head of the drainage and from the south side of the drainage is captured by the McNulty Demand Side Management (DSM) interceptor trench, which reports to the Eastside Tailings Delivery Line (ETDL) or East Side Channel.

Unimpacted surface water from the north side is captured by the East Interceptor system, which reports to Clinton Reservoir and ultimately Tenmile Creek

There is one water supply well completed downgradient of McNulty Gulch just south of the Sludge Densification Plant (SDP). This well is called the McNulty Well, and is a bedrock well used when additional water is needed for the Lime Station and SDP; it is also referred to as the "Lime Slaking Well". The McNulty Well was completed in a granitic sill and is sampled intermittently. In addition, five nested piezometers were installed in McNulty Gulch in exploratory borings in September 2005, as shown on **Figure 10** (Steffens 2005). These piezometers (1A, 1B, 1C; 2A, 2B, 2C; 3A, 3B; 4A and 4B, plus the interceptor ditch) were sampled twice in May and November 2006. The current condition of these piezometers is unknown.

Hydrogeology

Unconsolidated materials in McNulty Gulch include the waste rock in McNulty OSF at the head of the drainage, with Pinedale till covering most of the area (**Figure 1**). Bedrock in McNulty Gulch is predominantly the Minturn Formation with some Tertiary intrusions of quartz monzonite. **Figures 11** and **12** depict conceptual cross-sections of McNulty Gulch along the drainage axis and perpendicular to the drainage axis, respectively. Previous measurements of the piezometers indicate the existence of an upward gradient on the southern side of the drainage, from bedrock to the unconsolidated units (till/alluvium). The conceptual cross-section provided on **Figure 11** is transect B – B' in **Figure 1 and** the conceptual cross section shown on **Figure 12** is transect F – F'.

Estimated hydraulic conductivity values based on packer testing conducted in the exploratory borings in the Minturn Formation averaged 5.7×10^{-5} cm/sec, as indicated in **Table 1**; however, one of the holes did not take any water (Steffens 2005), indicating a very low permeability. Hydraulic conductivity in the granitic sill, as measured from step testing in the McNulty Well, was estimated at 8.9×10^{-4} cm/sec (Titan 1995). Based on water levels in the nested piezometers, two of the bedrock piezometers (1A and 4A) exhibited water levels above ground surface, indicating artesian pressure. The shallow piezometers paired with these wells exhibited lower groundwater levels.

Conceptually, recharge at the head of McNulty Gulch will infiltrate into bedrock, the McNulty OSF and the overlying till in the drainage. Groundwater in the till moves downgradient and either discharges to the surface, where it is collected and treated, or remains in the till until discharging into the Robinson TSF as indicated by the inferred shallow groundwater contours on **Figure 10**. Groundwater in the bedrock may discharge to the till in the drainage as well, as suggested by the upward gradient observed previously. Shallow bedrock groundwater is expected to flow down the gulch and report to the Robinson TSF, as indicated in **Figure 10**. Impacted surface water is captured in the DSM trench and directed to the ETDL or, during spring runoff, reports to the East Side Channel and the SDP.

Points of Compliance and Interior Monitoring Locations

It is assumed that, because McNulty Gulch is in the interior of the site, no POC locations were proposed by DRMS. ARCADIS does not perceive a need to establish a monitoring location in McNulty Gulch. If one or more of the existing piezometers are still functional, they could be converted into permanent monitoring locations (shallow/deep). However, because the conceptual model indicates that shallow groundwater ultimately reports to Robinson TSF, there is no clear justification for monitoring groundwater in McNulty Gulch.

Tenmile Creek Drainage

The majority of the Climax mine site is located in the Tenmile drainage on the eastern side of the Continental Divide (**Figure 1**). The major facilities and infrastructure located within the drainage, including the Robinson, Tenmile, and Mayflower TSFs. Clinton Reservoir is also located at the foot of Clinton Gulch, a tributary to Mayflower Gulch and Tenmile Creek. Like Eagle Park Reservoir, Clinton Reservoir is owned by private interests. The northernmost end of the property, where water from the Climax Mine discharges to Tenmile Creek, is shown in **Figure 13.**

The SDP treats impacted surface water and groundwater collected from numerous locations across the site, including all water that discharges from 5-Shaft and seepage from the TSF dams, which is collected in seepage collection ponds at the toe of each dam. The West Interceptor system and East Interceptor system capture unimpacted runoff above mine facilities and ultimately discharge to Tenmile Creek upgradient of monitoring well GWM-2.

There are two wells within the Tenmile drainage (**Figure 13**):

- GWM-1: monitoring well downgradient of Mayflower TSF and 5 Dam completed in alluvium

- GWM-2: monitoring well downgradient of GWM-1, completed in alluvium (a current POC well)

Hydrogeology

Unconsolidated material in Tenmile drainage consists of alluvium north of the Mayflower TSF, as well as Pinedale till (**Figure 1**), excluding mining-related materials in the TSFs and dams. The depth of the alluvium ranges from 0 to 90 ft in this portion of the drainage.

Bedrock in the Tenmile drainage is Precambrian east of the Mosquito Fault and Paleozoic Minturn Formation west of the fault, which is commonly intruded by Tertiary quartz monzonite. **Figures 14** and **15** depict conceptual cross-sections of the Tenmile drainage along the drainage axis and perpendicular to the drainage axis, respectively. The conceptual cross-section on **Figure 14** is transect E – E' on **Figure 1** and the conceptual cross-section on **Figure 15** is transect G – G'.

Hydraulic parameters were investigated by slug and packer testing during the design and construction of 5 Dam for the Mayflower TSF. The alluvium exhibited hydraulic conductivity values between 2.5×10^{-3} and 8.5×10^{-2} cm/sec. The Pinedale till exhibited hydraulic conductivity values between 2.1×10^{-5} and 1.2×10^{-3} cm/sec. The Minturn Formation in the vicinity of the TSF exhibited hydraulic conductivity values as high as 5.8×10^{-4} cm/sec. The Tertiary intrusive rocks exhibited hydraulic conductivity values between 1.7×10^{-5} and 5.2×10^{-5} cm/sec (Kumar 1994a). A summary of the data is provided in **Table 1**.

A 24-hour constant rate pumping test was performed in the alluvium using GWM-2 (as the pumping well) and two observation wells in October of 2011 (**Figure 13**). Analysis of the pumping test results provided the following hydrogeologic parameters for the alluvium (Kumar 2011):

- Aquifer saturated thickness: 56 ft
- Hydraulic conductivity: 3.4×10^{-3} cm/sec
- Specific yield of well: 3.3 gpm/ft

No change in water levels was recorded in GWM-1 during the test, located approximately 3,730 ft south of GWM-2.

Approximately one mile downgradient of GWM-2, a water gap just south of Spaulding Gulch reportedly forces groundwater to the surface and into Tenmile Creek (Climax 1985). The bedrock outcrop in Tenmile Creek can be seen on the geologic surface map at that location (Colorado Geologic Survey 2003).

Shallow groundwater in the Tenmile drainage upgradient of 5 Dam discharges to the TSFs, and ultimately reports to the Tenmile TSF and Mayflower TSF seepage collection facilities. Below 5 Dam and above GWM-1, shallow groundwater is assumed to occur in the underlying alluvium, till, and shallow bedrock. Groundwater movement through deeper bedrock beneath the Tenmile and Mayflower TSFs may be affected by the abandoned underground workings of the former Kokomo mining district, although the extent to which the workings are connected is unknown Otherwise, groundwater flow is believed to be limited by the low transmissivity of the Paleozoic bedrock in the area.

Groundwater preferentially moves through the alluvium at a rate three orders of magnitude above that of the Paleozoic bedrock beneath. In addition, Tenmile Creek is likely gaining from the toe of Mayflower Dam to the water gap south of the Spaulding Gulch confluence, where the bedrock outcrops to the streambed. Consequently, it is inferred that an upward vertical hydraulic gradient exists and that groundwater in the shallow bedrock discharges into the alluvium. Groundwater in the alluvium is inferred to flow north, parallel to Tenmile Creek. Conceptually, the flow of shallow groundwater near the northern property boundary is shown with the inferred contours provided on **Figure 13**.

Points of Compliance and Internal Monitoring Locations

Existing well GWM-2 is currently used as a site boundary POC well. ARCADIS agrees with the DRMS recommendation to construct a bedrock well adjacent to GWM-2 as an additional POC location (**Figure 16**). This bedrock well will also allow an assessment of the vertical hydraulic gradient at the site boundary.

ARCADIS also concurs with using existing well GWM-1 as an internal monitoring location, and agrees with the DRMS recommendation to construct a bedrock well adjacent to GWM-1 to monitor groundwater in the bedrock at this location and assess vertical gradients.

Summary of Recommendations

The primary purpose of this letter report is to describe a preliminary conceptual hydrogeologic model of the Climax Mine and, based on that model, provide recommendations for additional groundwater monitoring wells and POC locations as recommended by DRMS. Internal groundwater monitoring well and POC well locations are discussed above in the main body of this letter and shown on the attached figures.

ARCADIS appreciates the opportunity to provide these recommendations to Climax. If you have any questions or concerns, please contact us at your earliest convenience.

Sincerely,

ARCADIS U.S., Inc.

Paul Williams
Principal Hydrogeologist

Lee Christoffersen
Environmental Engineer 1

Copies:
Anne Thatcher, ARCADIS

List of Tables

List of Figures

References

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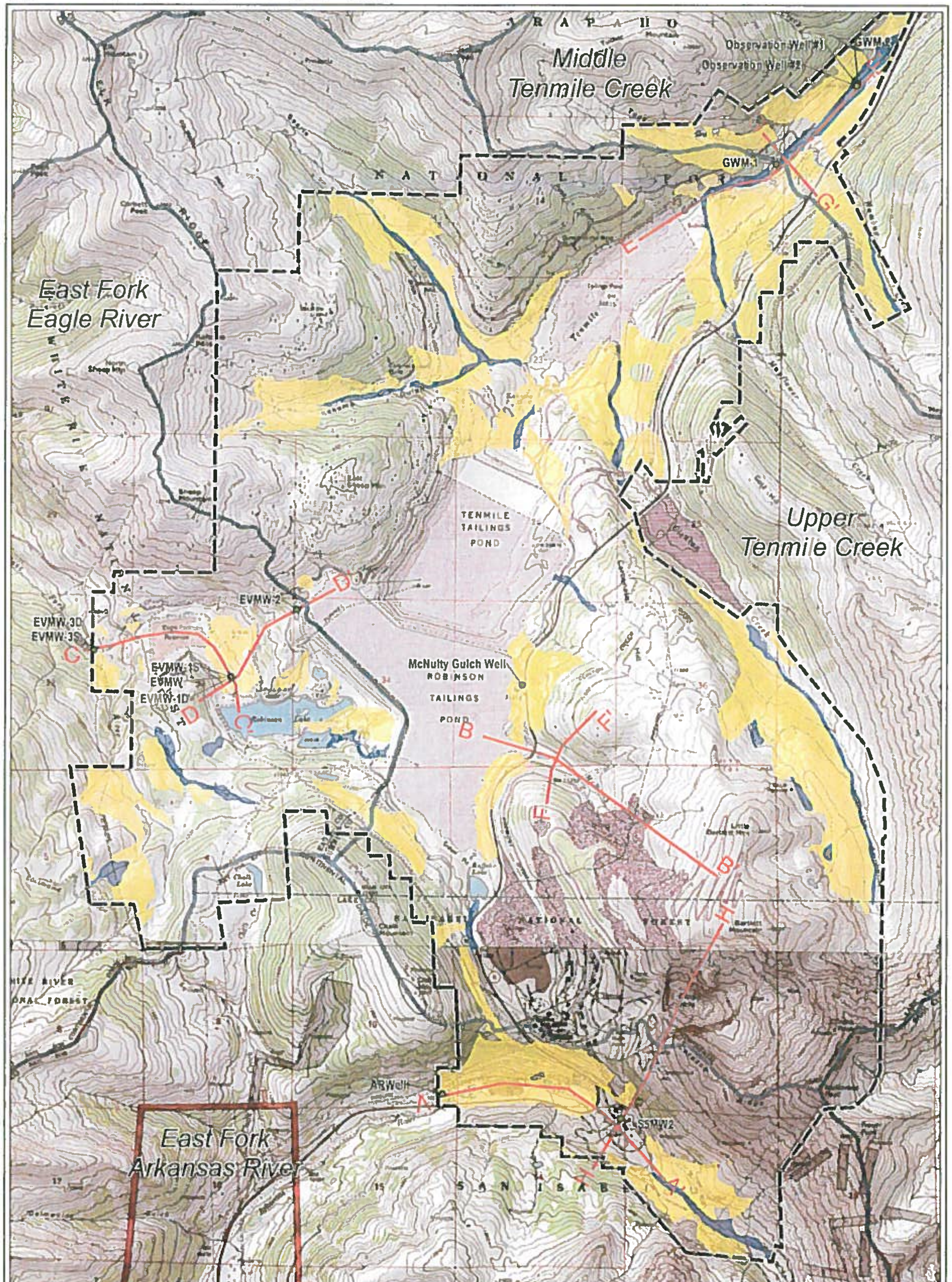
Table 1
Summary of Field-Derived Aquifer Parameters

Drainage	Unit	Unit Notation	Hydraulic Parameters Type	Hydraulic Parameters Value	Hydraulic Parameters Units	Location	Source and Notes	Converted K Values value	Converted K Values units	Converted K Values value	Converted K Values units
Arkansas	Alluvium	Qal	K	80	ft/day	Storke Yard	Percolation Test from 1967 Woodward-Clyde 1991 (GW Monitoring Plan)	5.6E-02	ft/min	2.8E-02	cm/s
Arkansas	Silver Plume Granite		K, avg	3.60E-05	cm/s	Near Henderson Mill	Packer Tests, as qtd. 1991 GW Monitoring Plan	7.1E-05	ft/min	3.6E-05	cm/s
Eagle	Quartz Monzonite	Tqpm	Recovery	1.50	gpm	EVMW-1S	Recovery Rate During Development Tetra-Tech 2011	–	–	–	–
			Recovery	0.15	gpm	EVMW-1D		–	–	–	–
			Recovery	0.50	gpm	EVMW-2		–	–	–	–
			Recovery	0.15	gpm	EVMW-3S		–	–	–	–
			Recovery	0.15	gpm	EVMW-3D		–	–	–	–
Tenmile	Alluvium	Qal	T	525.7 - 549.9	ft^2/day	Pump Test at GW#2 Proposed PDWTP	Pump Test at GW#2 Kumar 2011	–	–	–	–
			K, low	9.4	ft/day			6.5E-03	ft/min	3.3E-03	cm/s
			K, high	9.7	ft/day			6.7E-03	ft/min	3.4E-03	cm/s
			Yield	3.3	gpm/ft			–	–	–	–
			Thickness	36	ft			–	–	–	–
	Alluvium	Qal	K, low	2595	ft/yr	Near 5-Dam	Packer Tests Kumar 1994, as qtd. Tetra Tech 2011	4.9E-03	ft/min	2.5E-03	cm/s
			K, high	88378	ft/yr			1.7E-01	ft/min	8.5E-02	cm/s
	Glacial Till	Qtp	K, low	22	ft/yr	Near 5-Dam		4.2E-05	ft/min	2.1E-05	cm/s
			K, high	1238	ft/yr			2.4E-03	ft/min	1.2E-03	cm/s
	Minturn Fm	IPm	K, low	0	ft/yr	Near 5-Dam		0.0E+00	ft/min	0.0E+00	cm/s
			K, high	596	ft/yr			1.1E-03	ft/min	5.8E-04	cm/s
	Quartz Monzonite	Tqpm	K, low	18	ft/yr	Near 5-Dam		3.4E-05	ft/min	1.7E-05	cm/s
			K, high	54	ft/yr			1.0E-04	ft/min	5.2E-05	cm/s
	Minturn Fm	IPM	Yield, low	3	gpm	Office Well	Well Yield During Installation Curtis Wells 1996	–	–	–	–
			Yield, high	5	gpm			–	–	–	–
McNulty Gulch	Minturn Fm	IPm	K	5.70E-05	cm/s	Boring 1, deepest screen	Packer Test Steffens 2005	1.1E-04	ft/min	5.7E-05	cm/s
			K	8.80E-05	cm/s	Piezometer 2A (deepest)		1.7E-04	ft/min	8.8E-05	cm/s
	Gulch Slope		K	1.6	ft/yr	Test Pits in Gulch	Test Pits from 1963 Woodward 1963	3.0E-06	ft/min	1.5E-06	cm/s
	Gulch Bottom		K	6.6	ft/yr			1.3E-05	ft/min	6.4E-06	cm/s
	Quartz Monzonite	Tqpm	T	802.2	ft^2/day	McNulty Well	Step Drawdown Test Titan calculations 1995	–	–	–	–
			Thickness	320	ft in well			–	–	–	–
			K	2.51	ft/day			1.7E-03	ft/min	8.9E-04	cm/s



LEGEND

- Well
- Cross Section Line
- Project Boundary
- NHD* Watershed Boundary

Geologic Unit

- Qal: alluvium
- Qtp: Pinedale till

* NHD = National Hydrography Dataset

N

0 1,500 3,000 Feet

Basemap
USA Topo Maps, serviced by ESRI ArcGIS Online

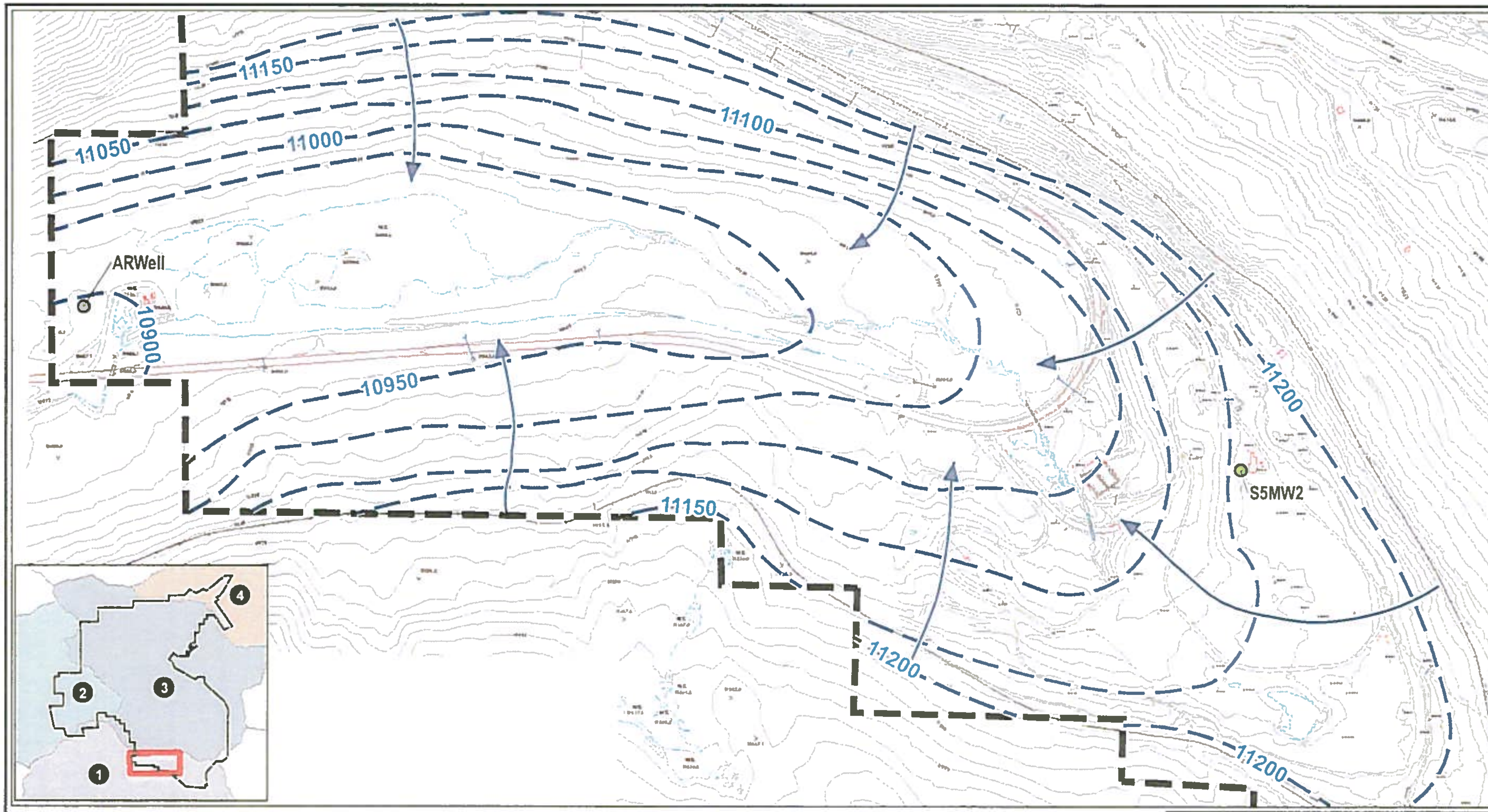
CLIMAX MOLYBDENUM COMPANY
CLIMAX, CO

Hydrogeologic Conceptual Model

SITE MAP WITH PROPERTY AND WATERSHED BOUNDARIES

ARCADIS

FIGURE
1



LEGEND

Well

Project Boundary

Groundwater Flow Path

Shallow Groundwater Elevation Contour (Estimated, in feet above mean sea level)

NHD* Watersheds (Inset Map):

1. East Fork Arkansas River
2. East Fork Eagle River
3. Middle Tenmile Creek
4. Upper Tenmile Creek

* NHD = National Hydrography Dataset

N

0 200 400 600 Feet

Basemap Source: CAD Drawing from Wheeler, 2006

CLIMAX MOLYBDENUM COMPANY
CLIMAX, CO

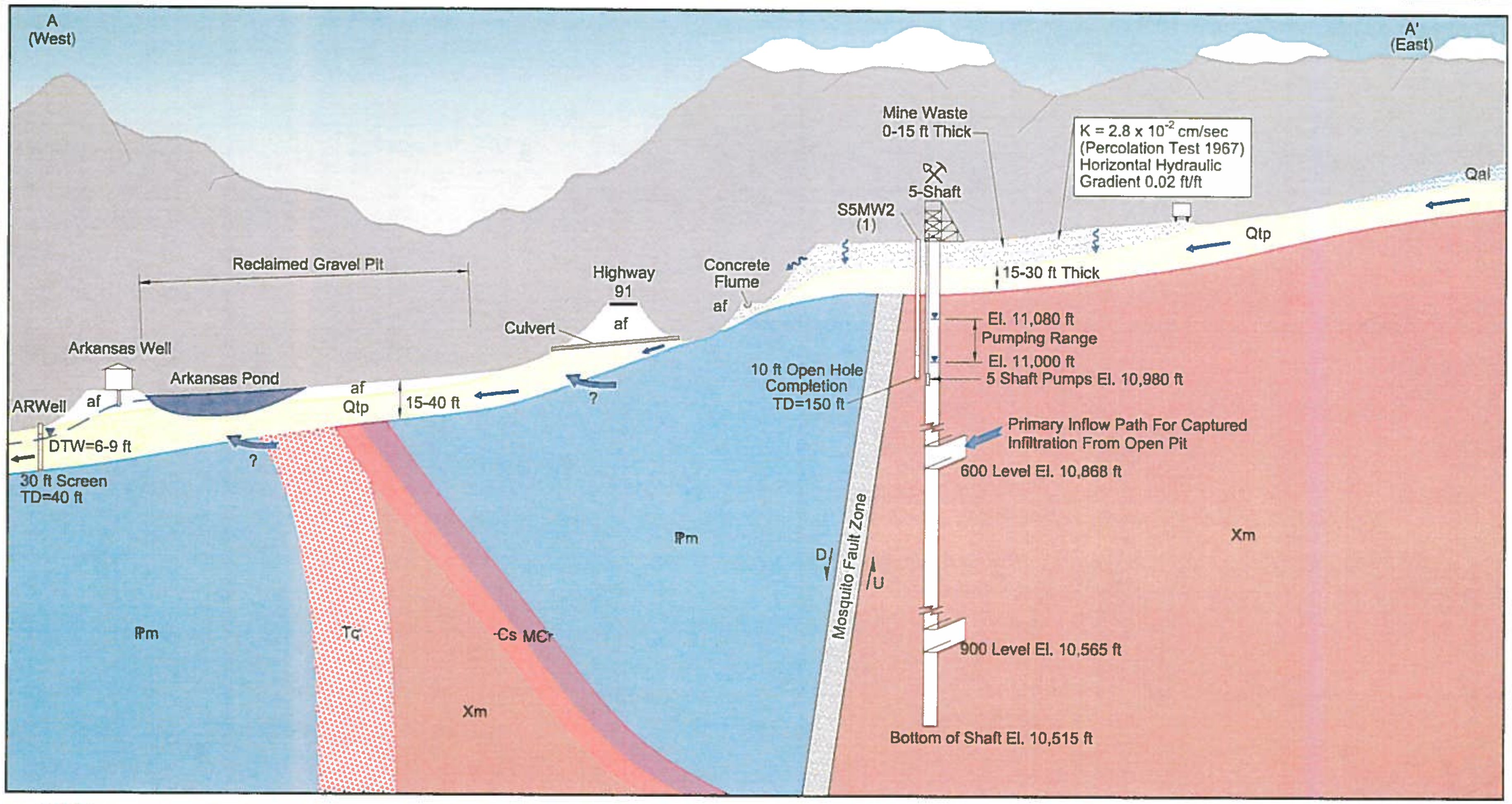
Hydrogeologic Conceptual Model

MAP OF ARKANSAS DRAINAGE AND ESTIMATED POTENTIOMETRIC SURFACE

ARCADIS

FIGURE 2

Path: K:\C001682_Climax\GIS\ArcMap_MXD\HgCM\Figure 2_Map of Arkansas Drainage and Estimated Potentiometric Surface.mxd Date Saved: 4/18/2012 3:22:48 PM User: jchen



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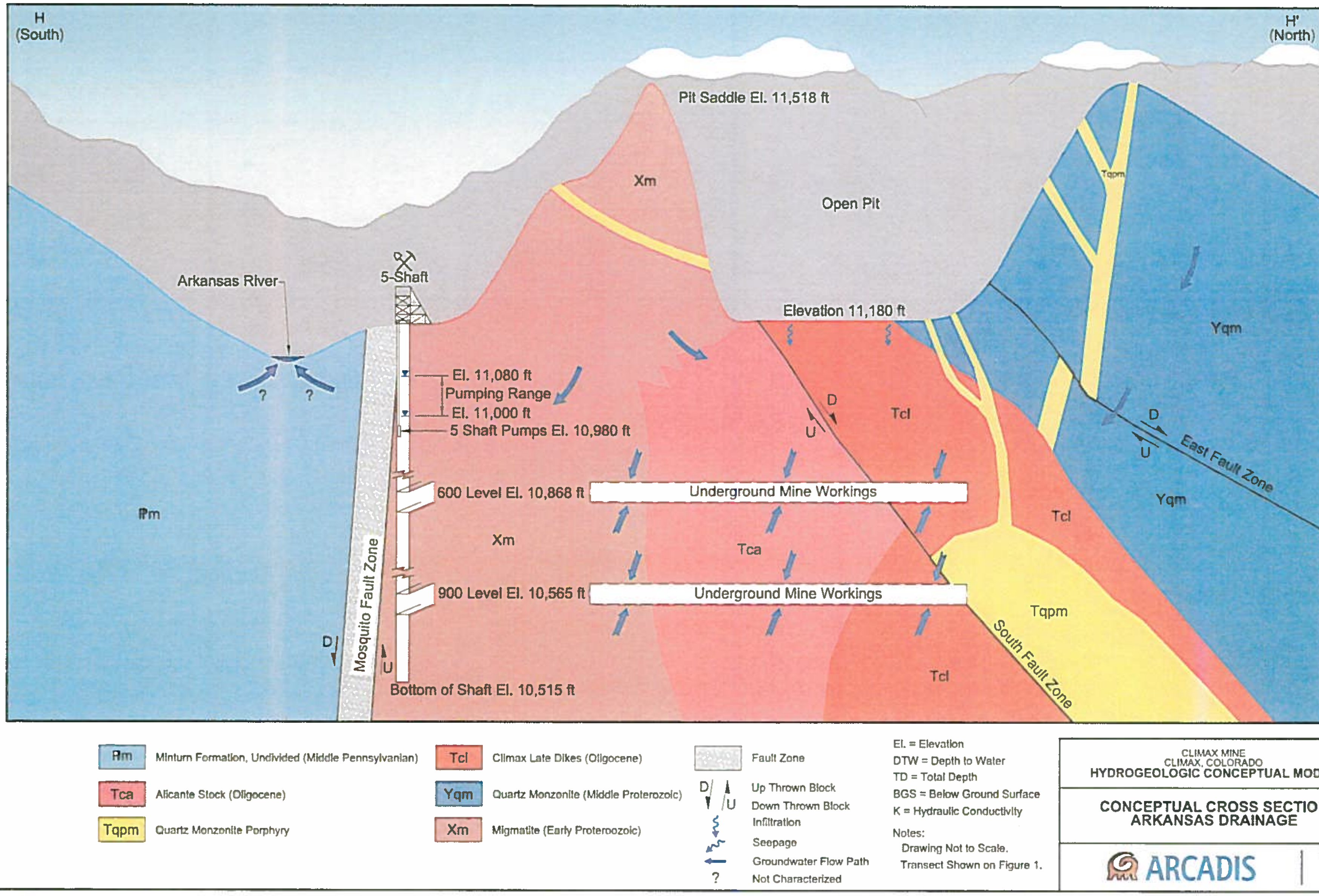
HYDROGEOLOGIC CONCEPTUAL MODEL

CONCEPTUAL CROSS SECTION
ARKANSAS DRAINAGE

ARCADIS

FIGURE 3



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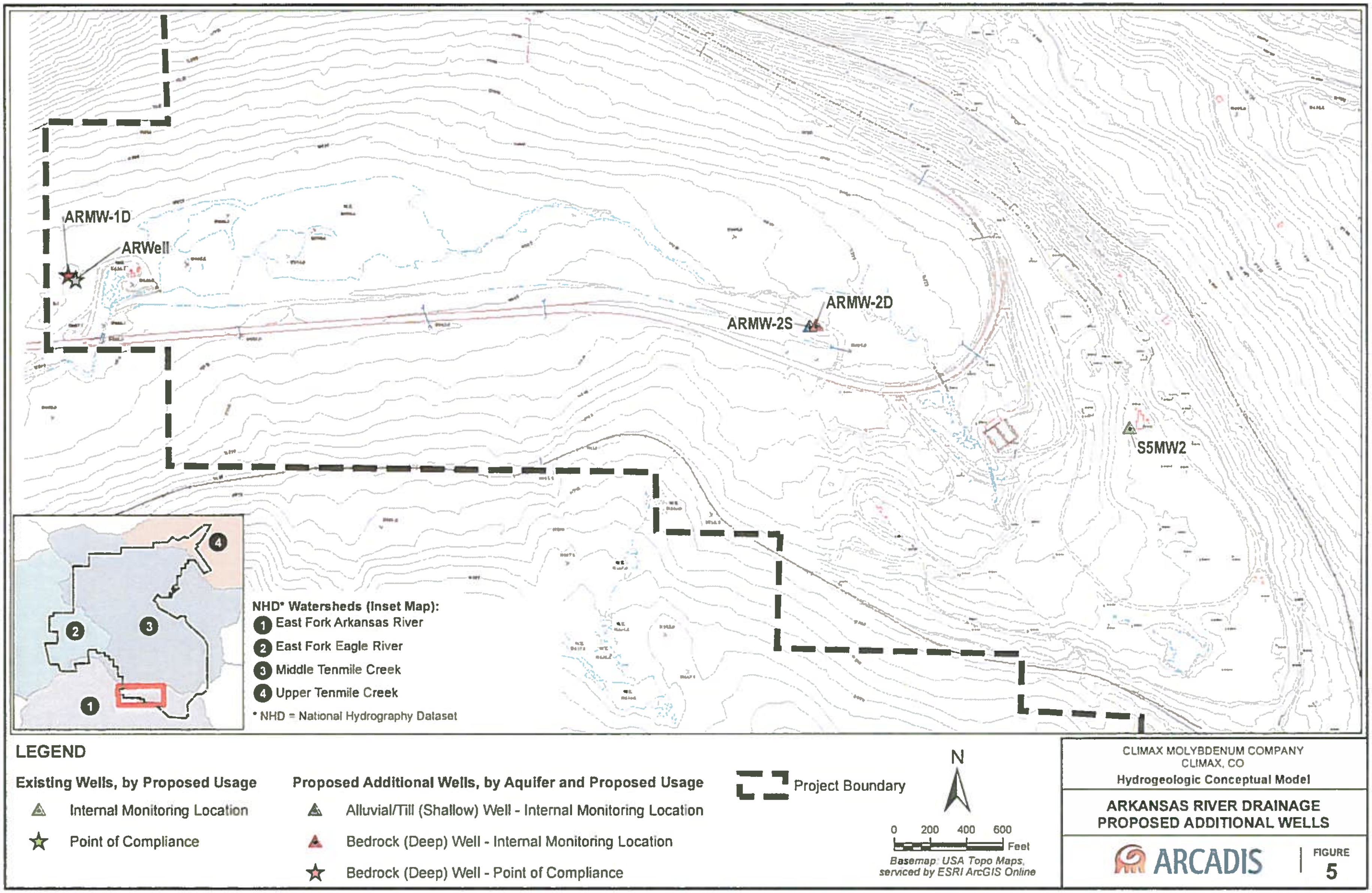
HYDROGEOLOGIC CONCEPTUAL MODEL

CONCEPTUAL CROSS SECTION ARKANSAS DRAINAGE

ARCADIS

FIGURE 4



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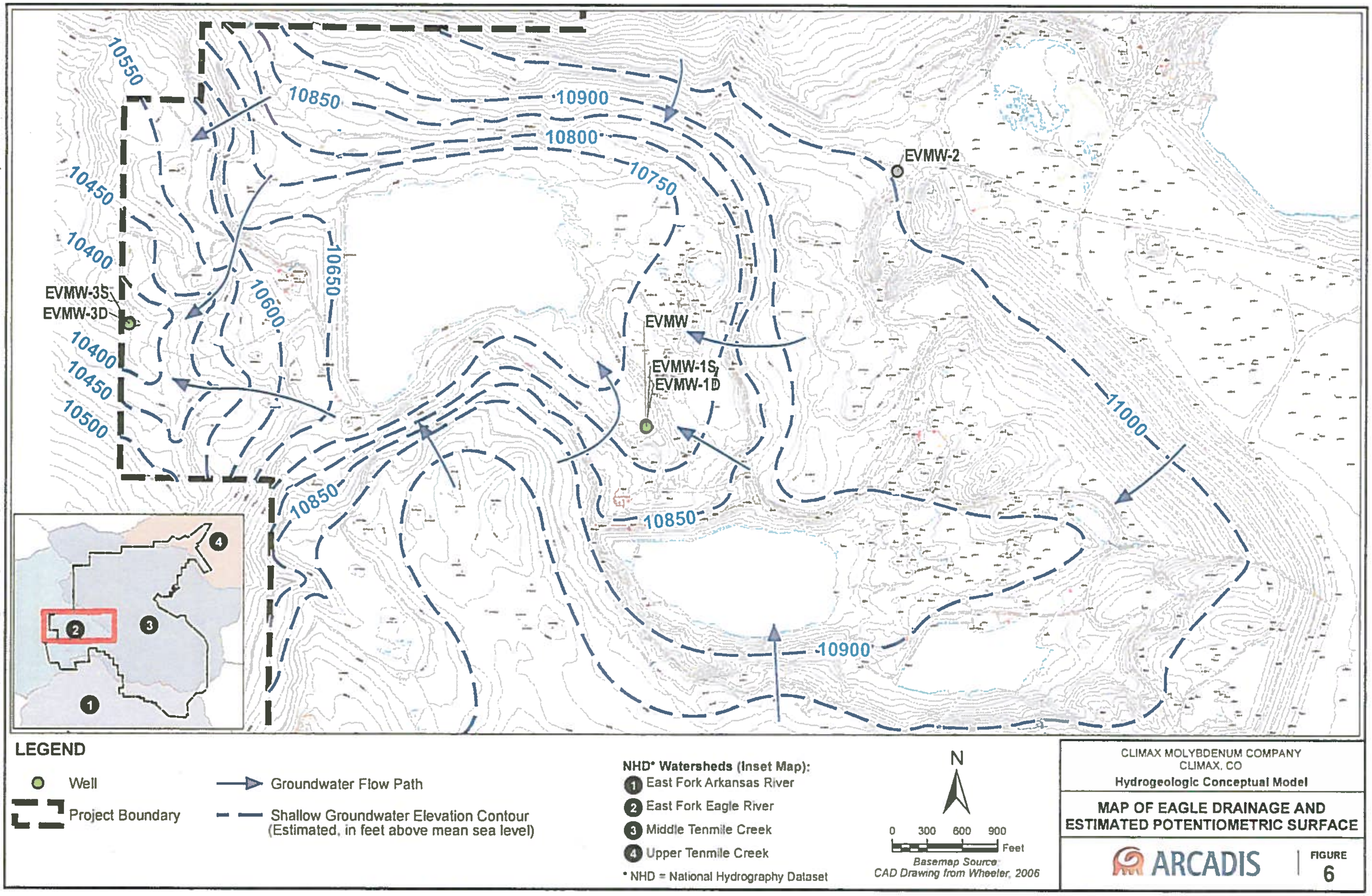
ARKANSAS RIVER DRAINAGE PROPOSED ADDITIONAL WELLS

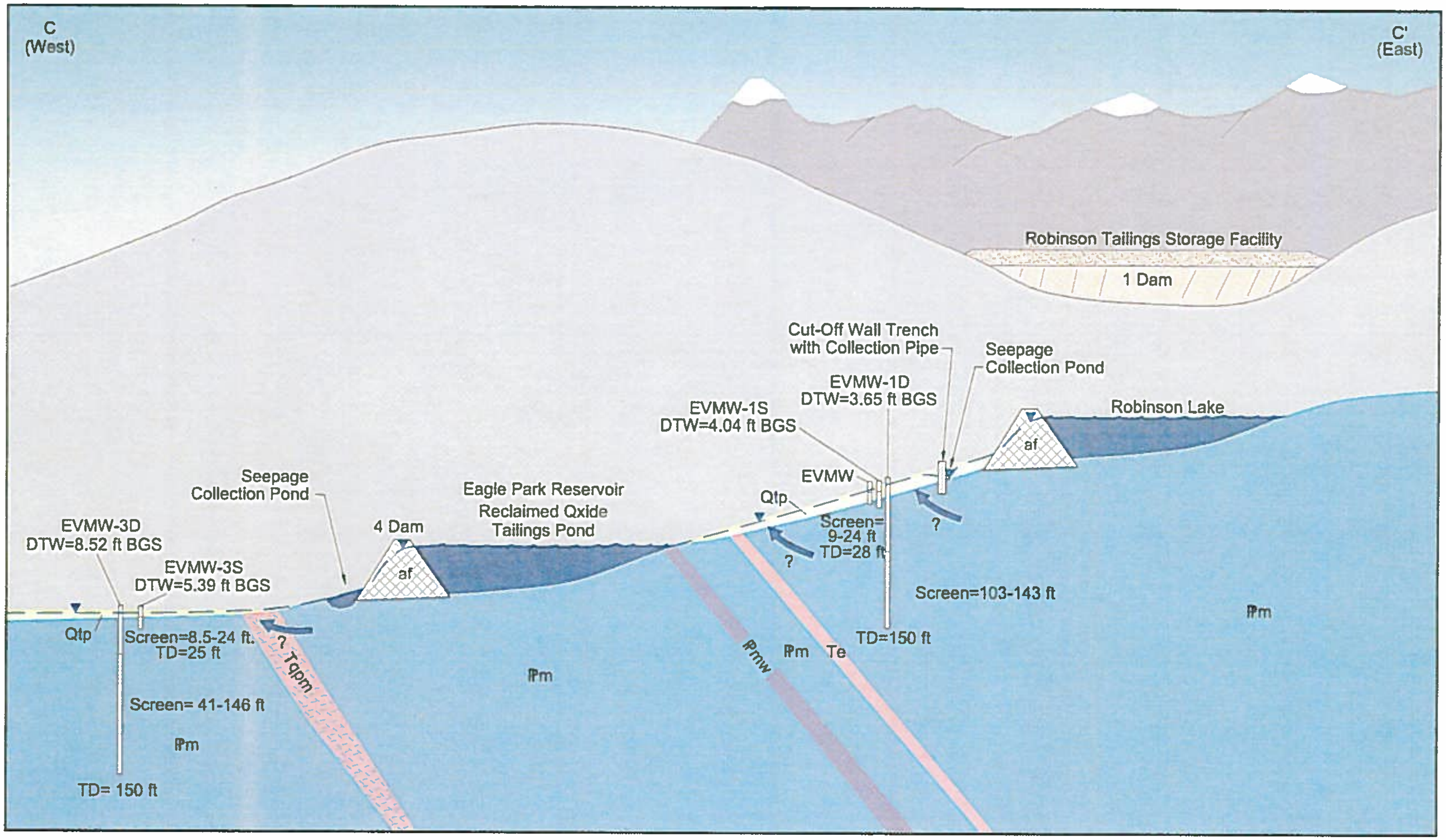
ARCADIS

FIGURE 5

Path: K:\C0001682_Climax\GIS\ArcMap_MXD\HgCM_shortList\Figure 5_Arkansas Drainage Proposed Additional Wells.mxd Date Saved: 4/18/2012 10:58:46 AM User: jchen



Path: K:\CO001682_Climax\GIS\ArcMap_MXD\HgCM_shortList\Figure 6_Map of Eagle River Drainage and Estimated Potentiometric Surface.mxd Date Saved: 4/18/2012 11:08:33 AM User: jchen



af	Artificial Fill	Te	Elk Mountain Porphyry (Eocene)
Pm	Minturn Formation, Undivided (Middle Pennsylvanian)	Tqpm	Quartz Monzonite Porphyry - Megacrystic Variety (Eocene)
Pmw	Wearyman Dolomite Member	Qtp	Pinedale till (late Pleistocene)

- Fault Zone
- D/U: Up Thrown Block / Down Thrown Block
- Infiltration
- Seepage
- Groundwater Flow Path
- ? Not Characterized

El. = Elevation
DTW = Depth to Water
TD = Total Depth
BGS = Below Ground Surface
K = Hydraulic Conductivity

Notes:
Drawing Not to Scale.
Transect Shown on Figure 1.

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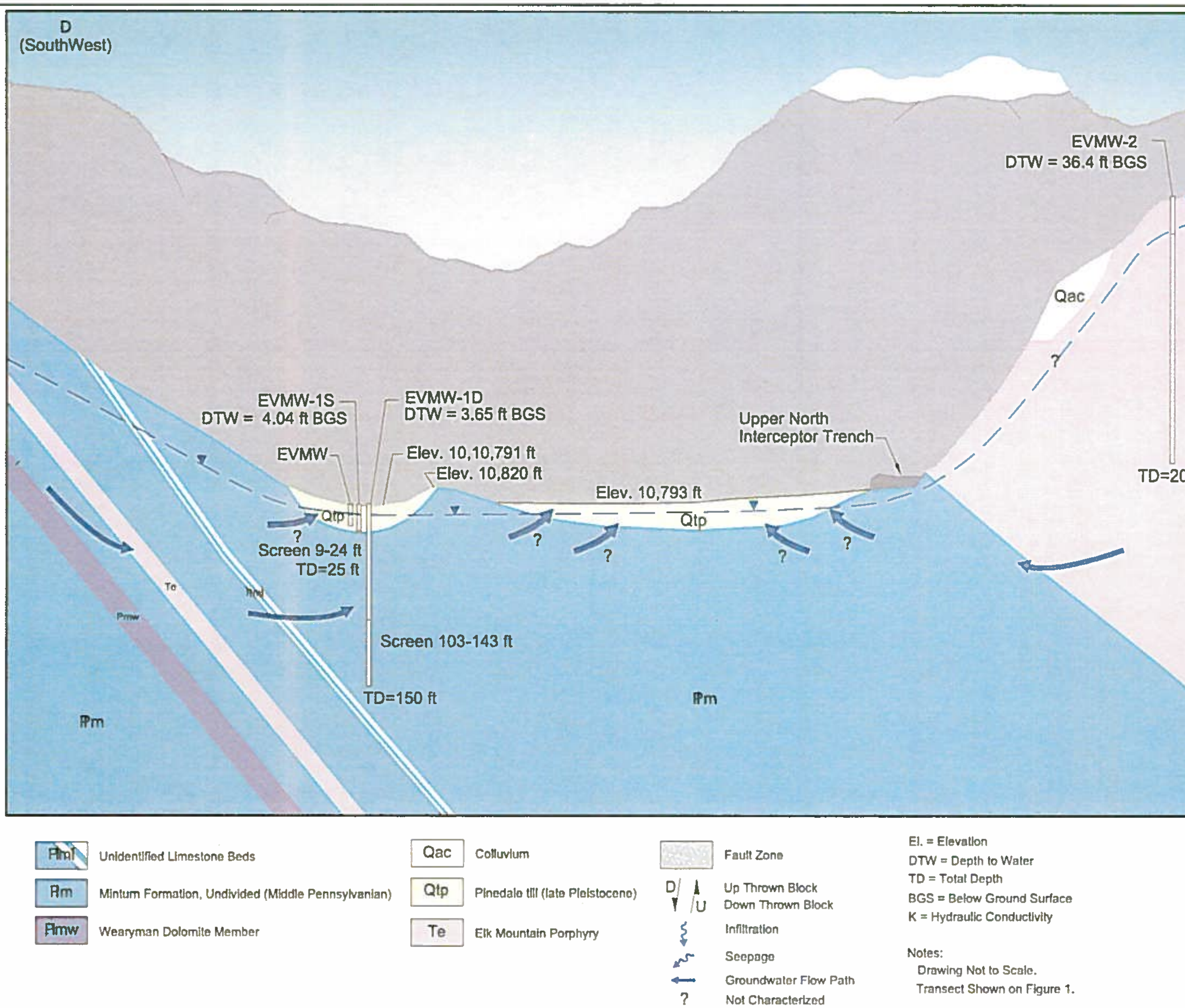
CONCEPTUAL CROSS SECTION
EAGLE VALLEY

ARCADIS

FIGURE 7



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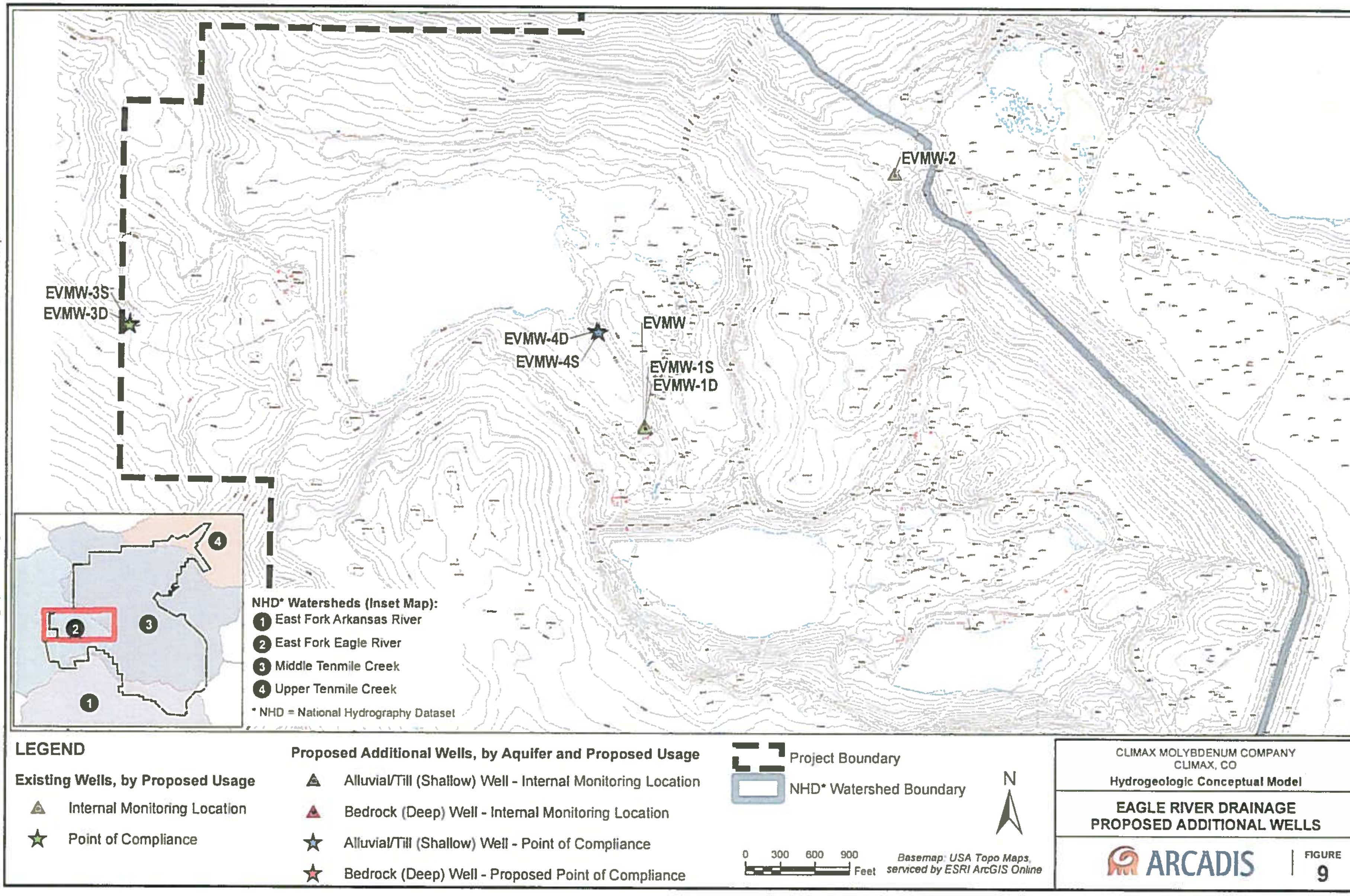
HYDROGEOLOGIC CONCEPTUAL MODEL

CONCEPTUAL CROSS SECTION
EAGLE VALLEY

ARCADIS

FIGURE 8



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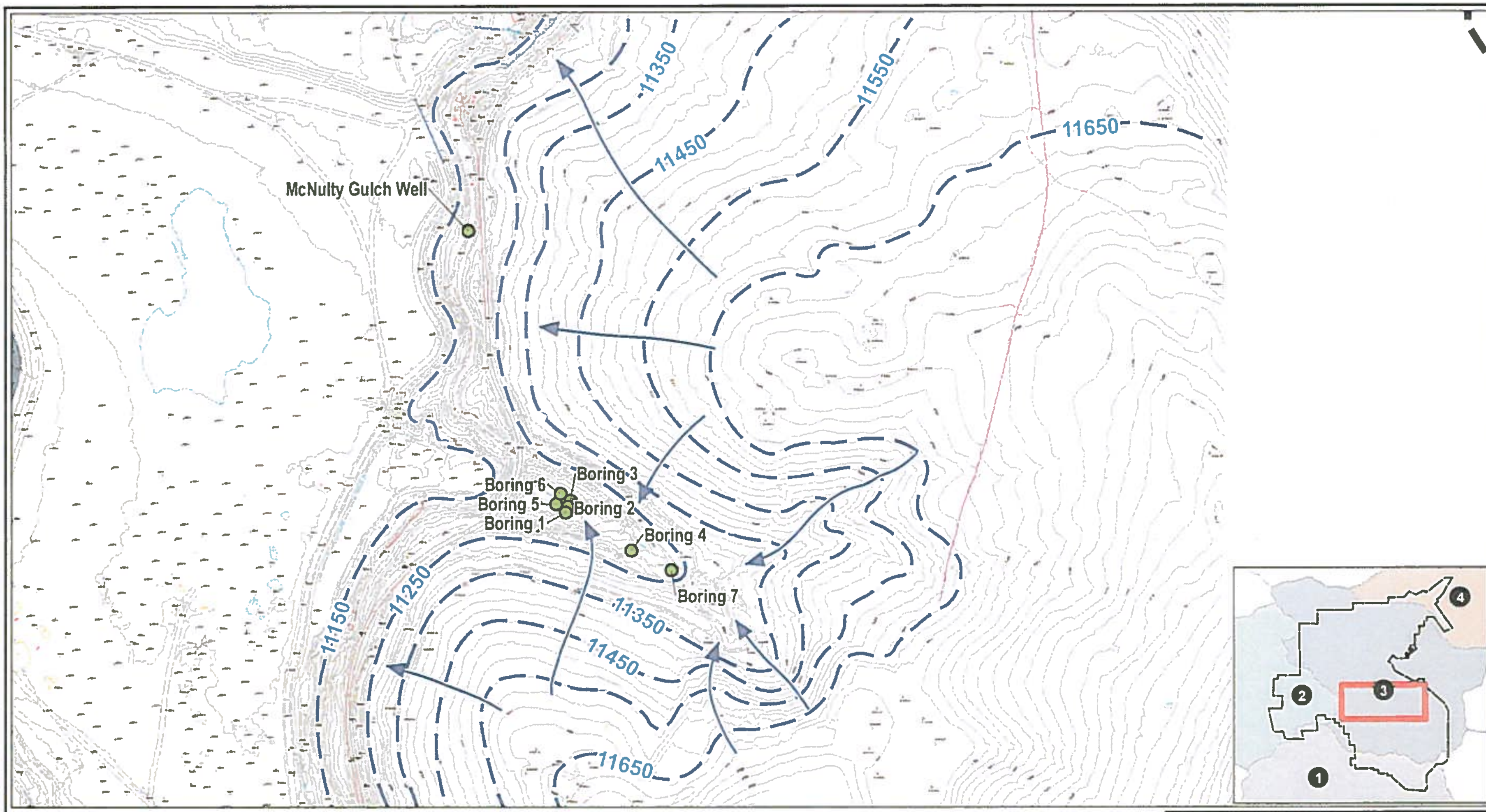
EAGLE RIVER DRAINAGE
PROPOSED ADDITIONAL WELLS

ARCADIS

FIGURE 9

Path: K:\C0001682_Climax\GIS\ArcMap_MXD\HgCM_shortList\Figure 9_Eagle River Drainage Proposed Additional Wells.mxd Date Saved: 4/18/2012 11:07:18 AM User: jchen



LEGEND

Well

Project Boundary

NHD* Watershed Boundary

Groundwater Flow Path

Shallow Groundwater Elevation Contour (Estimated, in feet above mean sea level)

NHD* Watersheds (Inset Map):

1. East Fork Arkansas River
2. East Fork Eagle River
3. Middle Tenmile Creek
4. Upper Tenmile Creek

* NHD = National Hydrography Dataset

N

0 350 700 1,050 Feet

Basemap Source: CAD Drawing from Wheeler, 2006

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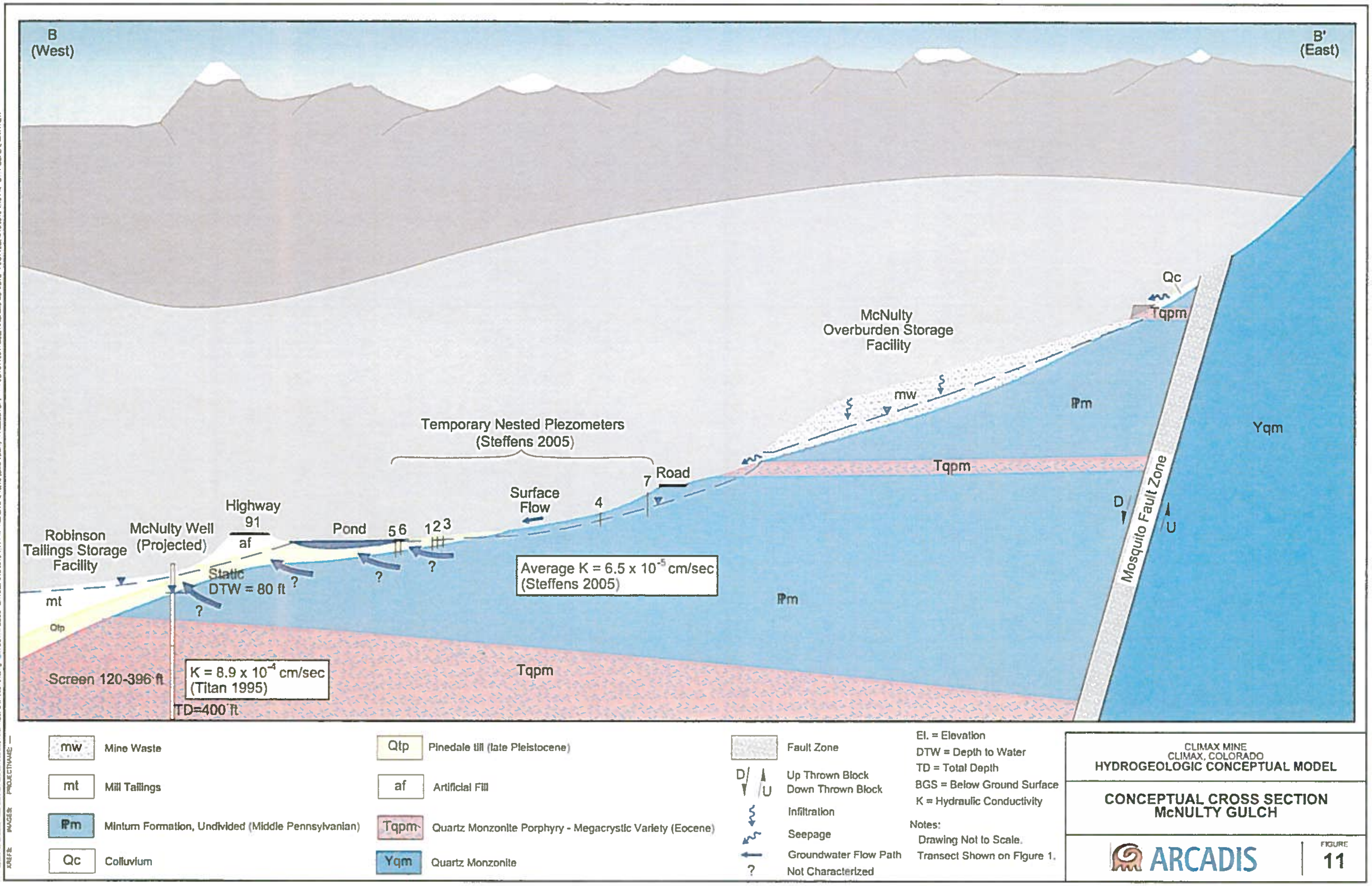
Hydrogeologic Conceptual Model

MAP OF McNulty DRAINAGE AND ESTIMATED POTENTIOMETRIC SURFACE

ARCADIS

FIGURE 10

Path: K:\CO001682_Climax\GIS\ArcMap_MXD\HGCM_shortList\Figure 10_Map of McNulty Drainage and Estimated Potentiometric Surface.mxd Date Saved: 4/18/2012 11:07:56 AM User: jchen


B (West)
B' (East)
Robinson Tailings Storage Facility
McNulty Well (Projected)
Highway 91
af
mt
Qtp
Static DTW = 80 ft
Screen 120-396 ft
K = 8.9 x 10^-4 cm/sec (Titan 1995)
TD=400 ft
Pond
5 6
1 2 3
Temporary Nested Piezometers (Steffens 2005)
Surface Flow
4
7
Road
Average K = 6.5 x 10^-5 cm/sec (Steffens 2005)
Tqpm
Pm
McNulty Overburden Storage Facility
mw
Qc
Mosquito Fault Zone
D
U
Yqm
mw Mine Waste
mt Mill Tailings
Pm Minturn Formation, Undivided (Middle Pennsylvanian)
Qc Colluvium
Qtp Pinedale till (late Pleistocene)
af Artificial Fill
Tqpm Quartz Monzonite Porphyry - Megacrystic Variety (Eocene)
Yqm Quartz Monzonite
Fault Zone
Up Thrown Block
Down Thrown Block
Infiltration
Seepage
Groundwater Flow Path
Not Characterized
El. = Elevation
DTW = Depth to Water
TD = Total Depth
BGS = Below Ground Surface
K = Hydraulic Conductivity
Notes:
Drawing Not to Scale.
Transect Shown on Figure 1.
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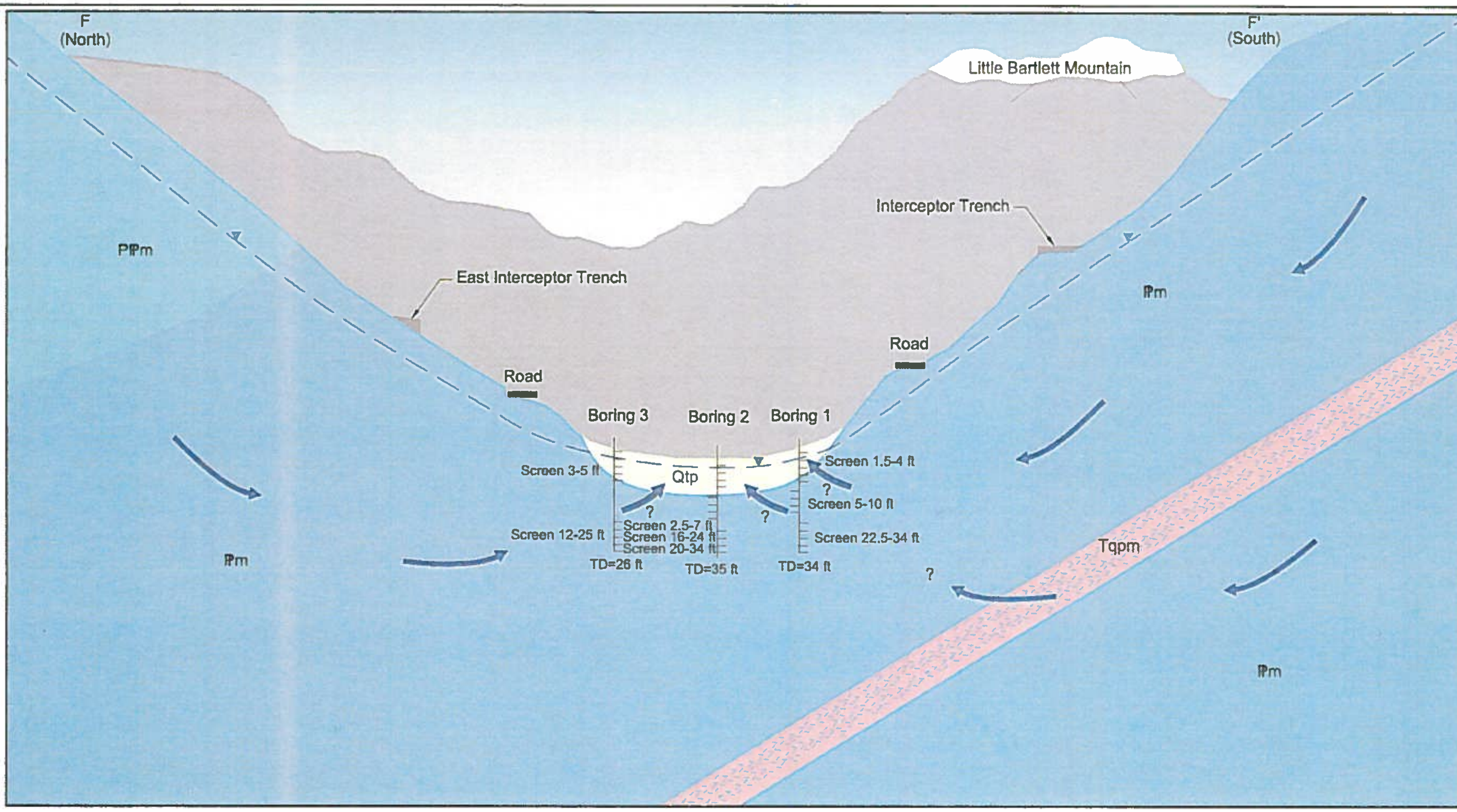
HYDROGEOLOGIC CONCEPTUAL MODEL
CONCEPTUAL CROSS SECTION
McNULTY GULCH
ARCADIS
FIGURE
11



IPm — Minturn Formation, Undivided (Middle Pennsylvanian)

PIPm — Minturn Formation, Undivided (Middle Pennsylvanian)

Qtp — Pinedale till (late Pleistocene)

Tqpm — Quartz Monzonite Porphyry - Megacrystic Variety (Eocene)

Fault Zone

D/U — Up Thrown Block / Down Thrown Block

Infiltration

Seepage

Groundwater Flow Path

? — Not Characterized

El. = Elevation
DTW = Depth to Water
TD = Total Depth
BGS = Below Ground Surface
K = Hydraulic Conductivity

Notes:
Drawing Not to Scale.
Transect Shown on Figure 1.

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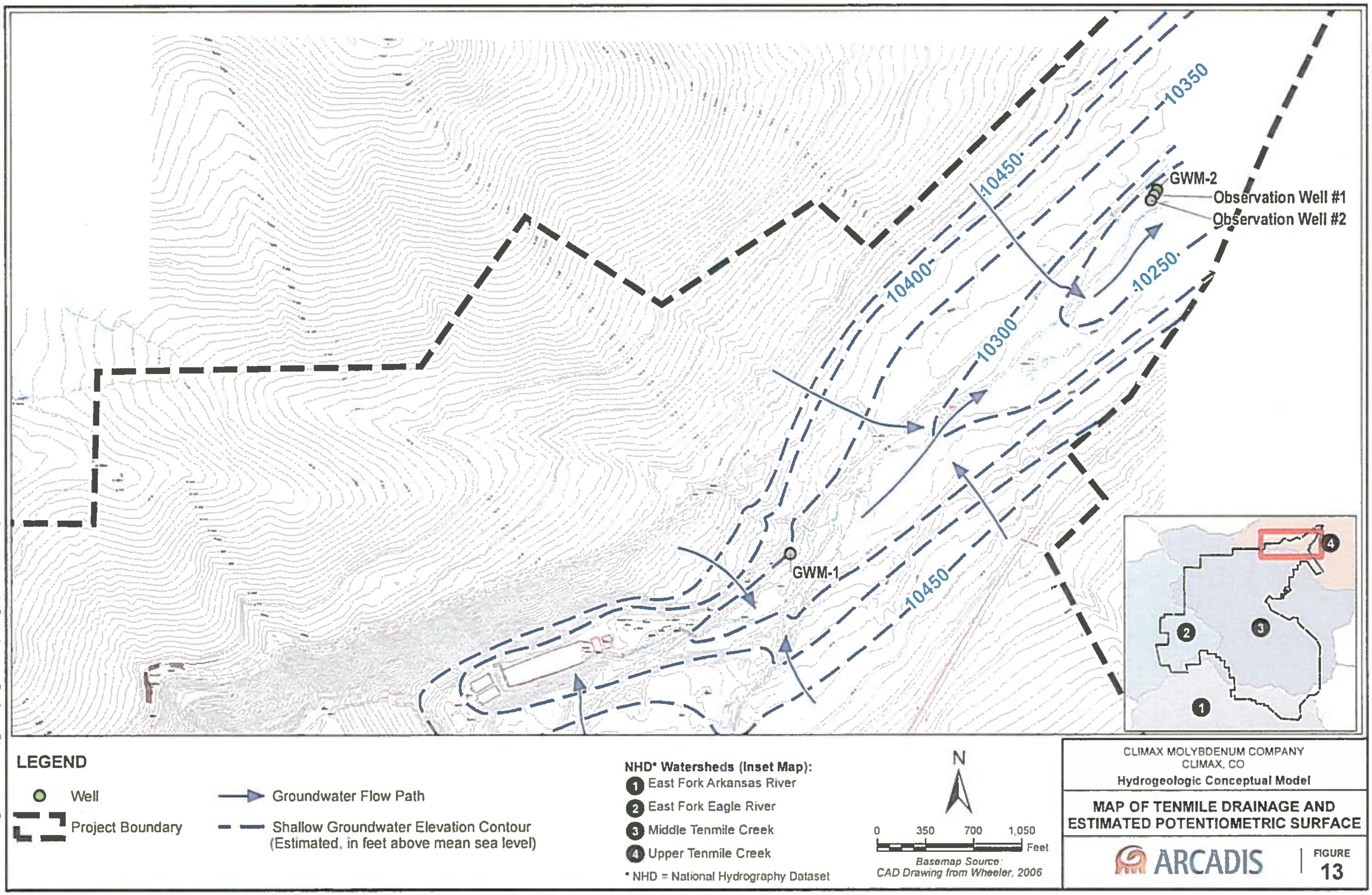
HYDROGEOLOGIC CONCEPTUAL MODEL

CONCEPTUAL CROSS SECTION
McNULTY GULCH

ARCADIS

FIGURE
12


10350
10450
10400
10300
10250
10450
GWM-2
Observation Well #1
Observation Well #2
GWM-1
LEGEND
Well
Project Boundary
Groundwater Flow Path
Shallow Groundwater Elevation Contour
(Estimated, in feet above mean sea level)
NHD* Watersheds (Inset Map):
1 East Fork Arkansas River
2 East Fork Eagle River
3 Middle Tenmile Creek
4 Upper Tenmile Creek
* NHD = National Hydrography Dataset
N
0 350 700 1,050 Feet
Basemap Source:
CAD Drawing from Wheeler, 2006
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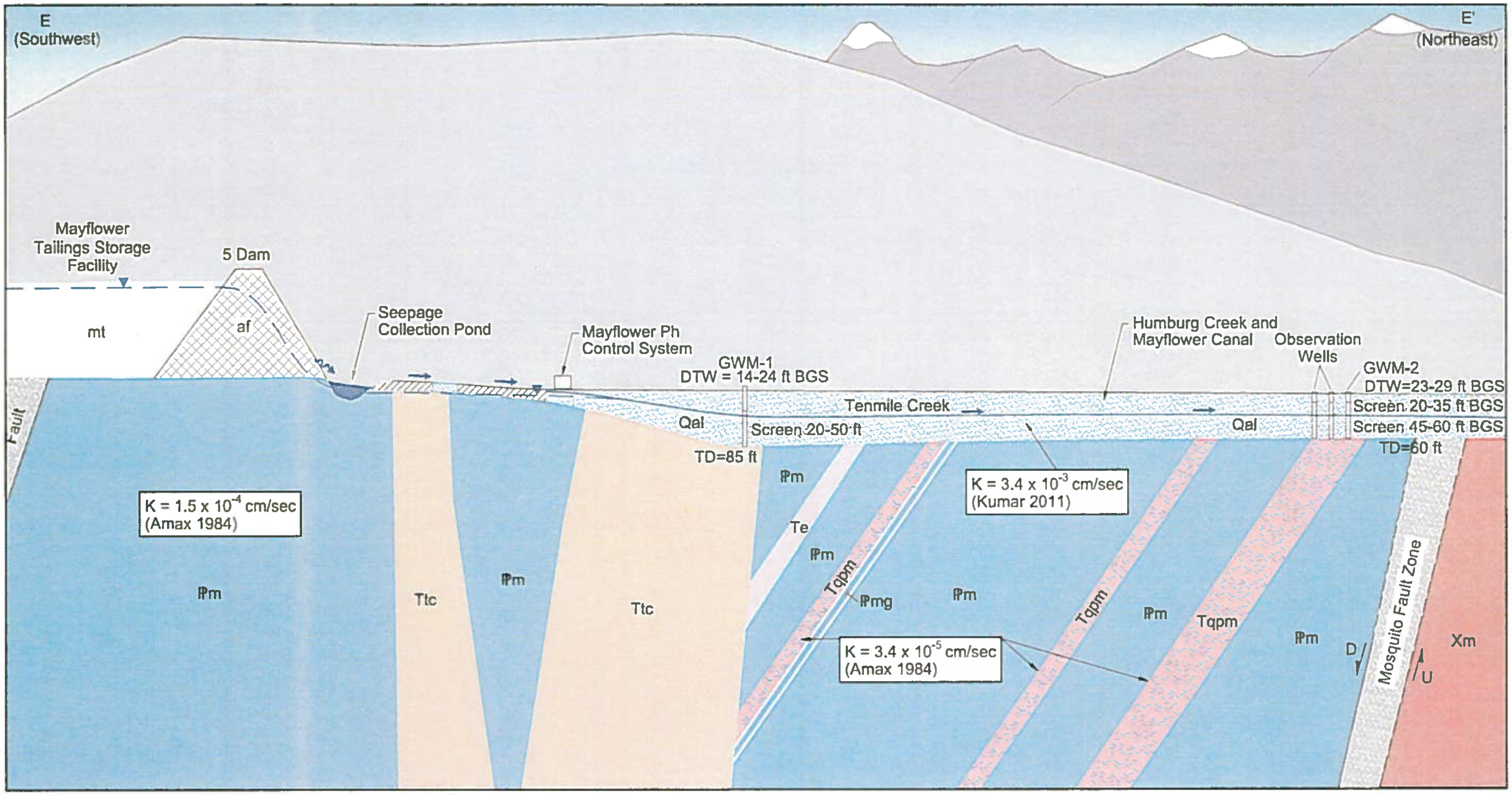
MAP OF TENMILE DRAINAGE AND
ESTIMATED POTENTIOMETRIC SURFACE
ARCADIS
FIGURE
13



af	Artificial Fill
mt	Mill Tailings
Pm	Minturn Formation, Undivided (Middle Pennsylvanian)
Pmg	White Quail Limestone Member
Tqpm	Quartz Monzonite Porphyry - Megacrystic Variety (Eocene)
Te	Elk Mountain Porphyry
Ttc	Tenmile Creek Quartz
Qal	Stream-channel, flood-plain
Xm	Migmatite (Early Proterozoic)
	Fault Zone
D/U	Up Thrown Block / Down Thrown Block
	Infiltration
	Seepage
	Groundwater Flow Path

El. = Elevation
DTW = Depth to Water
TD = Total Depth
BGS = Below Ground Surface
K = Hydraulic Conductivity

Notes:
Drawing Not to Scale.
Transect Shown on Figure 1.

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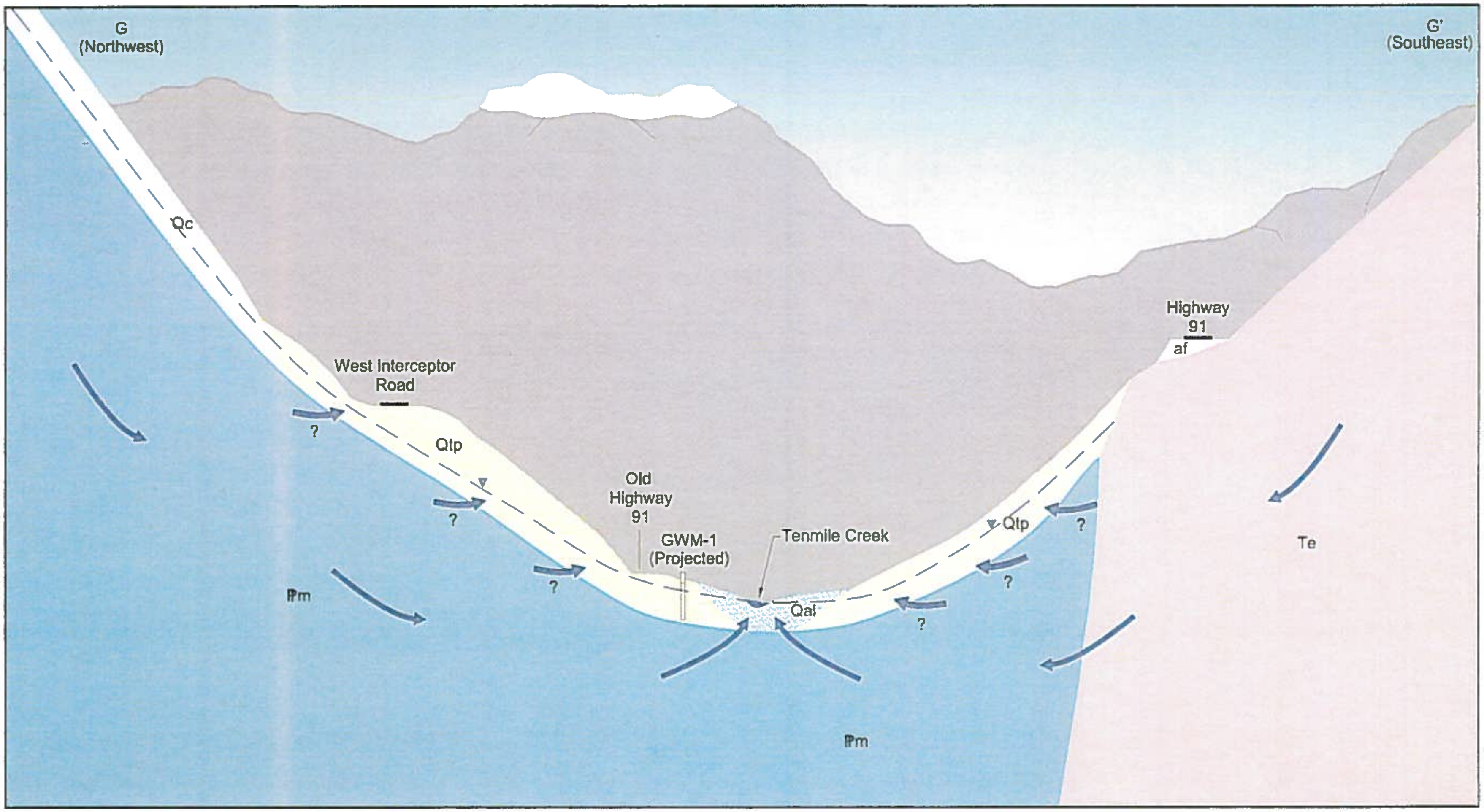
HYDROGEOLOGIC CONCEPTUAL MODEL

CONCEPTUAL CROSS SECTION TENMILE CREEK

ARCADIS

FIGURE 14



af	Artificial Fill
Qal	Stream-channel, flood-plain
Qc	Colluvium
Te	Elk Mountain Porphyry
Pm	Minturn Formation, Undivided (Middle Pennsylvanian)
Qtp	Pinedale till (late Pleistocene)
	Fault Zone
D / U	Up Thrown Block Down Thrown Block
	Infiltration
	Seepage
	Groundwater Flow Path
?	Not Characterized

El. = Elevation
DTW = Depth to Water
TD = Total Depth
BGS = Below Ground Surface
K = Hydraulic Conductivity

Notes:
Drawing Not to Scale.
Transect Shown on Figure 1.

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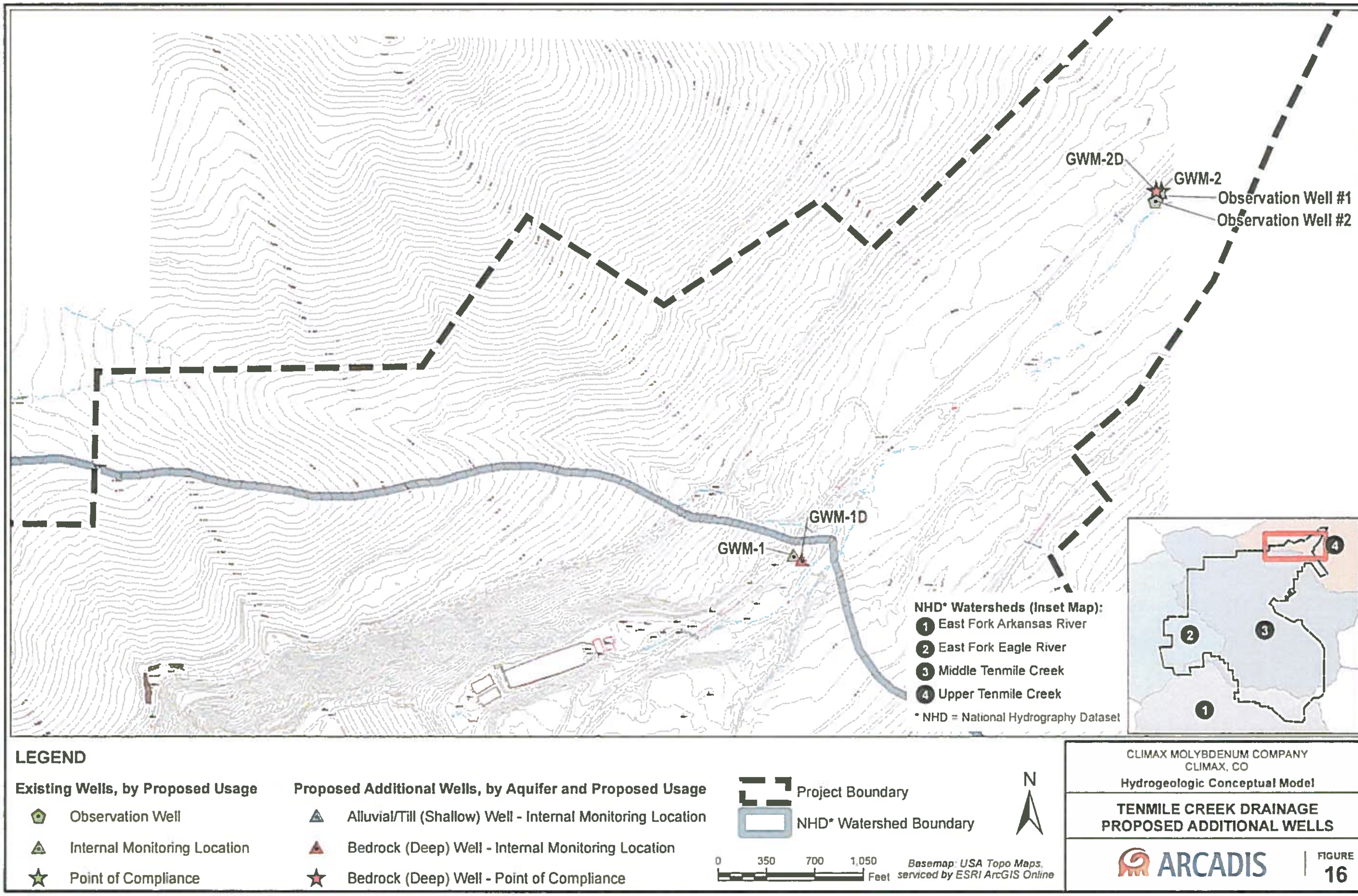
HYDROGEOLOGIC CONCEPTUAL MODEL

CONCEPTUAL CROSS SECTION
TENMILE CREEK

ARCADIS

FIGURE 15



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TENMILE CREEK DRAINAGE PROPOSED ADDITIONAL WELLS

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FIGURE 16

Path: K:\C0001682_Climax\GIS\ArcMap_MXD\HgCM_shortList\Figure 16_Tenmile Creek Drainage Proposed Additional Wells_.mxd Date Saved: 4/18/2012 11:09:11 AM User: jchen