

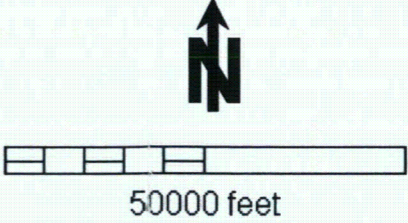


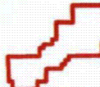




**Legend**

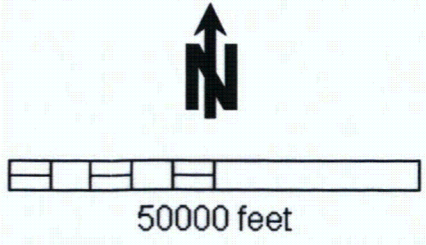
-  Permit Boundary
-  10-mile Buffer

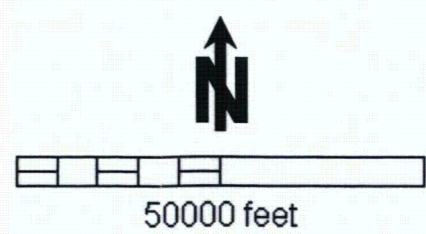
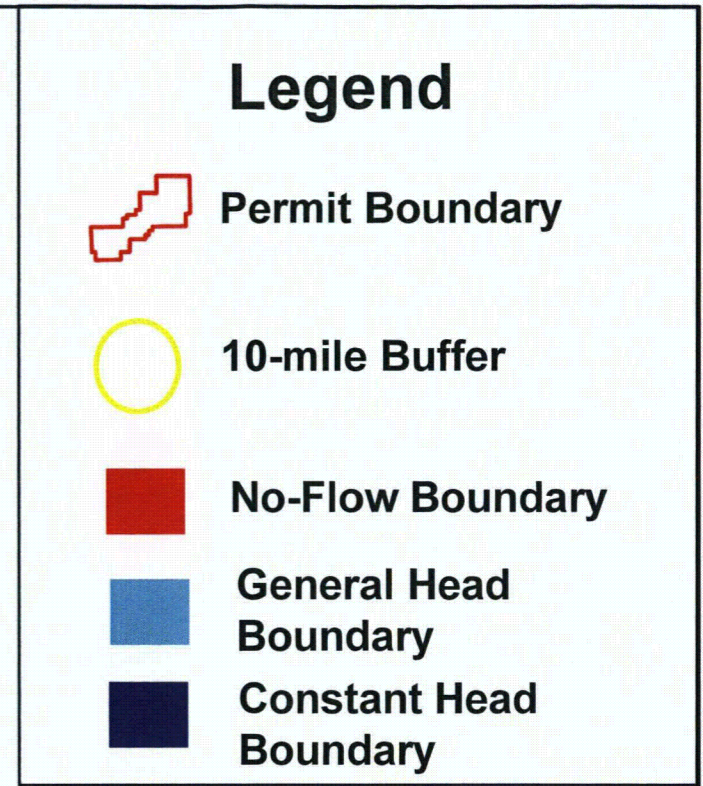
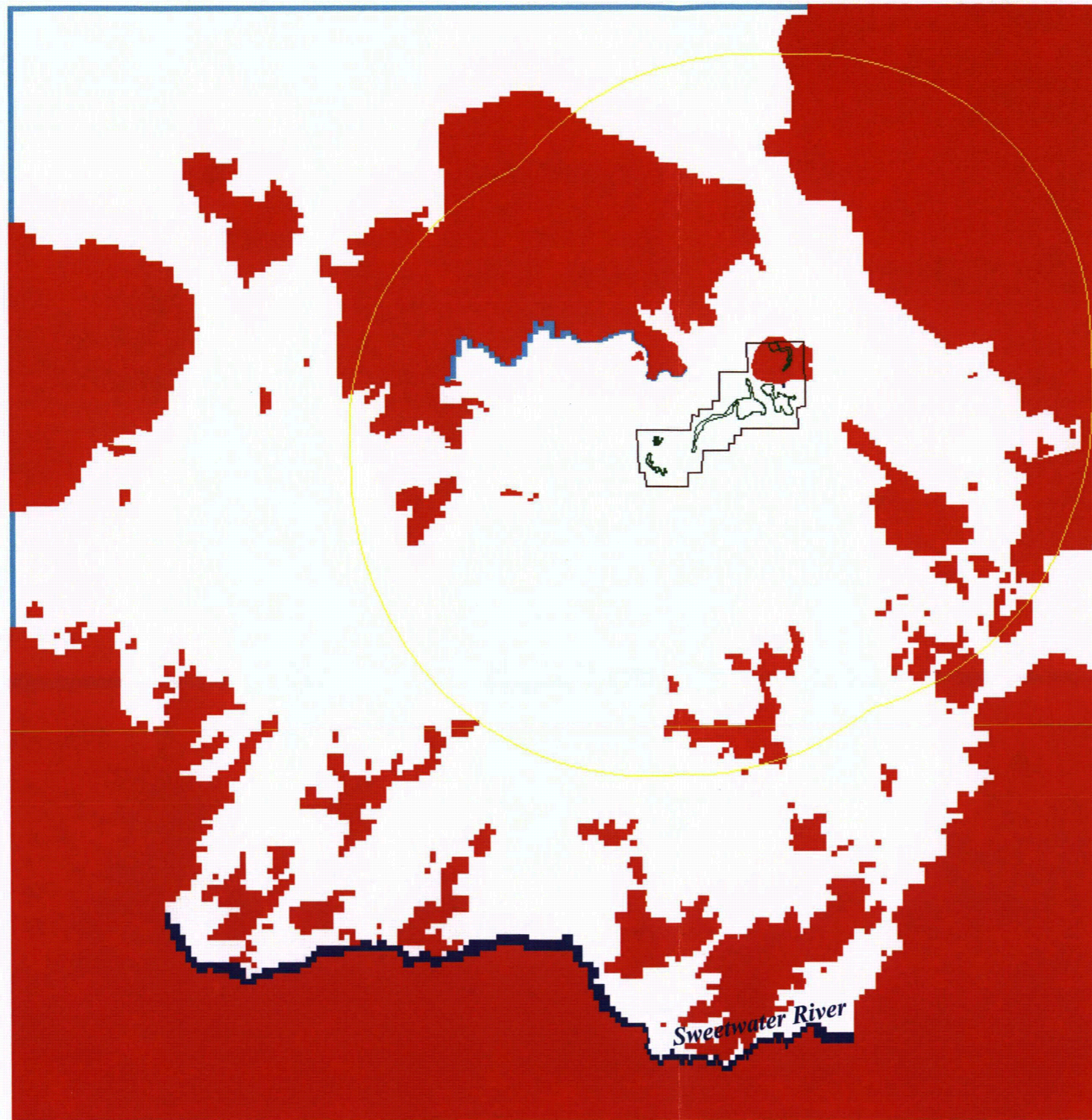


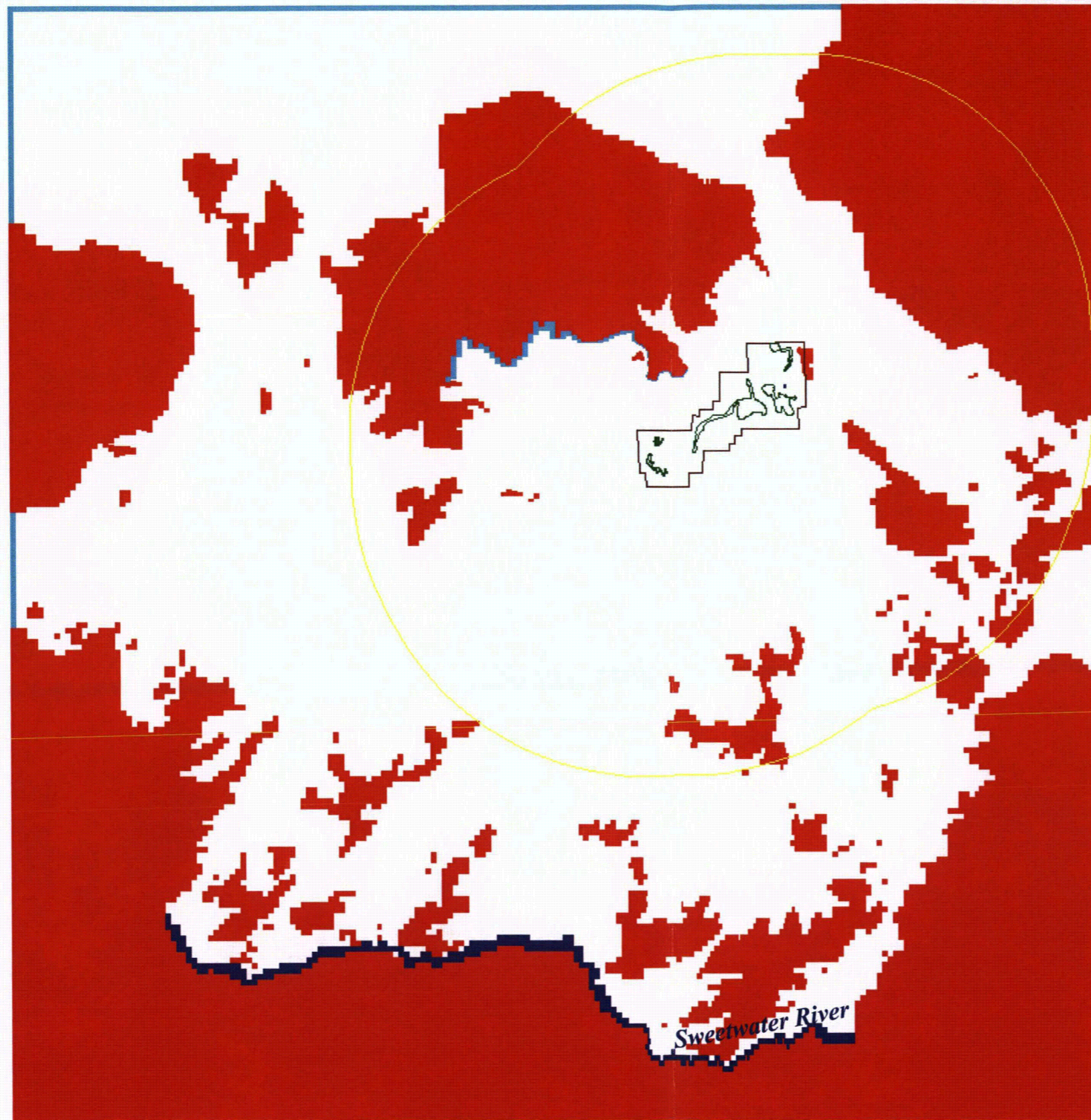


### Legend






-  Permit Boundary
-  10-mile Buffer
-  No-Flow Boundary
-  General Head Boundary
-  River Boundary







### Legend

-  Permit Boundary
-  10-mile Buffer
-  No-Flow Boundary
-  General Head Boundary
-  Constant Head Boundary

**AQUI-VER, INC.**

*Hydrogeology, Water Resources & Data Services*

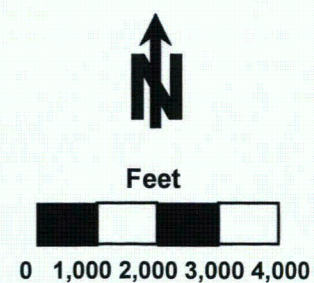
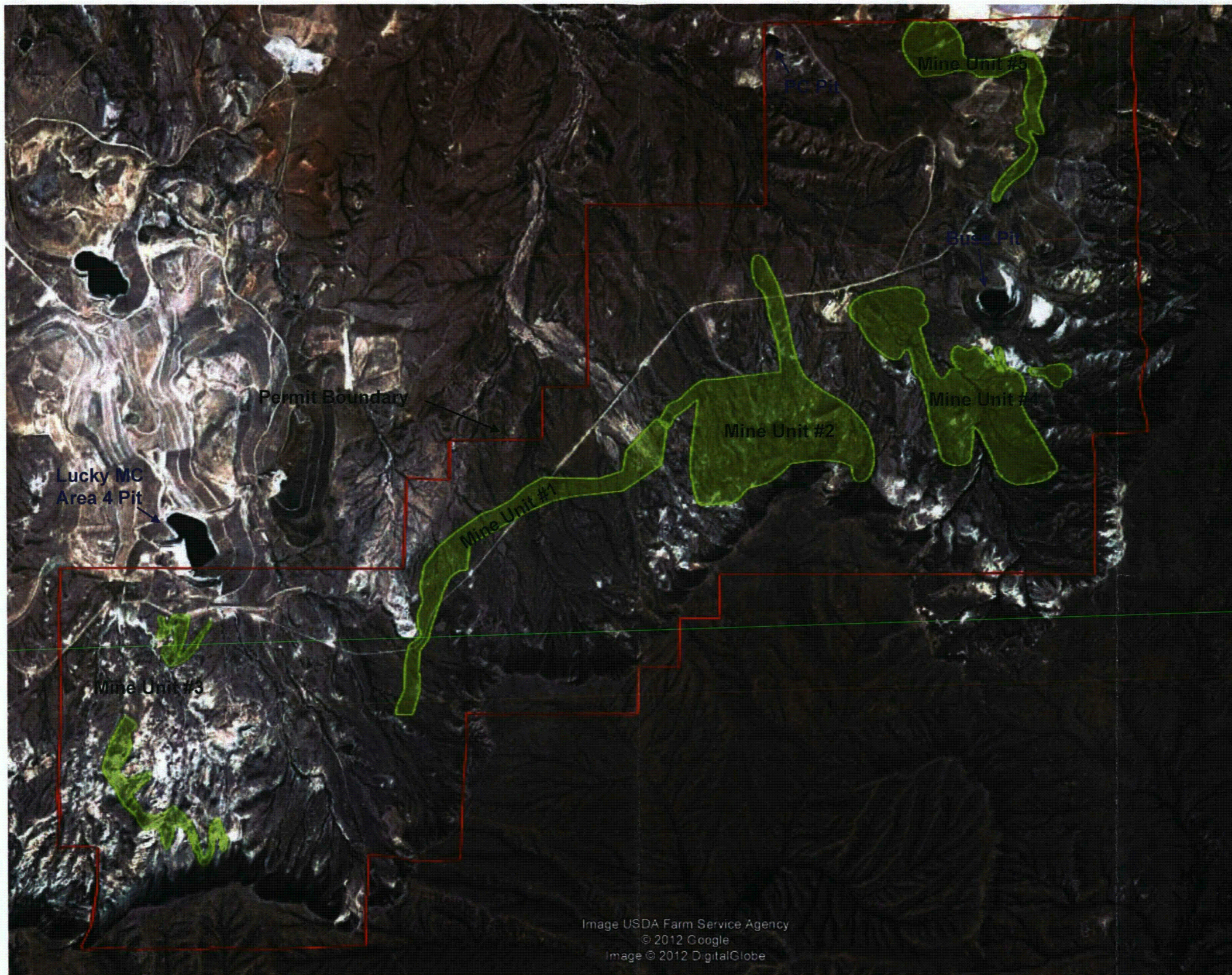
**Layer 3 Boundary Conditions**

Hydrologic Impact Assessment – Gas Hills Facility  
Natrona and Fremont Counties, Wyoming



FIGURE:

**4-4**



**AQUI-VER, INC.**

*Hydrogeology, Water Resources & Data Services*

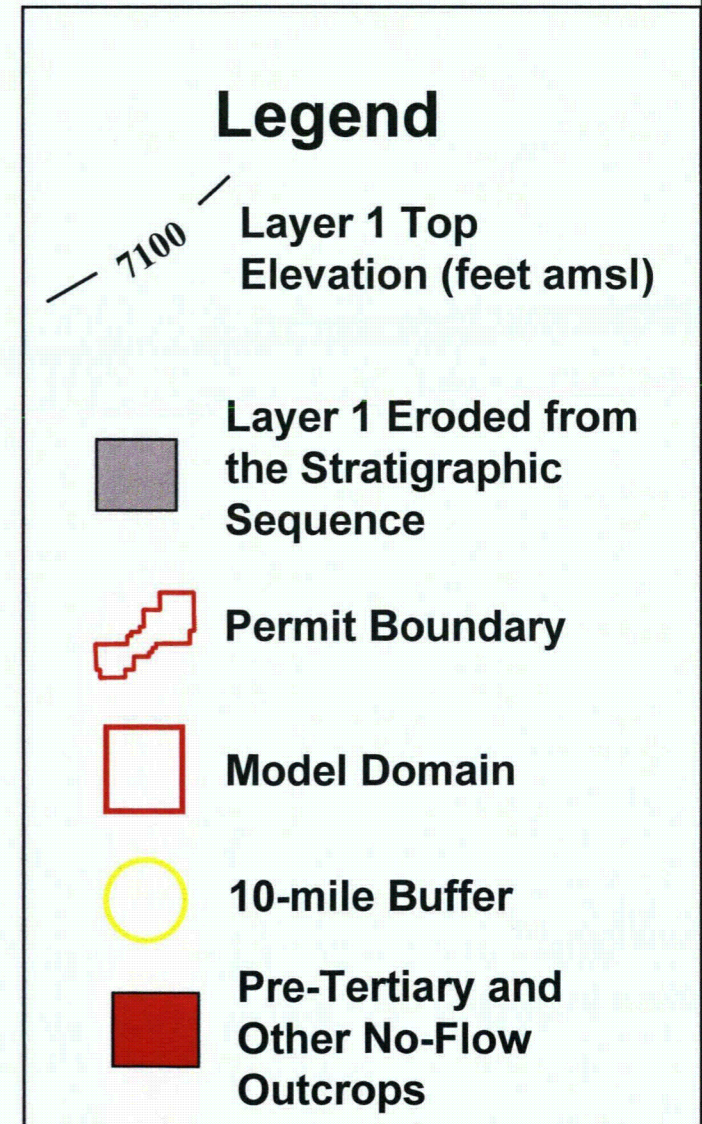
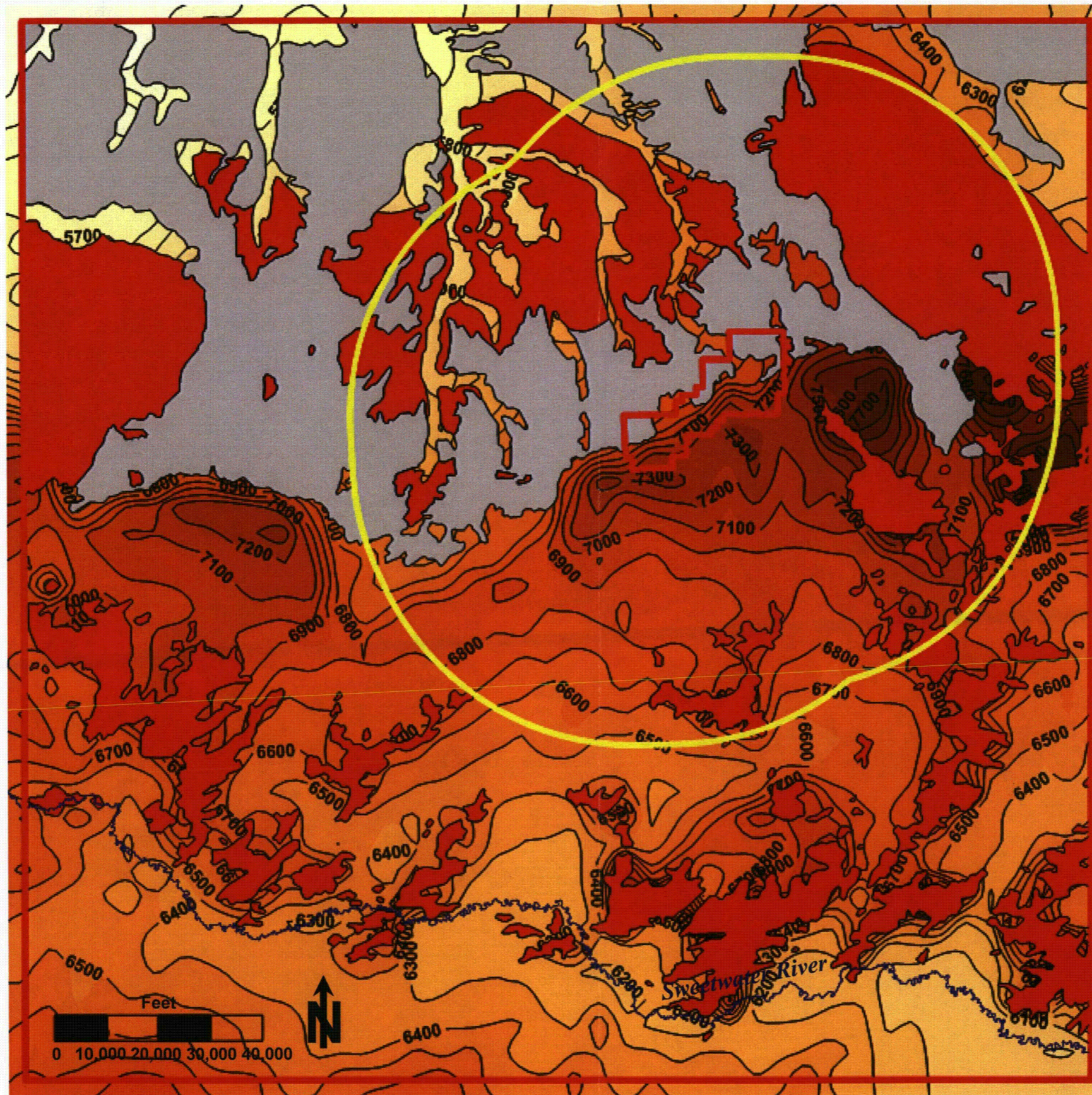
**Groundwater-Fed Historic Mining Pits**

Hydrologic Impact Assessment – Gas Hills Facility  
Natrona and Fremont Counties, Wyoming



FIGURE:

**4-5**



**AQUI-VER, INC.**

Hydrogeology, Water Resources & Data Services

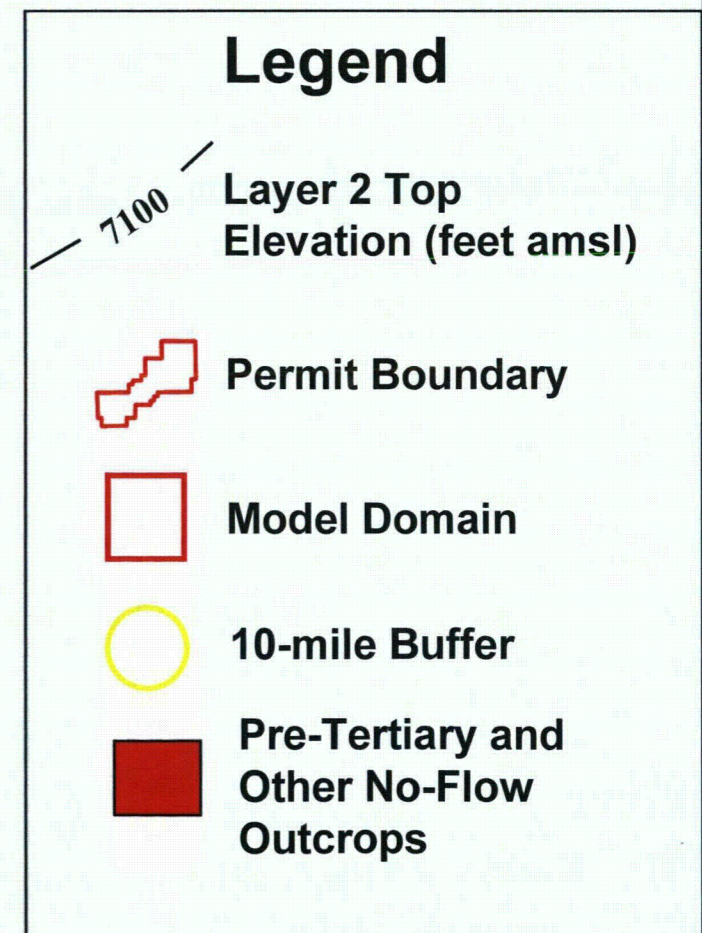
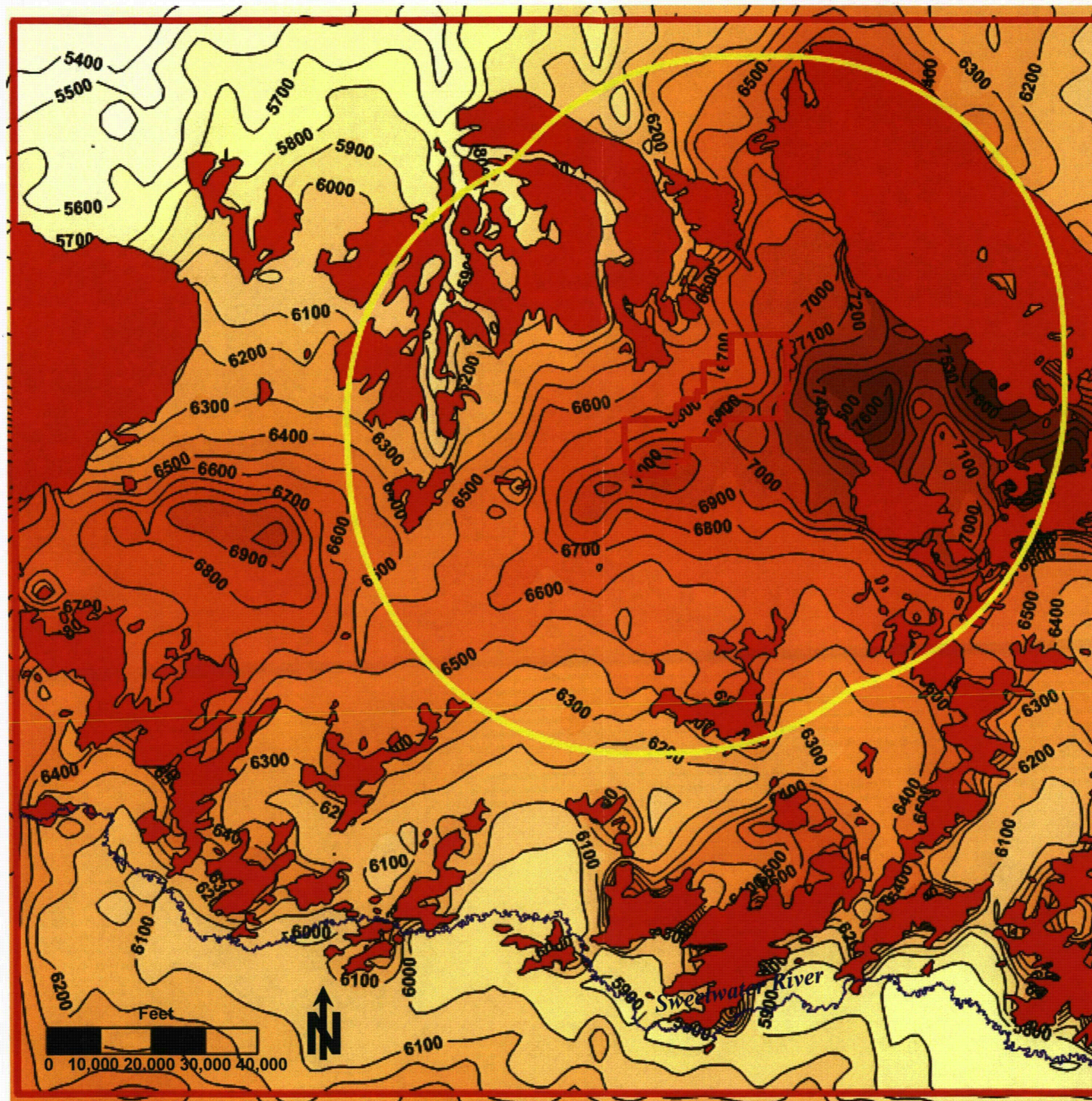
**Top of Layer 1**

Hydrologic Impact Assessment – Gas Hills Facility  
Natrona and Fremont Counties, Wyoming



FIGURE:

**4-6**



**AQUI-VER, INC.**

Hydrogeology, Water Resources & Data Services

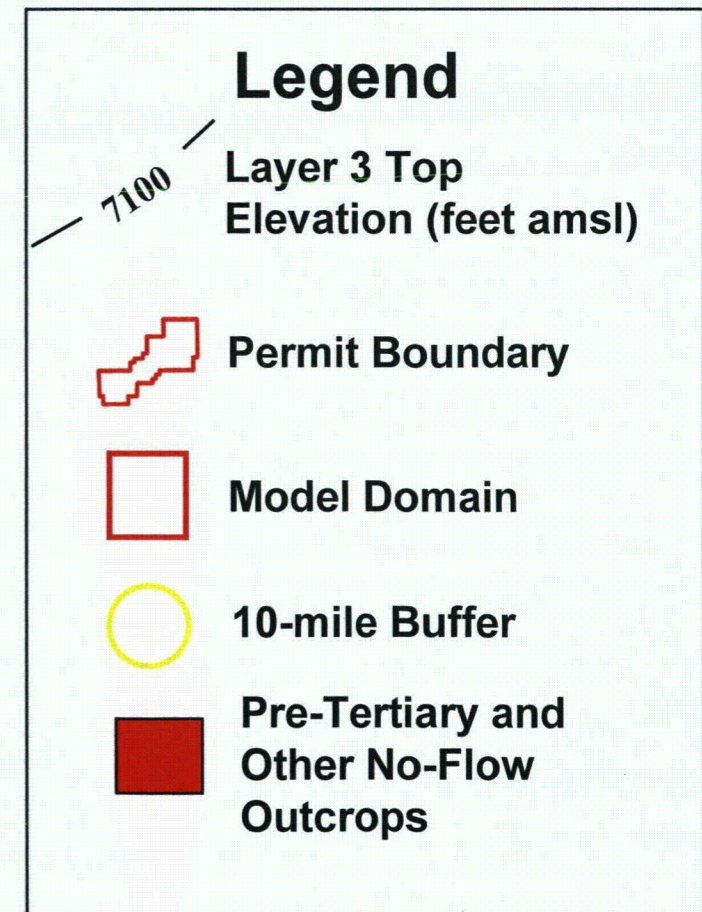
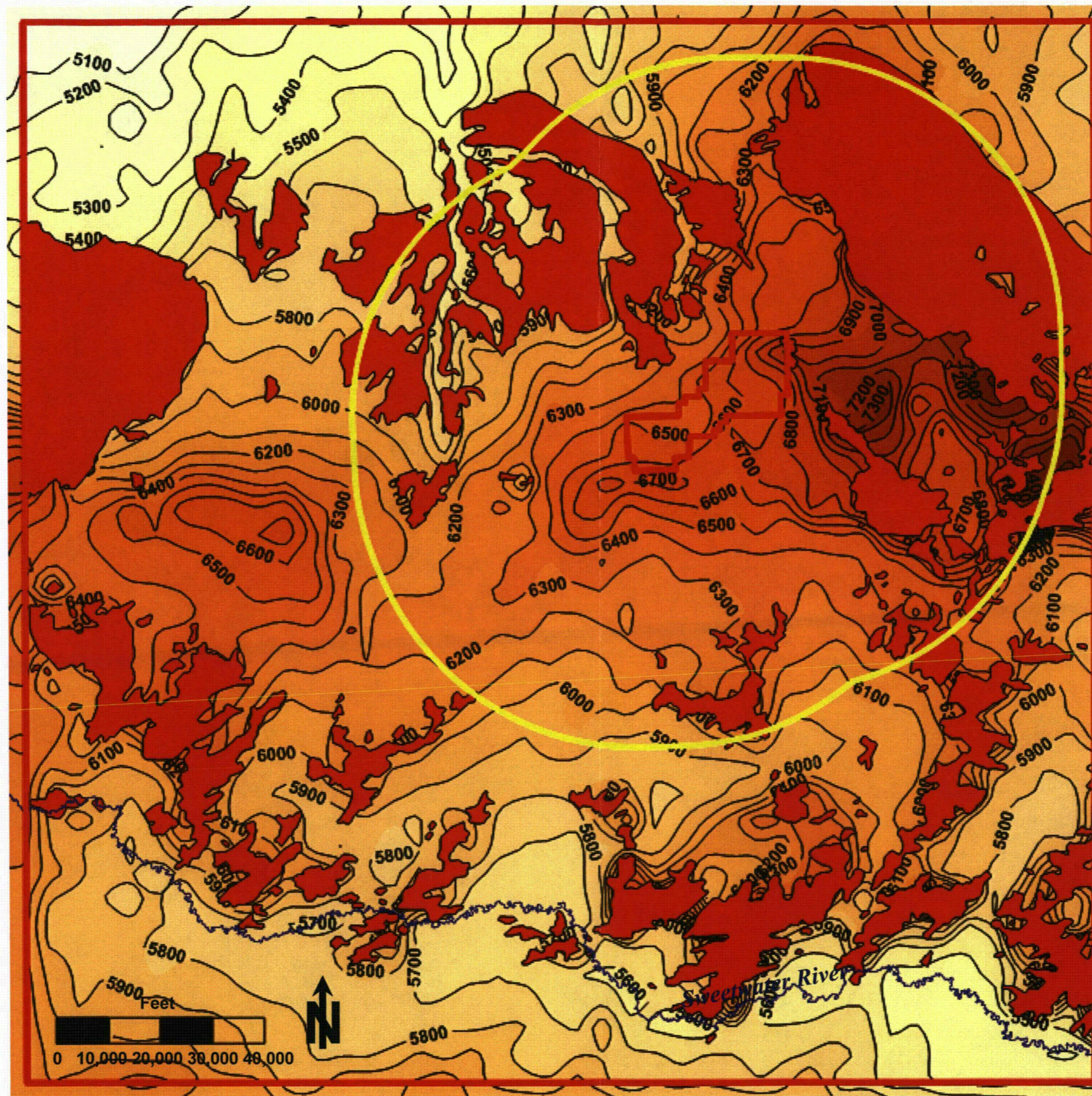
**Top of Layer 2**

Hydrologic Impact Assessment – Gas Hills Facility  
Natrona and Fremont Counties, Wyoming

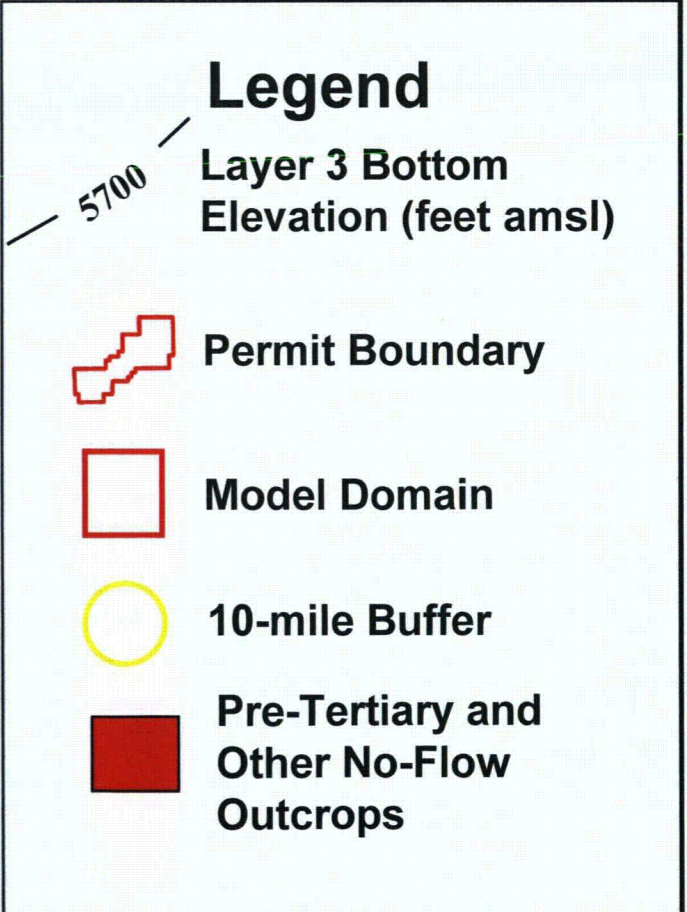
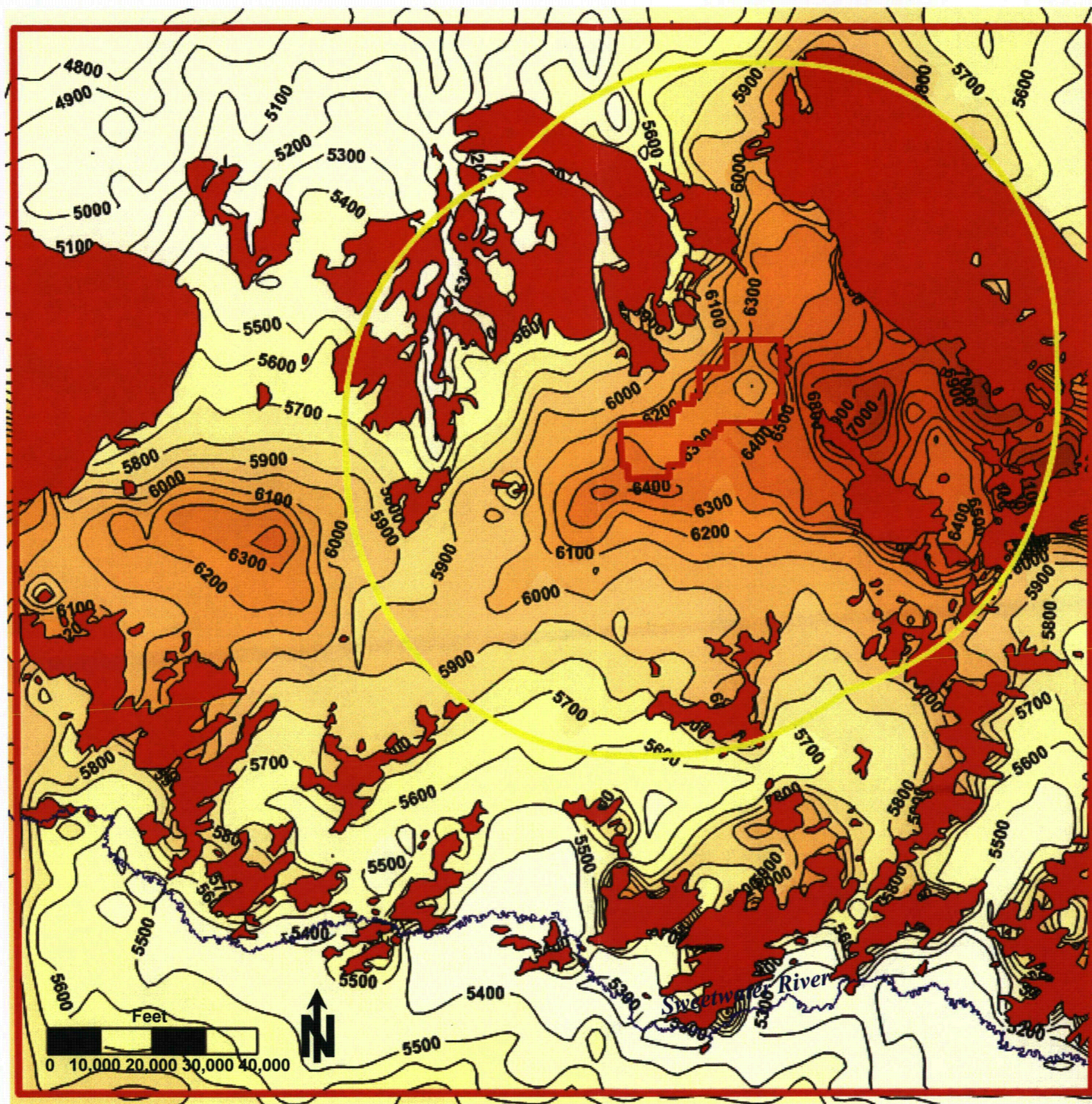


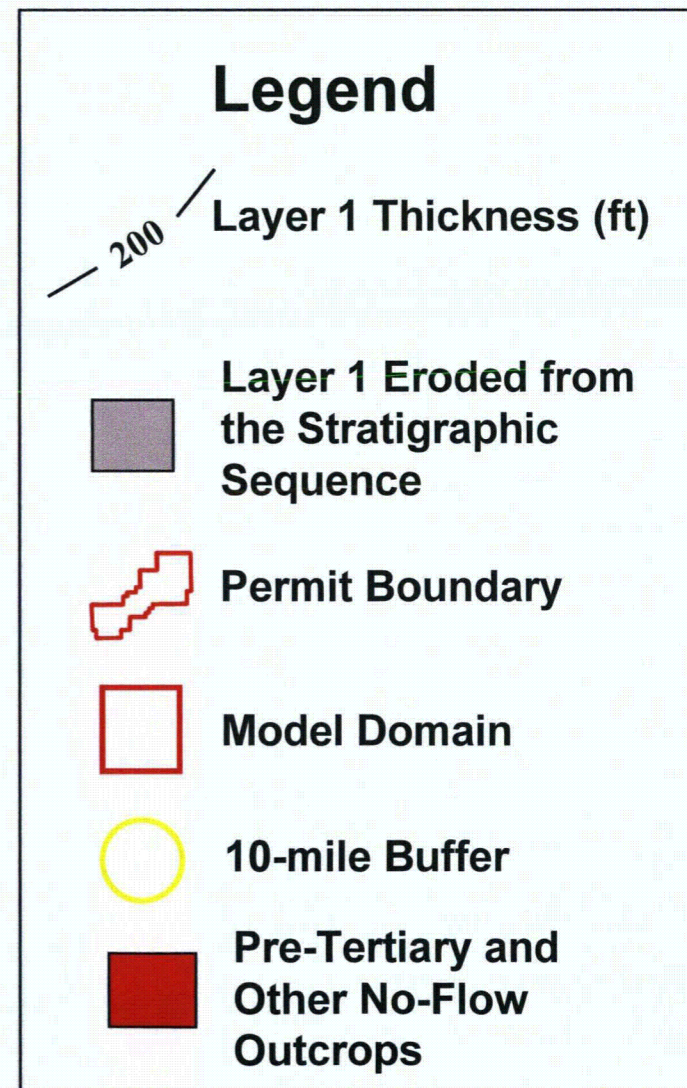
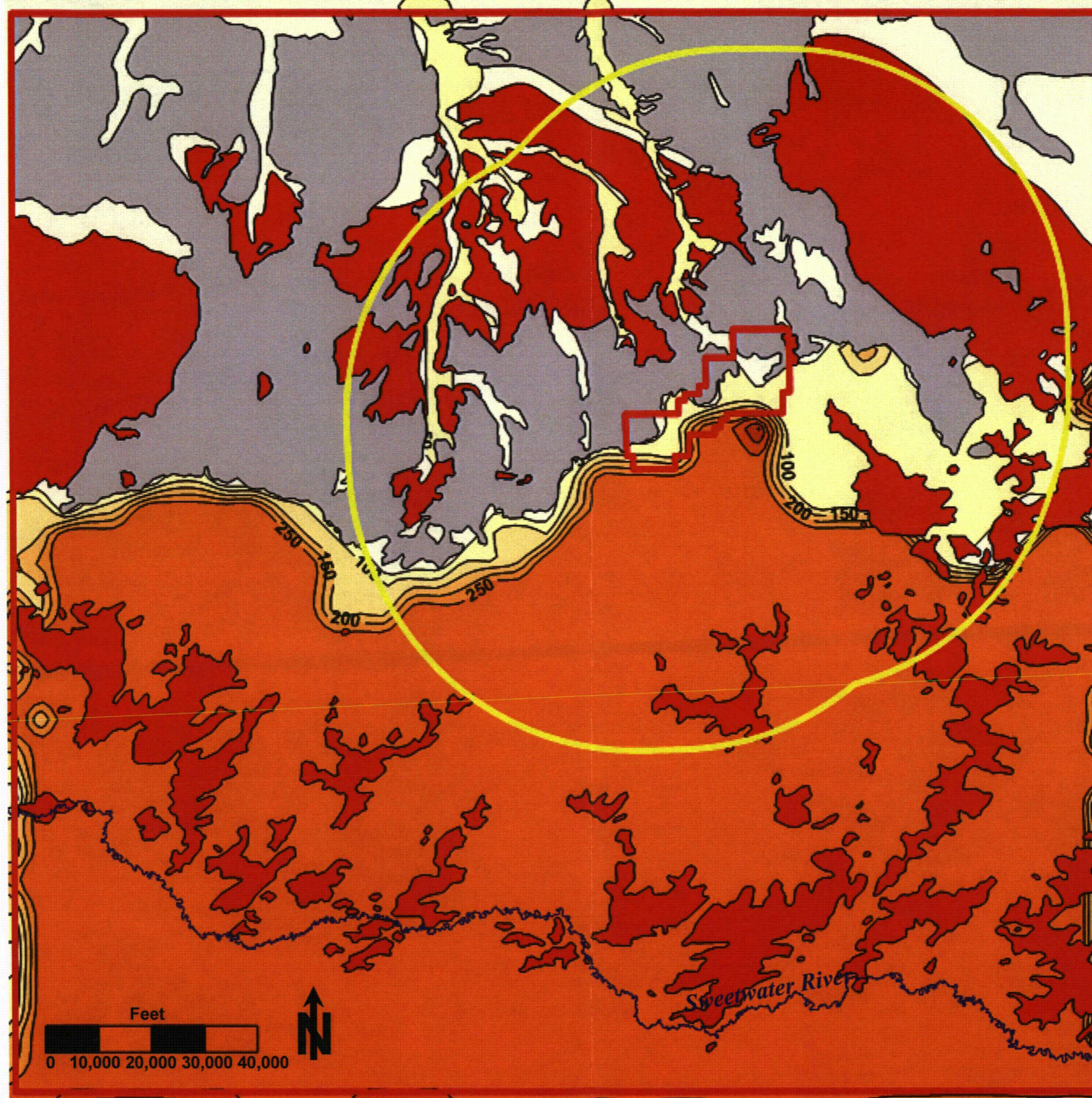
FIGURE:

**4-7**









**AQUI-VER, INC.**

Hydrogeology, Water Resources & Data Services

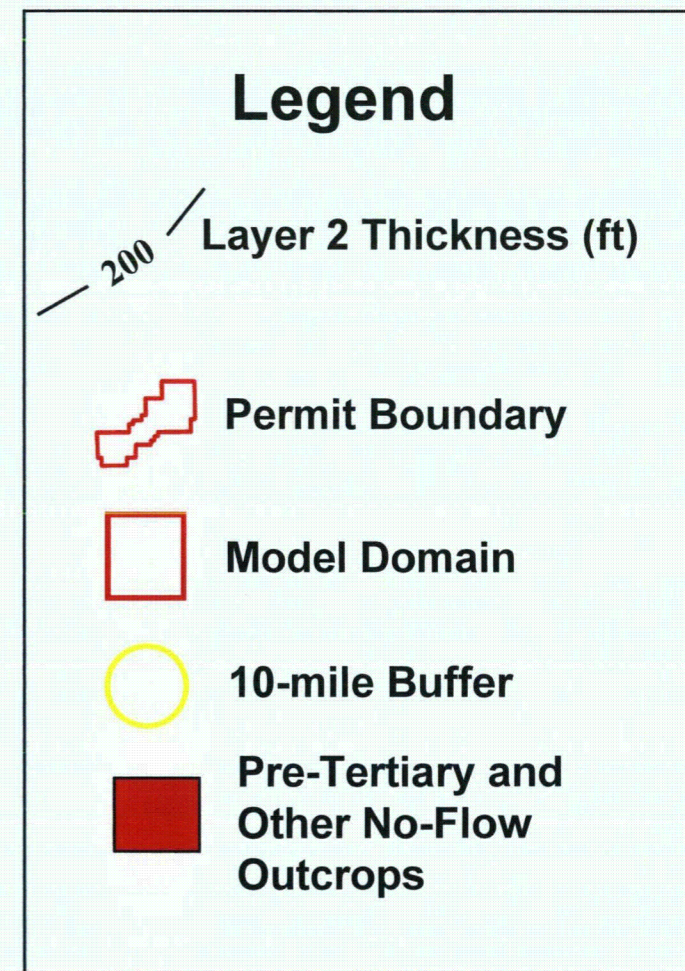
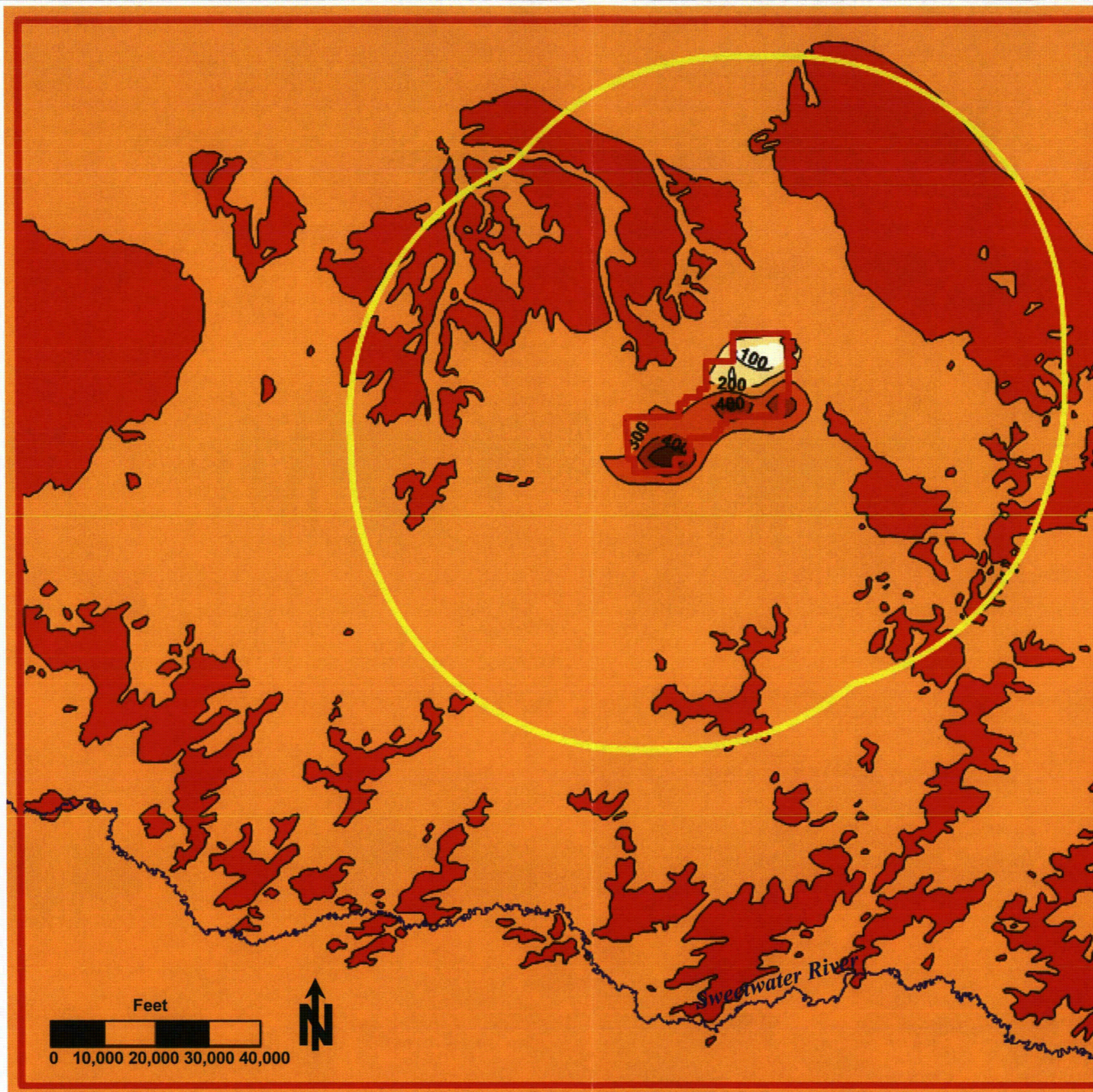
**Layer 1 Isopach**

Hydrologic Impact Assessment – Gas Hills Facility  
Natrona and Fremont Counties, Wyoming



FIGURE:

**4-10**



**AQUI-VER, INC.**

Hydrogeology, Water Resources & Data Services

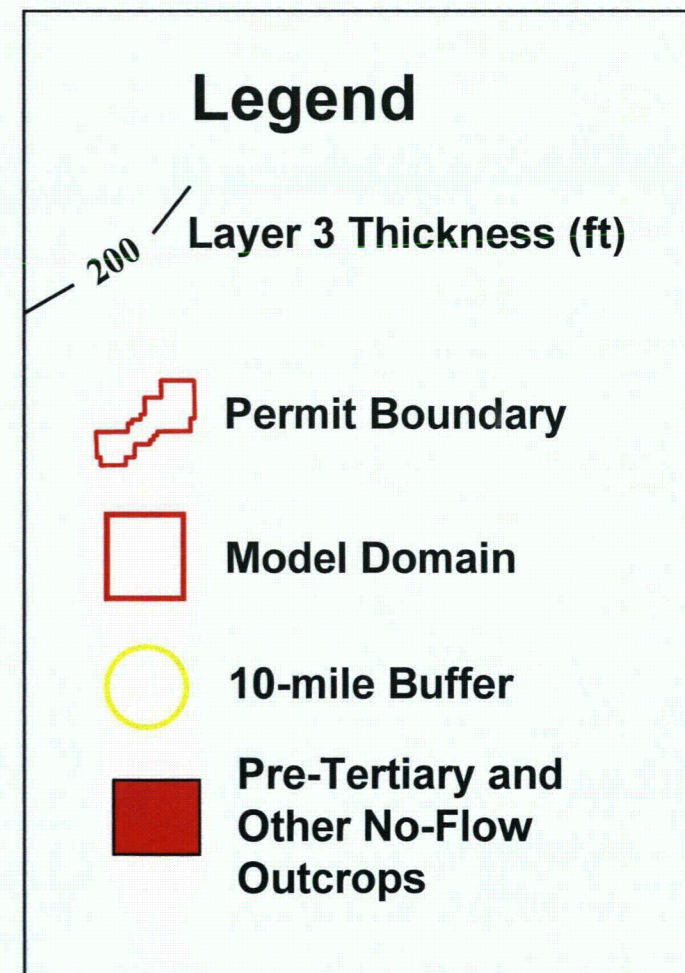
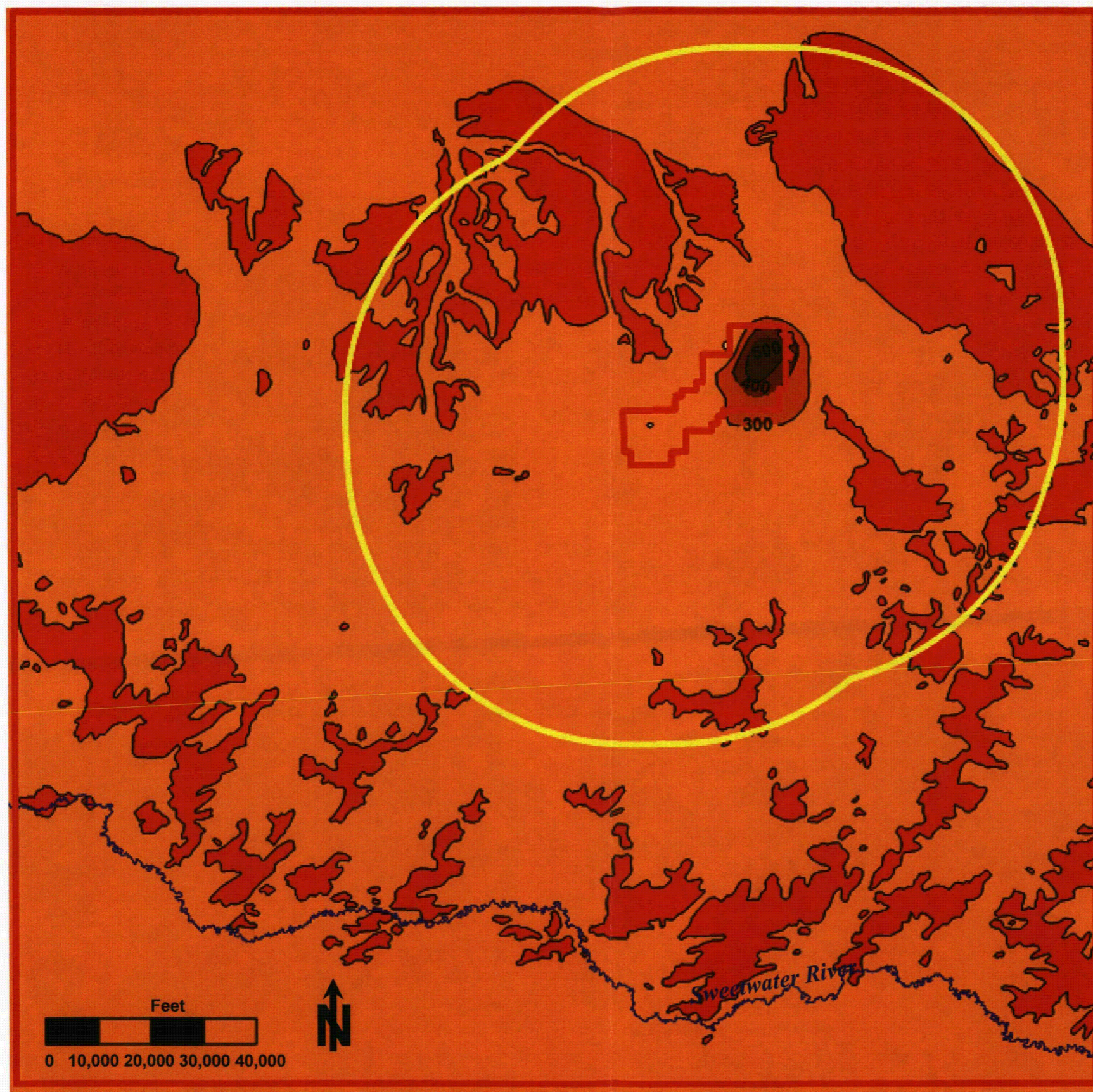
**Layer 2 Isopach**

Hydrologic Impact Assessment – Gas Hills Facility  
Natrona and Fremont Counties, Wyoming



FIGURE:

**4-11**



**AQUI-VER, INC.**

Hydrogeology, Water Resources & Data Services

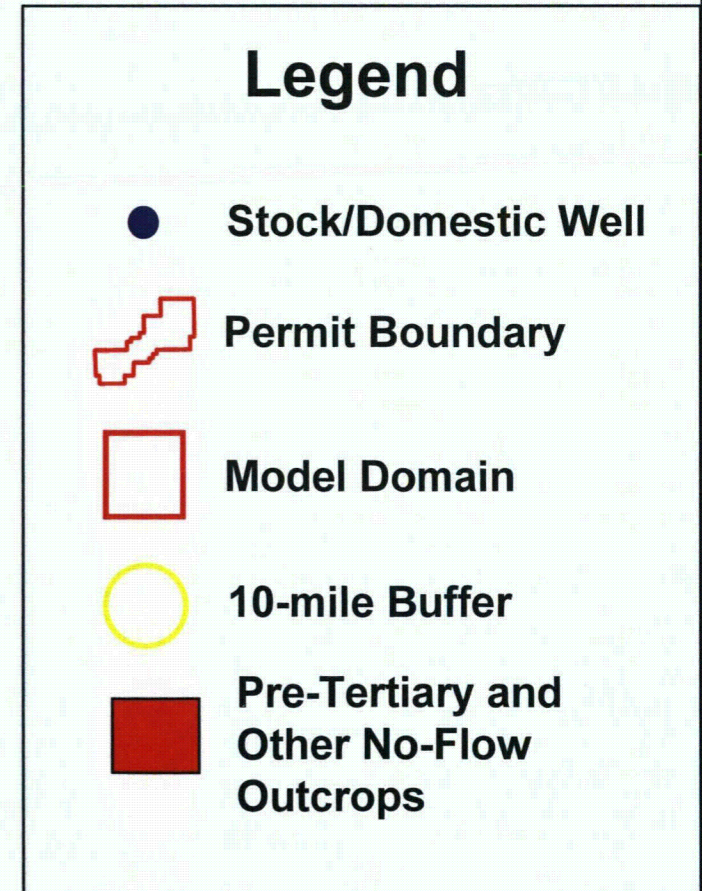
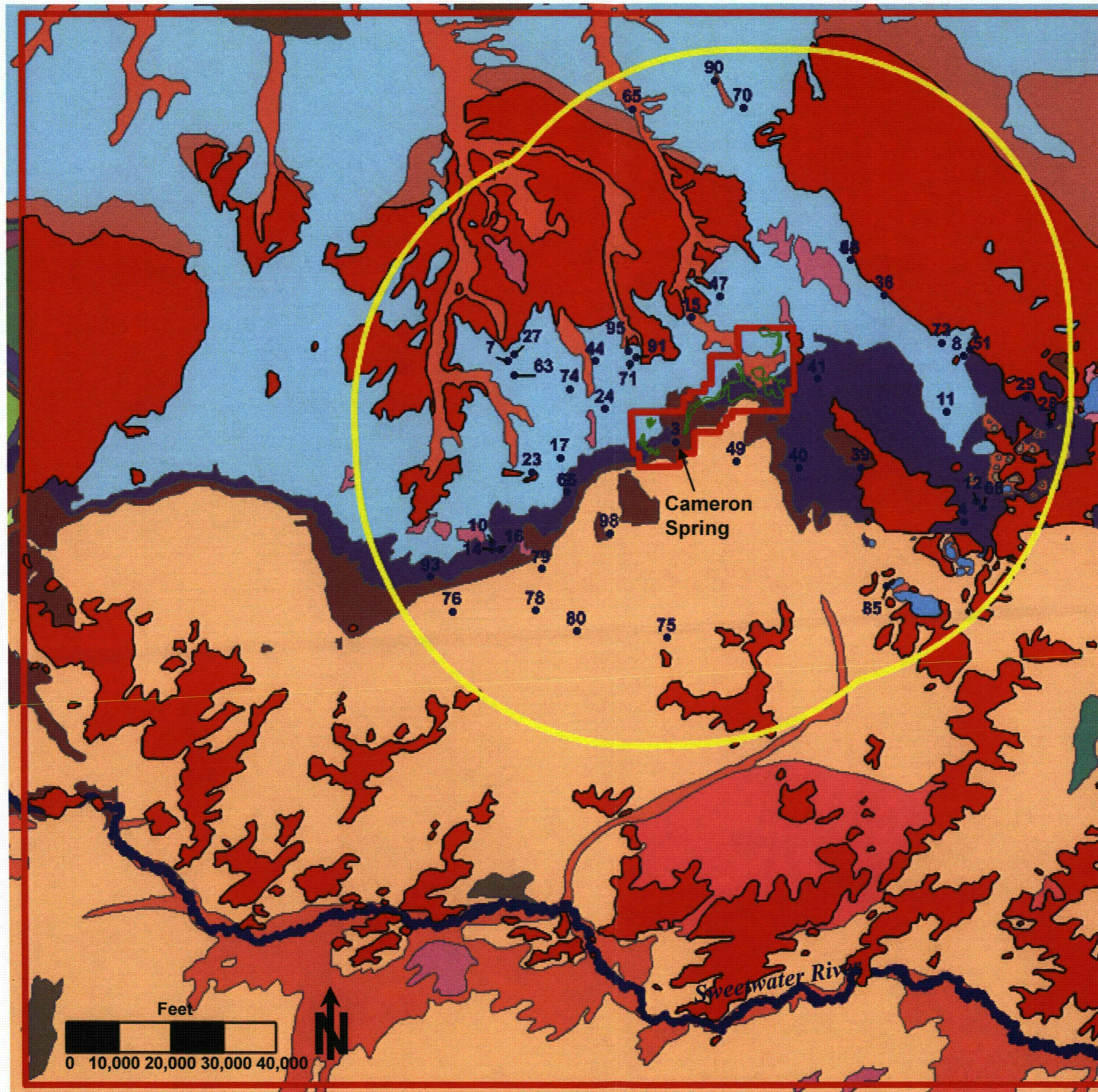
**Layer 3 Isopach**

Hydrologic Impact Assessment – Gas Hills Facility  
Natrona and Fremont Counties, Wyoming



FIGURE:

**4-12**



**AQUI-VER, INC.**

Hydrogeology, Water Resources & Data Services

**Stock and Domestic Wells in a 10-mile Radius**

Hydrologic Impact Assessment – Gas Hills Facility  
Natrona and Fremont Counties, Wyoming



FIGURE:

**4-13**

## 5. MODEL CALIBRATION

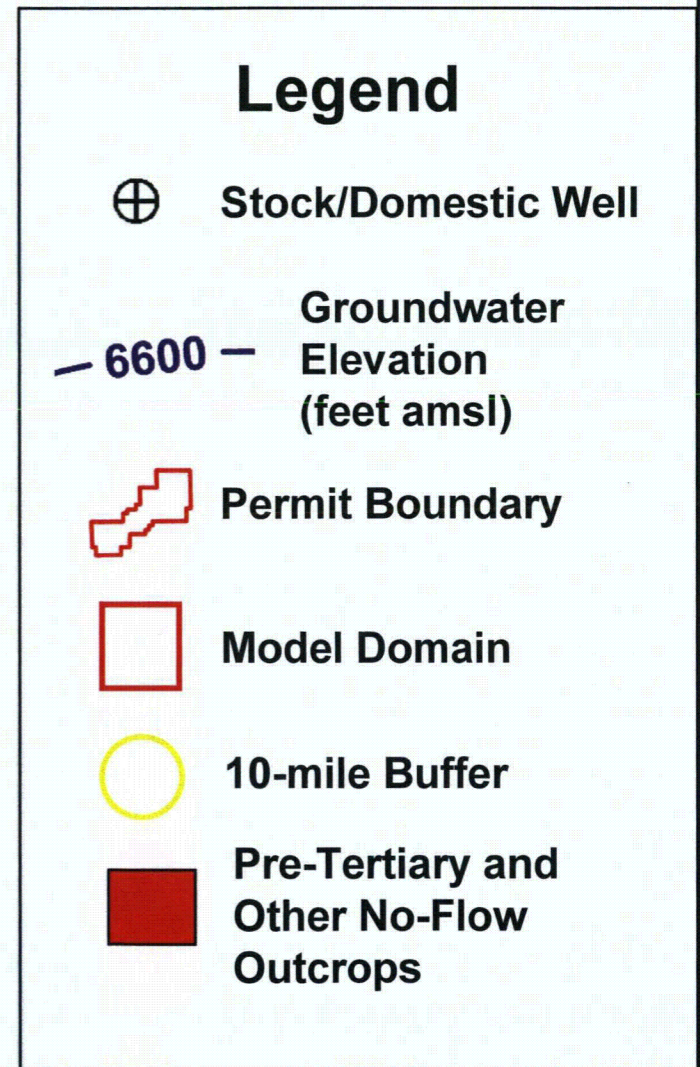
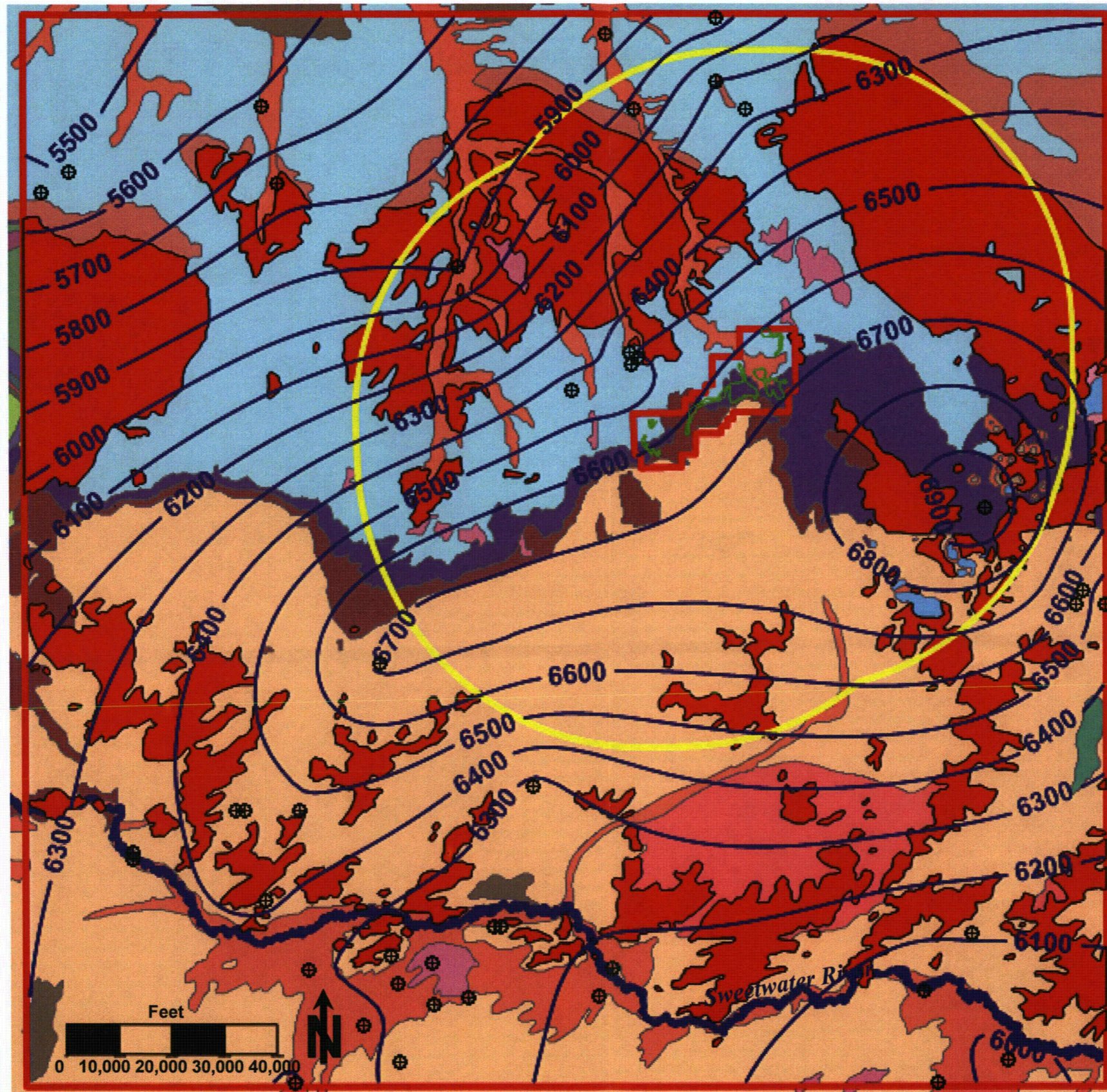
In order to increase the reliability of hydrologic impact predictions, the groundwater flow model was calibrated. Although aquifer tests were conducted within the Project area, few wells were utilized for testing and the data are not suitable for regional model calibration. Therefore, the model was calibrated to steady-state pre-mining (pre-1970) water level elevations reported in the SEO wells database. Based on a review of the available data, 12 wells were determined to be suitable as calibration targets. The water level data are considered to contain significant uncertainty associated with variable measurement dates, seasonal fluctuations, well completion depths, and approximate land surface elevation (e.g. +/- 20 feet). However, given the regional scale of the model and the wide range of water level elevations (e.g., up to approximately 1,500 feet over the model domain) the accuracy of the water levels are considered acceptable for use in calibration.

**Figure 5-1** illustrates the approximate water-table configuration prior to mining. Based on these data, there is a regional groundwater flow divide that corresponds to the location of the Beaver Rim Escarpment and recharge area. To the north of the escarpment, groundwater generally flows to the northwest towards the Boysen Reservoir and the Wind River discharge areas. To the south of the escarpment, groundwater generally flows to the south towards the Sweetwater River discharge area.

**Table 5-1** summarizes the results of the regional model calibration based on the static water elevation in the target wells. **Figure 5-2** shows a plot of observed versus computed (modeled) heads. The scaled residual error between the observed and computed water levels is just slightly greater than 1 percent, which is considered acceptable given the regional scale of the model and uncertainty associated with water level measurements representing variability over several decades. Model calibrated flow direction and gradients are consistent with measured regional water level elevations in **Figure 5-1**.

**Table 5-1 – MODFLOW Model Calibration Results**

ID	Permit #	Date of Measurement	Easting (X)	Northing (Y)	Layer	Observed Groundwater Elevation (feet amsl)	Computed Groundwater Elevation (feet amsl)	Residual (feet)
4	P12441P	10/20/1964	761160.05	725584.96	1	6718	6718	0
17	P7013P	7/20/1948	745831.71	697772.72	1	6488	6467	20
21	P7438P	4/25/1929	805472.45	668069.40	1	6180	6178	2
33	P12331P	9/11/1964	894086.01	736576.10	1	6605	6633	-27
35	P3021W	9/10/1969	876755.29	754757.10	1	6990	7026	-36
39	P11151P	12/21/1942	733945.80	697680.50	1	6456	6479	-23
44	P12439P	4/14/1965	790361.48	702225.25	1	6267	6286	-20
57	P439G	5/1/1956	810532.49	783202.95	2	6503	6485	18
58	P2661P	12/21/1942	825530.78	847588.19	2	5956	5967	-11
59	P5281P	6/27/1960	697159.79	814598.51	2	5537	5520	17
60	P5282P	6/28/1960	702386.20	818646.82	2	5498	5508	-10
63	P5285P	5/12/1958	739060.00	830942.80	2	5614	5639	-25
Residual Mean		-7.935969						
Abs. Res. Mean		16.634352						
Res. Std. Dev.		17.714935						
Sum of Squares		4898.380998						
RMS Error		19.411299						
Min. Residual		-36.05543						
Max. Residual		20.276093						
Number of Observations		13						
Range in Observations		1492.74						
Scaled Std. Dev.		0.011867						
Scaled Abs. Mean		0.011144						
Scaled RMS		0.013004						



**AQUI-VER, INC.**

Hydrogeology, Water Resources & Data Services

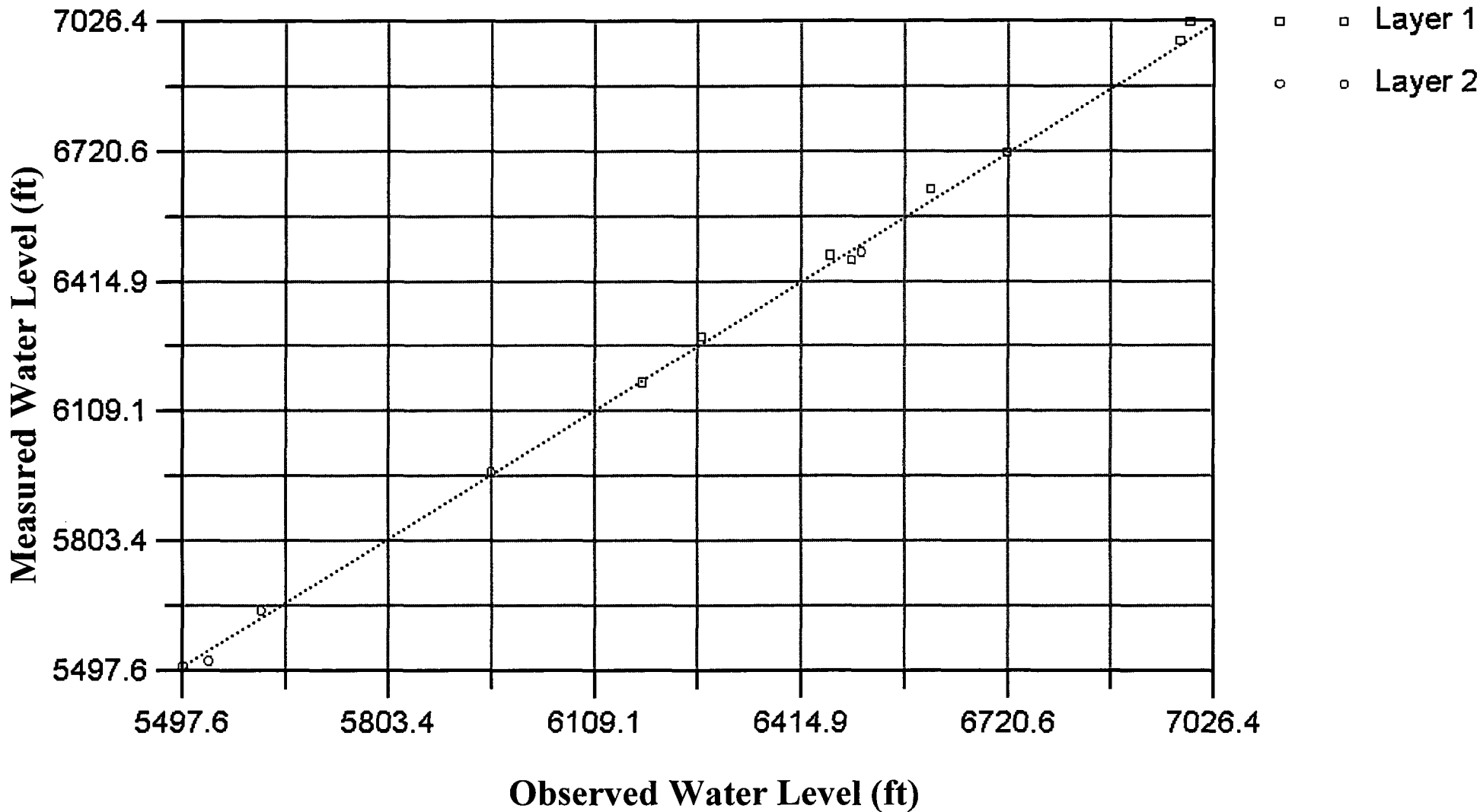
**Pre-1970 (Pre-Mining) Water Table Surface**

Hydrologic Impact Assessment – Gas Hills Facility  
Natrona and Fremont Counties, Wyoming



FIGURE:

**5-1**



**AQUI-VER, INC.**

*Hydrogeology, Water Resources & Data Services*

**Observed vs. Modeled Water Levels  
Steady-State Calibration**

Hydrologic Impact Assessment  
Gas Hills Facility  
Natrona and Fremont Counties, Wyoming



FIGURE:

**5-2**



## 6. HYDROLOGIC IMPACT SIMULATIONS

Hydrologic impacts due to the operation of the Project were simulated over an estimated 20 year development and restoration period beginning in 2014 and continuing through 2033. The Gas Hills ISR facility will include development of five Mine Units (MU-1 through MU-5) as shown on **Figure 2-2**.

### 6.1.1 Gas Hills ISR Operations

The mining and restoration schedule and water balance assumptions for the Project are provided in **Attachment A**. Mining is planned to proceed sequentially in numerical order, beginning with Mine Unit 1 and ending with the development of Mine Unit 5.

Economically recoverable uranium is present in the 30 through 80 Sands. These sand units are semi-continuous and are treated as a single production aquifer for purposes of this impact assessment. Therefore, all Project groundwater withdrawals are taken from model Layer 3, which includes all production sands. Groundwater withdrawals were simulated using a series of 3 to 5 pumping centers (wells) per Mine Unit depending on the relative size of the unit.

Groundwater withdrawals due to ISR production are assumed to be 1 percent of total wellfield production (1 percent bleed). The ISR production bleed is expected to vary from a minimum of 10 gallons per minute (gpm) to a maximum of 119 gpm. Production bleed generally increases from Development Year 1 to a maximum in Development Year 8.

Groundwater withdrawals due to ISR restoration are assumed to be 20 percent of total restoration flow (20 percent bleed). The 20 percent restoration bleed is assumed to be equivalent to the Reverse Osmosis (RO) brine reject volume for disposal (e.g. 80 percent RO efficiency). The simulated ISR restoration bleed therefore varies from 40 to 240 gpm over the life of the mine. In practice, groundwater withdrawals during restoration are likely to be reduced substantially (e.g. 5 percent restoration bleed) by recovery of condensate from a planned forced evaporation treatment system.

### 6.1.2 Initial Conditions

Prior to conducting the hydrologic impact simulation, initial conditions were established that correspond to the approximate current hydrologic conditions at the site. Pre-mining water level elevations (**Figure 5-1**) used for model calibration did not include the important impact of legacy pit lake dewatering and evaporation (drawdown) on the aquifer system. Therefore, evaporation from pit lakes was simulated using a free water surface evaporation rate of 40 inches per year, minus the average annual direct precipitation rate of 9.4 inches, resulting in a net pit lake evaporation rate of 2.55 feet per year (WRCC, 2012 and WRDS, 2012). The rate of evaporation was multiplied by the estimated surface area of the Buss Pit, Lucky Mc Pit, and PC Pit, resulting in pit lake groundwater withdrawal rates of 15, 51, and 4 gpm, respectively.

The modified flow model was run to steady-state to establish initial conditions for the impact simulation. **Figures 6-1 through 6-3** illustrate the resulting initial water level elevations used for the impact simulation. The simulated initial water level elevation for the production aquifer (**Figure 6-3**) closely approximates recent water level elevations observed in the production aquifer at the site (Cameco, 2010).

### 6.1.3 Gas Hills Impact Assessment Results

In general, maximum drawdown impacts are predicted to occur around Development Year 9, corresponding to the time of maximum groundwater withdrawals. Maximum on-site drawdown impacts are predicted to be

approximately 10-feet at the permit boundaries within the production sand aquifer, as shown by **Figure 6-4**. Drawdowns of greater than 1-foot were only observed on-site and to the north of the site in model Layer 3 (production aquifer). As shown by **Figure 6-4**, the drawdown cone in the production sand aquifer is attenuated to the south by the recharge boundary along the Beaver Rim Escarpment, and elsewhere by the presence of pit lakes that act as recharge boundaries. Drawdowns are also less significant in the eastern portion of the Project area, where the East Canyon Conglomerate is in hydraulic communication with the overlying production aquifer, resulting in increased aquifer transmissivity.

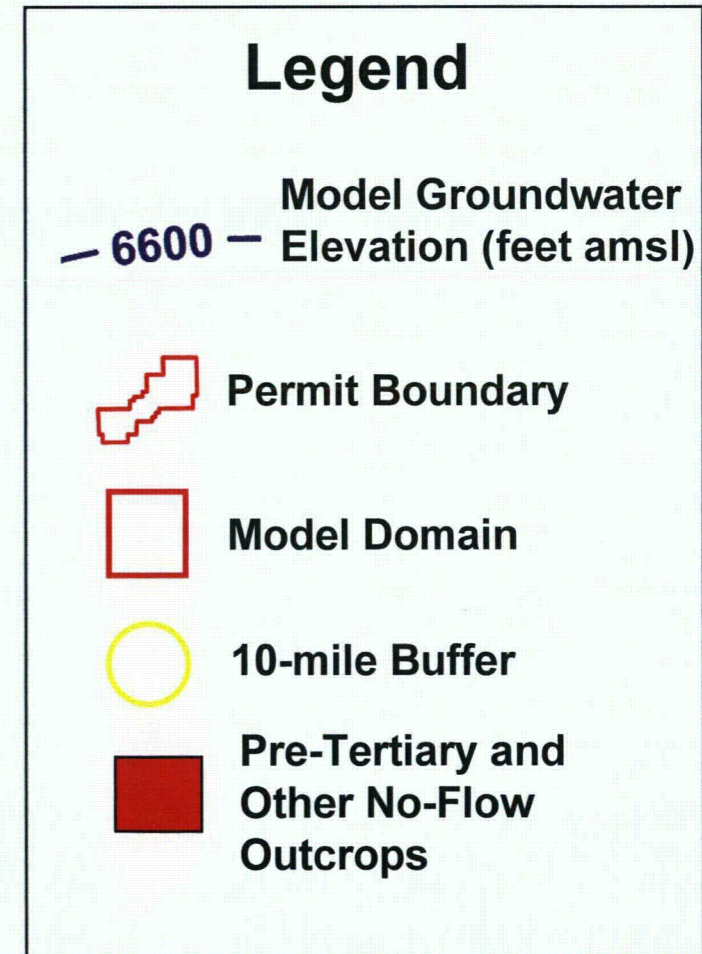
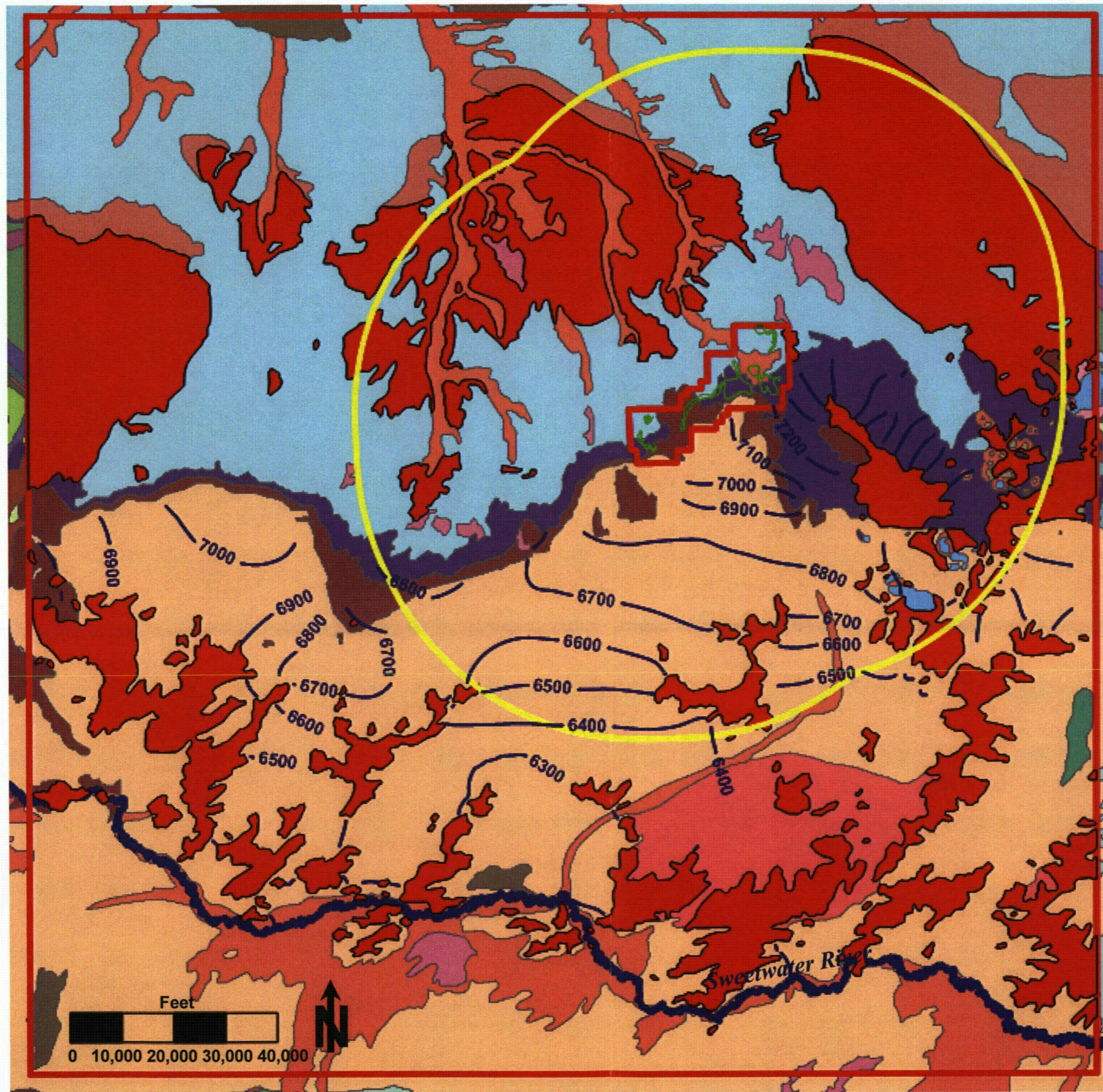
Maximum drawdown impacts are predicted to be less than 1-foot at all domestic and stock well locations. No measurable impact was observed in the Cameron Spring, which is located on-site in model Layer 1. Drawdown impacts to stock and domestic wells are limited largely because these wells are installed in the shallow water-table aquifer and are separated vertically from the production aquifer by a thick sequence of lower permeability sediments.

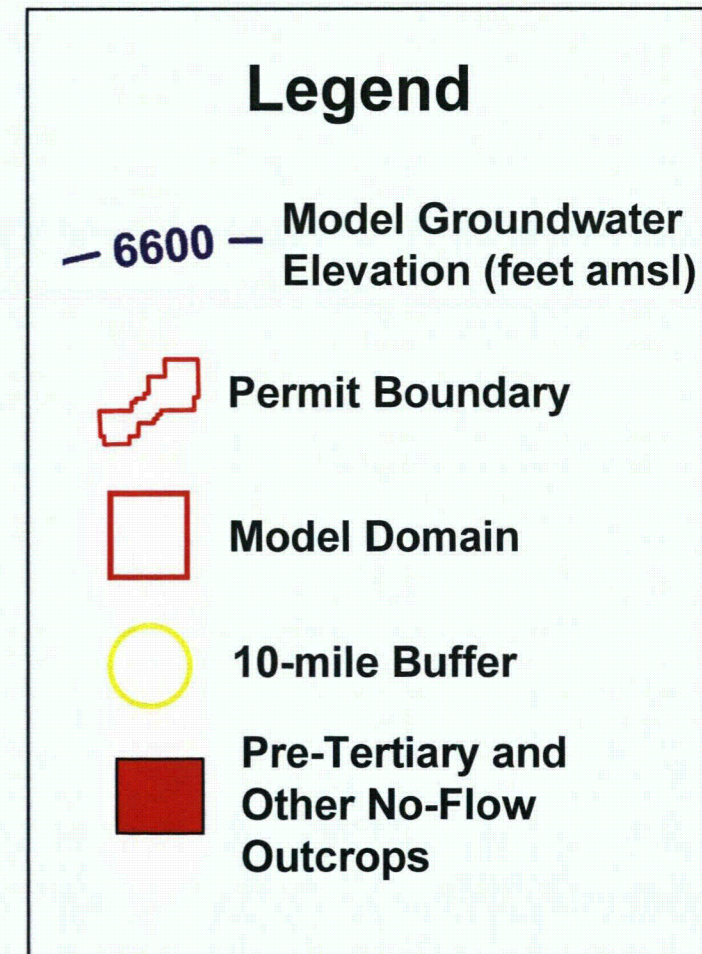
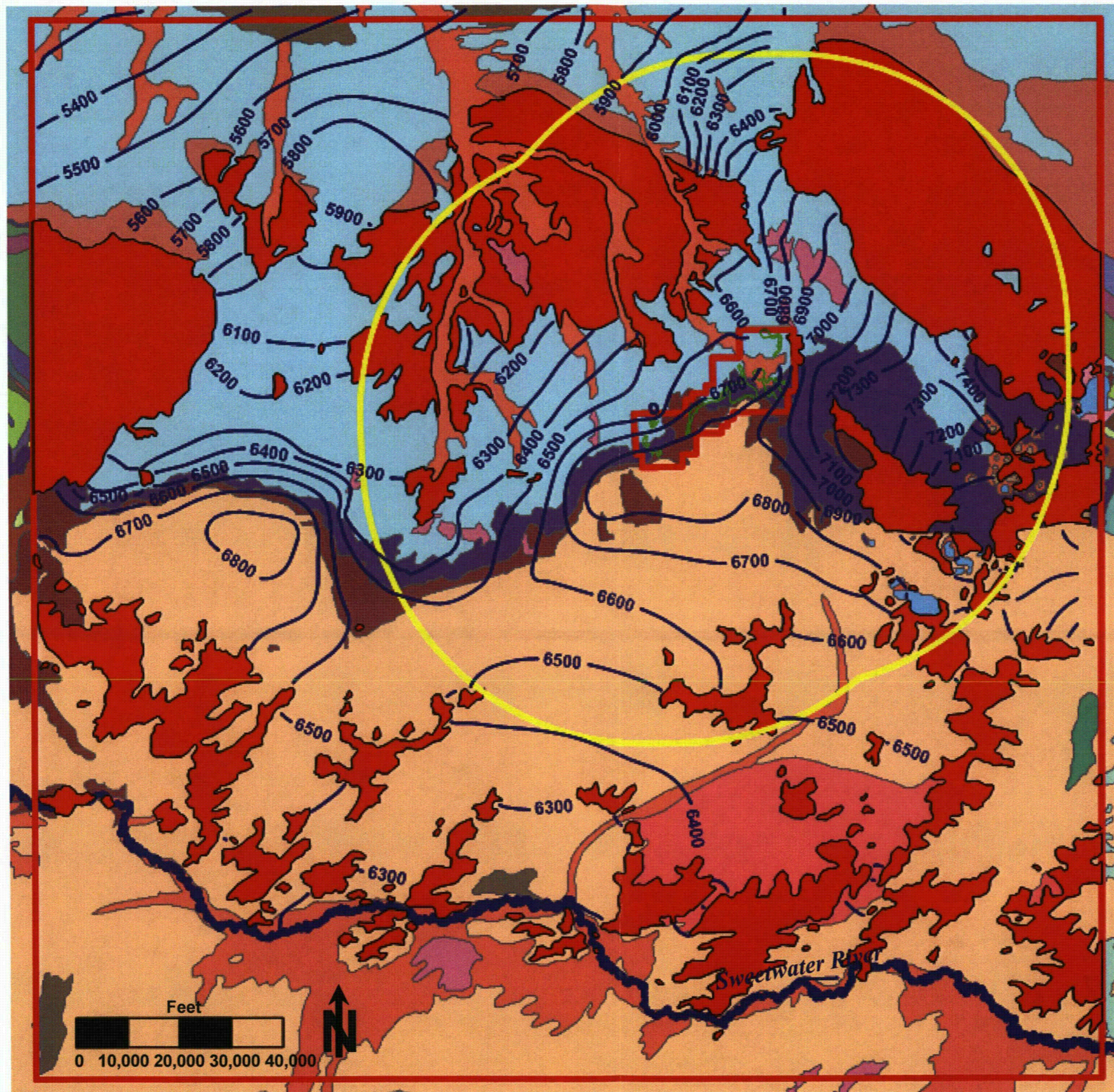
## 6.2 SUMMARY AND CONCLUSIONS

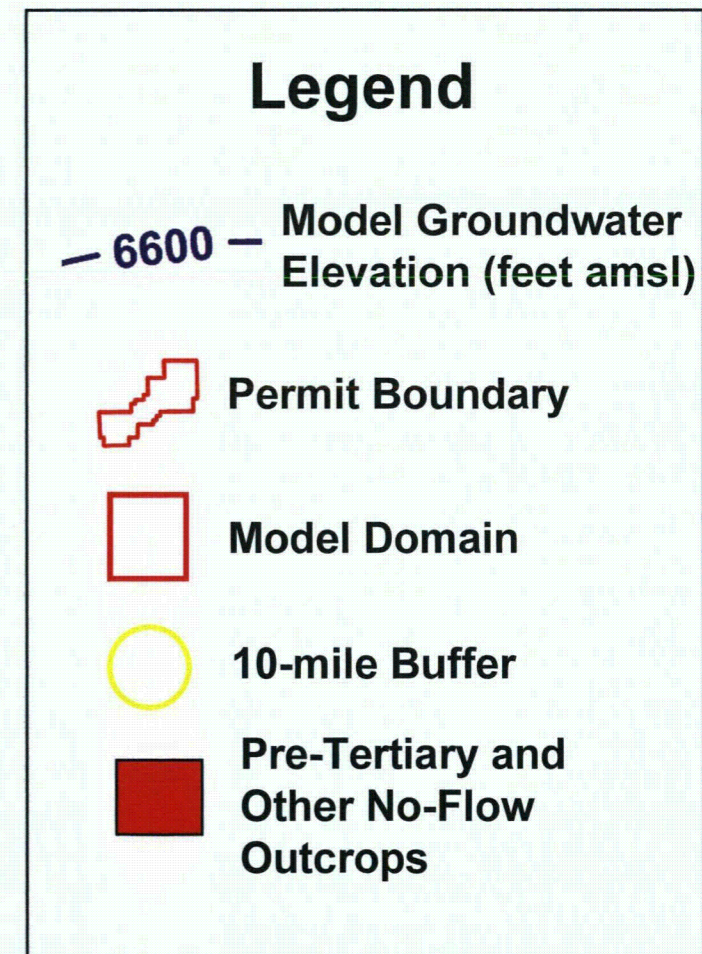
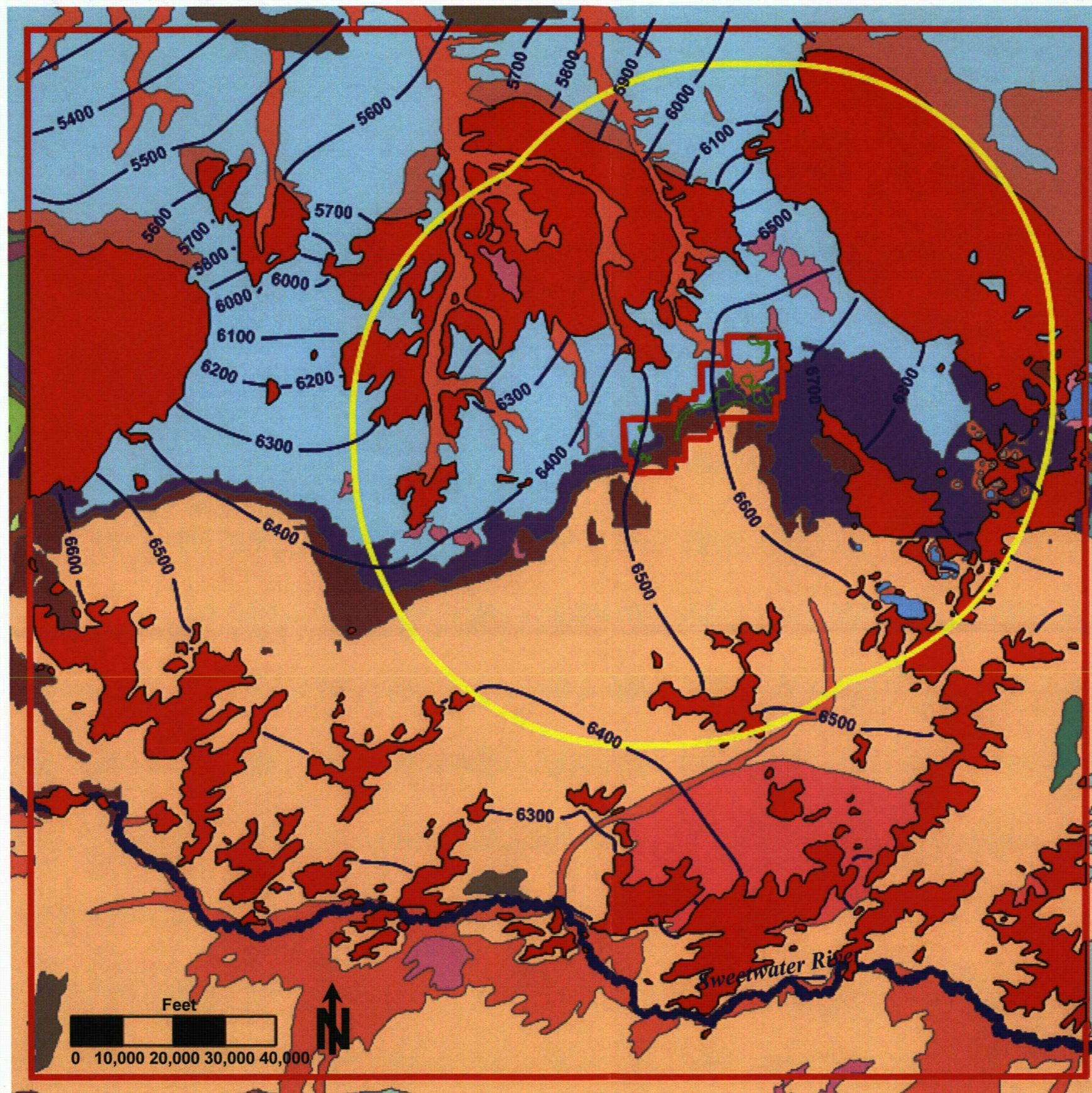
Hydrologic impacts associated with Cameco's Gas Hills ISR Project were evaluated over an estimated 20 year ISR development and restoration period. The drawdown impact computed by the groundwater flow model was evaluated at 45 water well and spring locations within a 10-mile radius of the Gas Hills facility.

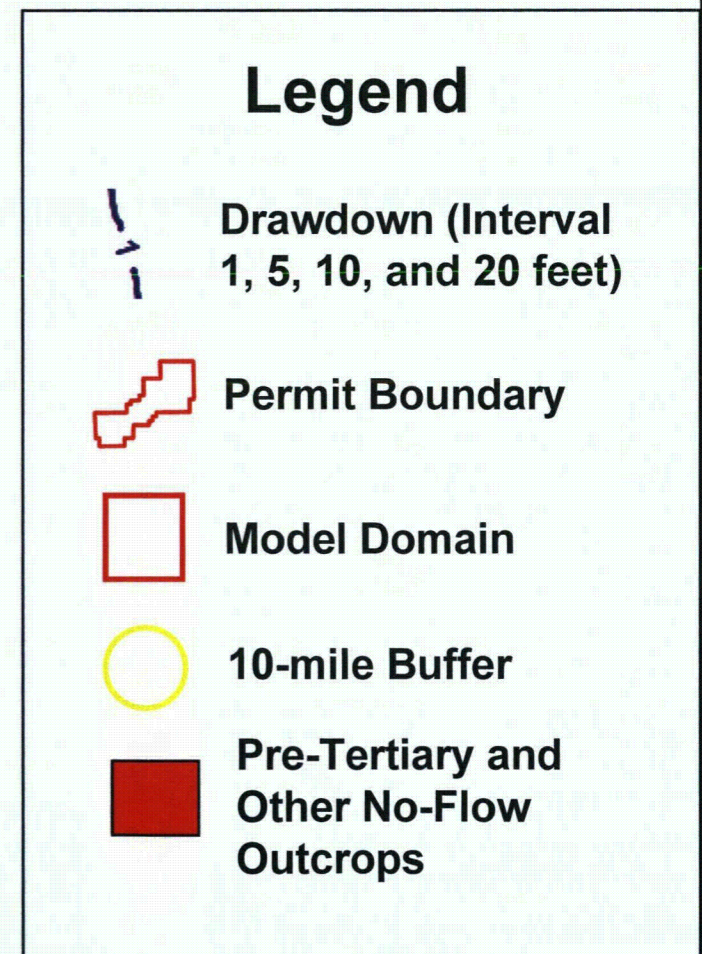
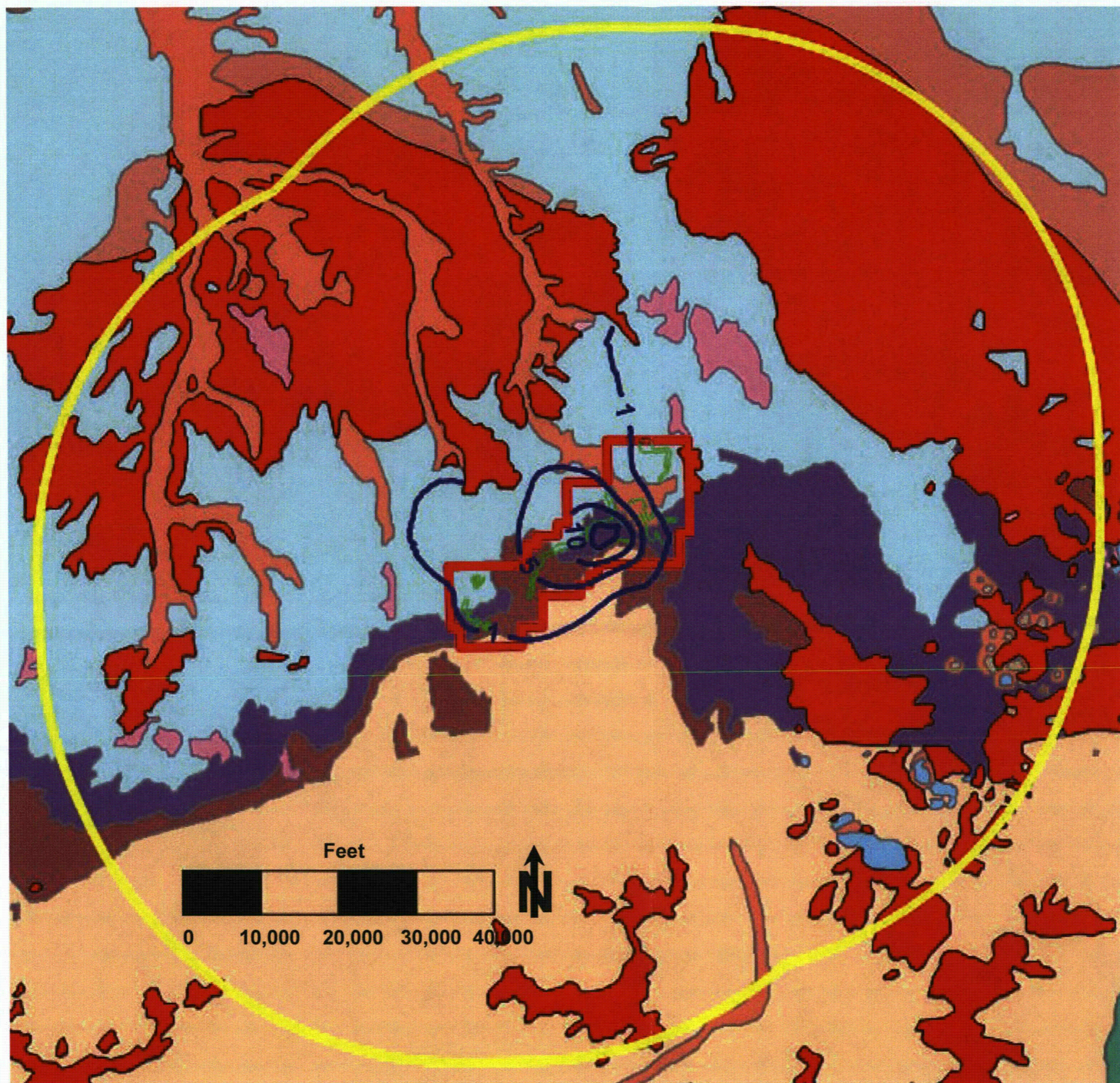
In general, maximum drawdown impacts are predicted to occur around Development Years 8 and 9, corresponding to the period of maximum groundwater withdrawals. Maximum on-site drawdown impacts are predicted to be approximately 10-feet at the Project boundaries within the production sand aquifer. Impacts to all domestic and stock wells are predicted to be less than 1-foot over the life of the mine development, with no measurable decrease in spring flows. Drawdown impacts are predicted to be relatively small primarily because stock and domestic wells are installed in the shallow water-table aquifer and are hydraulically isolated from the underlying production sand aquifer by lower permeability sediments. Drawdown in the production sand aquifer is also limited by the presence of pit lakes with large storage capacity, areas of higher transmissivity across the eastern portion of the facility, and the location of the facility adjacent to the Beaver Rim Escarpment groundwater recharge area.

There are a number of assumptions incorporated into the impact assessment that render model drawdown predictions conservative (e.g. the model is likely to over-estimate drawdown impacts). These include the absence of legacy underground mine workings in the groundwater model, and the use of conservative (maximum) groundwater withdrawal rates for the ISR Project development (1 percent production bleed and 20 percent restoration bleed).









**AQUI-VER, INC.**

*Hydrogeology, Water Resources & Data Services*

**Maximum Drawdown Layer 3 – Development Year 9**

Hydrologic Impact Assessment – Gas Hills Facility  
Natrona and Fremont Counties, Wyoming



FIGURE:

**6-4**

**REFERENCES**

Cameco Resources, 1998, WDEQ-LQD Permit to Mine Application, Appendix D-5 – Geology, Revised February 1998.

Cameco Resources, 2010, WDEQ-LQD Permit to Mine Application, Appendix D-6 – Hydrology, Revised October 2010.

Cameco Resources, 2011, Operations Plan, Gas Hills Project, Revised October 2011.

Harbaugh, A.W., Banta, E.R., Hill, M.C., and McDonald, M.G. (2000). MODFLOW 2000 - The U.S. Geological Survey Modular Ground-Water Model – User Guide to Modularization Concepts and the Ground-Water Flow Process, Open File Report 00-92

Johnson, A.I., 1967, Specific Yield – Compilation of Specific Yields for Various Materials. U.S.G.S Water Supply Paper 1662-D.

Lidstone and Associates, 2012, Personal Communication, January 2012.

Love, J.D., 1970, Cenozoic Geology of the Granite Mountain Area, Central Wyoming: U.S. Geological Survey Prof. Paper 495-C, 154p.

Richter, H.R., 1981, Occurrence and Characteristics of Ground Water in the Wind River Basin, Wyoming, Water Resources Research Institute, University of Wyoming.

WRCC, 2012, Gas Hills Wyoming Climate Summary (483801), [www.wrcc.dri.edu/cgi-bin/cliRECTM.pl?wygash](http://www.wrcc.dri.edu/cgi-bin/cliRECTM.pl?wygash)

WRDS, 2012, Wyoming Climate Atlas, [www.wrds.uwyo.edu/sco/climateatlas/evaporatoin.html](http://www.wrds.uwyo.edu/sco/climateatlas/evaporatoin.html)

Wyoming Oil and Gas Commission (2011). Electronic Database of Producing Oil and Gas Wells, September 2011.

**ATTACHMENT A**

Gas Hills ISR Project Schedule and Water Balance



**Gas Hills Production Water Balance**

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20		
<b>Production</b>																						
Mine Unit Flow (gpm)	2800	5600	7100	8500	9500	9900	11500	11900	11400	10800	10300	10000	9700	7760	6208	4346	3042	2129	1491	1043		
<b>Operation Timeframe</b>																						
Mine Unit One	[Yellow Bar]																					
Mine Unit Two		[Orange Bar]																				
Mine Unit Three			[Dark Green Bar]																			
Mine Unit Four				[Blue Bar]																		
Mine Unit Five							[Red Bar]															
Production Bleed (gpm) (Assume 1% bleed)	28	56	71	85	95	99	115	119	114	108	103	100	97	78	62	43	30	21	15	10		
<b>Restoration</b> (Assume nine CPV of treatment)																						
Mine Unit 1 (gpm) Total (Mgal.) (Annually) Total Cumulative Treated (Mgal.)	1CPV= 180 Mgal.				550	1000	1000	750														
Mine Unit 2 (gpm) Total (Mgal.) (Annually) Total Cumulative Treated (Mgal.)	1CPV= 293 Mgal.					200	450	1200	1200	1200	1000											
Mine Unit 3 (gpm) Total (Mgal.) (Annually) Total Cumulative Treated (Mgal.)	1CPV= 148.5 Mgal.											200	450	1200	200							
Mine Unit 4 (gpm) Total (Mgal.) (Annually) Total Cumulative Treated (Mgal.)	1CPV= 160 Mgal.													200	1000	1200	500					
Mine Unit 5 (gpm) Total (Mgal.) (Annually) Total Cumulative Treated (Mgal.)	1CPV= 180 Mgal. (est.)																	700	1200	1200	200	
Restoration Bleed (gpm) (Assume 20% bleed)					110	200	240	240	240	240	240	240	240	240	240	240	240	240	240	240	40	

**Definitions**

Mine Unit 1	[Yellow Bar]
Mine Unit 2	[Orange Bar]
Mine Unit 3	[Dark Green Bar]
Mine Unit 4	[Blue Bar]
Mine Unit 5*	[Red Bar]

gpm = gallons per minute  
 CPV = Contacted Pore Volume  
 Mgal= Million Gallons

# Appendix F

---

## Cultural and Historical Information (CONFIDENTIAL)