APPENDIX B
SUPPLEMENTAL INFORMATION
WATER RESOURCES (HYDROLOGY)

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LIST OF ABBREVIATIONS AND ACRONYMS

2-D	two-dimensional
3-D	three-dimensional
af/yr	acre-feet per year
cfs	cubic feet per second
CHIA	Cumulative Hydrologic Impact Analysis
D aquifer	Dakota aquifer
EA	Environmental Assessment
EIS	Environmental Impact Statement
ET	evapotranspiration
LOM	life of mine
mg/L	milligrams per liter
N aquifer	Navajo aquifer
NPDES	National Pollutant Discharge Elimination System
NTUA	Navajo Tribal Utility Authority
OSM	Office of Surface Mining Reclamation and Enforcement
PHC	Probable Hydrologic Consequences
PWCC	Peabody Western Coal Company
TDS	total dissolved solids
USEPA	U.S. Environmental Protection Agency
USGS	United States Geological Survey

APPENDIX B
SUPPLEMENTAL INFORMATION
WATER RESOURCES (HYDROLOGY)

A. IMPACT ASSESSMENT METHODOLOGY

This appendix describes the rationale and impact factors applied to assessing changes to the water resources of the study area due to the proposed action. The definition of key hydrologic impacts and the rationale for assigning impacts are described. A section also is presented that describes the analytical tools that were available for quantifying impacts, where appropriate and possible.

B. IMPACT ASSESSMENT TOOLS

SURFACE WATER

Chapter 18, Probable Hydrologic Consequences (PHC) in the approved Kayenta Mine permit application package (PAP) for the Kayenta Mine permit No. AZ-0001D provides detailed impact analyses on surface water flow and water quality. The PHC addresses potential impacts on runoff in Moenkopi and Dinnebito Washes at points just below the downstream portion of the Peabody lease area and for each entire basin at their confluence with the Little Colorado River. OSM recently updated the Cumulative Hydrologic Impact Assessment (CHIA) to evaluate the potential for damage to the hydrologic balance outside the Kayenta Mine permit area (USDI 2008). The hydrologic balance is the relationship between the quality and quantity of water inflow to, and water outflow from, a hydrologic unit such as a drainage basin or aquifer. The 2008 CHIA includes updated water resource information and determines potential mining-related hydrologic impacts on the existing and foreseeable water uses. The Cumulative Impact Area for surface water includes the uppermost portions of the Moenkopi and Dinnebito Wash watersheds down to a point in each wash that encompasses all of the potentially impacted areas of mining related activities within the Peabody lease area.

The assessment of impacts on surface water in this EA used data and analysis presented in the PHC of the Kayenta Mine PAP. Design drawings for typical sedimentation ponds, impoundments, and diversions as approved by OSM were utilized for assessing surface water impacts as appropriate. Potential impacts to surface water runoff were evaluated using data collected at gaging stations operated by the United States Geological Survey (USGS), and by Peabody Western Coal Company (PWCC) in accordance with procedures approved by OSM as described in Chapter 16, Hydrologic Monitoring Program in the Kayenta Mine PAP. Other runoff volumes were estimated using the program SEDIMOT II. SEDIMOT II was also used to predict the suspended sediment concentration of runoff entering the major washes (PWCC, 2005). Other water-quality impacts were evaluated using data collected by PWCC in accordance with methods described in Chapter 16, Hydrologic Monitoring Program.

GROUNDWATER

The effects of groundwater pumping for the Kayenta mining operation on the shallow aquifers (Wepo and stream alluvium) and on the deeper Navajo aquifer (N aquifer) have been investigated in numerous studies. Evaluation of project effects on groundwater considered information available from these studies and models and are discussed below.

B.1.1 Wepo and Alluvial Aquifers

Potential groundwater impacts of the mining plan were assessed for this EA using a variety of methods. Inflow to the mining pit from the Wepo Formation (coal) aquifer was assessed using an analytical model based on the constant drawdown, variable-discharge formula for confined aquifers (Jacob-Lohman method, in Kruseman and de Ridder 1994). Other modeling was accomplished using the computer code TWODAN.

Tests on wells drilled into the Wepo aquifer indicate transmissivity values of between 0.07 and 1,990 gallons per day per foot. This large range indicates considerable heterogeneity in hydraulic conductivity, consistent with a deltaic depositional environment. Reported storage coefficients for the Wepo aquifer are between 1.9×10^{-5} and 1.45×10^{-4}, indicating confined or delayed yield conditions in the area of the test wells. PWCC has evaluated the hydrogeology of water flow to the open pits from the Wepo aquifer using simple models, which assume homogeneous hydrostratigraphy (PWCC 2005). Aquifer testing indicated that some flow in the Wepo aquifer is confined and that coal beds act as confining layers in some sequences. In general, however, groundwater modeling assumed that the alluvial and Wepo aquifers were hydraulically connected and, upon excavation, groundwater would flow towards the face of the mine pits. Wepo-aquifer water from background wells located a significant distance from the area disturbed by mining indicates median sulfate concentrations may be as high as 1,100 milligrams per liter (mg/L).

B.1.2 N Aquifer

N Aquifer Description

The N aquifer includes the Navajo Sandstone, sandstones of the Kayenta Formation, and the Lukachukai member of the Wingate Formation. The N aquifer consists of 4 million acres within the Little Colorado River basin. The aquifer is composed of fine-grained sandstone alternating with siltstone and ranges in thickness from a few feet to 1,300 feet thick (Farrar 1979). The average thickness of the aquifer is approximately 400 feet (Eychaner 1983). Groundwater primarily occurs in the Navajo sandstone, where the total water in storage has been estimated at 166 million acre-feet (Eychaner 1983). Transmissivity values in the N aquifer range from 560 to 2,600 gallons per day per foot and storage coefficients are estimated to range from 0.00022 to 0.008 for the confined portions of the aquifer and 0.10 to 0.15 for the unconfined aquifer areas (PWCC 2005).

The underlying Kayenta and Wingate Formations also contain water, and a volume of 450 million acre-feet was calculated from the 3D flow model developed by GeoTrans and Waterstone for PWCC (1999). Recharge to the N aquifer occurs primarily from precipitation falling on outcrops of the Navajo sandstone and is estimated to range between 2,500 and 3,500 af/yr (for the outcrop area north of Black Mesa) to 20,248 af/yr (Brown and Eychaner 1988 ; Eychaner 1983; GeoTrans 1987; Lopes and Hoffman 1997; and Zhu 2000), with a median recharge rate of 13,000 af/yr. Most of the N aquifer is confined in the center of the basin. As recharge is largely limited to the margins, water levels in the N aquifer throughout most of the basin do not respond to short-term changes in recharge. However, water levels in the recharge areas can respond to precipitation events.

Recharge of this system generally occurs in the north-central part of the aquifer, north and west of Kayenta, where N aquifer formations are exposed at the land surface and precipitation is relatively high. Some N aquifer groundwater flows to the northeast, where it discharges into Laguna Creek; to the northwest where it discharges into Navajo Creek; and to the southwest where it discharges into Moenkopi Wash and other washes southwest of the PWCC lease area. Navajo Creek is separated from the N aquifer underlying the Black Mesa basin by a 40-mile wide unconfined area, which isolates Navajo Creek from any pumping effects in the aquifer beneath Black Mesa (see Figure D-2).

Perennial stream reaches and springs occur along washes in the unconfined part of the N aquifer, and could be affected by groundwater pumping from the N aquifer. Areas of groundwater discharge that have been modeled to assess potential impacts due to pumping include:

- Chinle Wash
- Laguna Creek
- Pasture Canyon
- Moenkopi Wash
- Dinnebito Wash
- Oraibi Wash
- Polacca Wash
- Jaidito Wash
- Begashibito Wash/Cow Springs

In the 1989 CHIA, N aquifer groundwater impacts were analyzed using a reconstructed version of the USGS groundwater model of Eychaner (1983). The model used in the 1989 CHIA was a two-dimensional (2-D) model of the N aquifer system based on MODFLOW (Brown and Eychaner 1988). PWCC commissioned HSI GeoTrans and Waterstone to develop a three-dimensional (3-D) groundwater flow model of the N aquifer and Dakota aquifer (D aquifer) (PWCC 1999). These models are described below.

- ***USGS Black Mesa Model***. The USGS developed a finite-difference model of the N aquifer in 1983. This model was upgraded, including reformatting to the MODFLOW code, in 1988 by Brown and Eychaner and again in 2000 to reflect 1999 conditions. The model was designed to evaluate the impacts of current and future groundwater withdrawals for PWCC coal mining, as well as municipal withdrawals from surrounding Indian communities.

  The model is 2-D and is comprised of one layer that represents the N aquifer. A general head boundary was used to simulate vertical flow between the D aquifer and N aquifer. The model was calibrated to equilibrium conditions (pre-1965) and to transient conditions (1965-1984). The aquifer's response to pumping was predicted to 2051 for five pumping alternatives.

  This model has undergone the most extensive peer review of the available models. It is generally recognized as providing a reasonable simulation of the N aquifer's response to pumping.

- ***GeoTrans D and N Aquifer Model***. PWCC retained HSI GeoTrans and Waterstone to develop a finite-difference model of the D and N aquifers using the MODFLOW numerical code (PWCC 1999). This is a regional 3-D groundwater flow model developed to estimate the effects of pumping by PWCC and several Indian communities on the aquifers and on surface water flows.

The GeoTrans model covers a slightly larger area than the USGS model. Additional hydrogeologic field data were collected and compiled as part of studies to develop the model. The model has seven layers and simulates the D aquifer, N aquifer, and intervening Carmel Formation aquitard. Recharge is estimated through a complex function of precipitation, soils, and topography. Predevelopment water levels (1956) were used for steady-state calibration of the model. Initial transient calibration used 1956 to 1996 water levels. The model has undergone extensive sensitivity testing and validation. Evaluation of the model indicates that it successfully simulates historic water-level response to pumping in the N aquifer. It also produces N aquifer drawdowns that are essentially the same as the USGS model.

Both the USGS and GeoTrans models estimate changes in groundwater levels and aquifer discharge over time. Aquifer discharge occurs primarily through discharge to streams and springs. However, neither model attempts to simulate individual spring flows, which typically occur within a limited local area. This is due to (1) the regional nature of the models (including grid size); (2) the lack of detailed hydrogeologic information on individual springs, including measured spring flow; and (3) the limited drawdown in the unconfined area of the aquifer where springs occur (PWCC 1999). The models do simulate groundwater discharge to streams on a regional scale where discharge occurs over many miles of stream reach. This discharge is essentially made up of multiple spring discharges, in that groundwater is moving into the stream channel or alluvium, such as at Begashibito Wash/Cow Springs, discussed previously. In an arid environment such as Black Mesa, not all of this groundwater discharge appears as stream flow; much of it is evapotranspired or becomes alluvial-aquifer subflow.

OSM independently reviewed the GeoTrans model and determined that the model satisfies the intended objectives and is the most comprehensive groundwater assessment tool for predictive impact evaluations necessary to address concerns related to PWCC's pumping of the N aquifer. For the following reasons, the GeoTrans model, rather than the USGS model, is used to describe the impacts (water-level and streamflow changes) due to N aquifer pumping scenarios evaluated in this EA:

- It has a more comprehensive inclusion of hydrologic features and multiple aquifers;
- It has a finer grid spacing, which allows for a more accurate simulation of pumping effects near both the mine and adjacent communities;
- It incorporates more recent data on water levels and withdrawals;
- It examined a longer historical data period (beginning in 1956 rather than 1965);
- It provides a more detailed characterization and analysis of system recharge;
- It evaluates geologic structure that influences groundwater flow;
- It provides better model boundaries and increases the model extent; and
- It provides a more complex definition of the hydrologic system, using additional model layers to simulate the D aquifer system.

Groundwater models are widely acknowledged to be "non-unique." Different models (boundary conditions, geometries, material properties, solution techniques) can produce equally good agreement with available information. However, they may yield different results when used to make predictions. Therefore, after the base model was developed by GeoTrans and Waterstone, three additional models that used different assumptions for recharge rate and upland evapotranspiration (ET) were also calibrated to determine if different water-budget assumptions had much of an effect on the predictions made by the models. This effort determined that although the modeling results were slightly different, the impact on the predictions was very minor. Because more effort had been spent calibrating the base-case model, its agreement with water-level data was slightly better than the agreements of the other three models, and the base-case model has been adopted for the predictions used in this EA.

An important aspect of using models to guide resource management decisions is to evaluate whether the model results agree with data not used to calibrate the model, such as newly collected water-level data. If the agreement is good, confidence in the model's predictive ability is increased. However, if the agreement is poor, the need for additional calibration work is indicated.

The accuracy of the 3D model to simulate water-level changes beyond the calibration period was tested using pumping and water level data through 2009, which includes the period beginning in January 2006 when PWCC pumping was considerably less than in previous periods. Water-level data from the BM-series wells and annual community pumping data were obtained from USGS through the end of 2009. Monthly pumpage data from each of the PWCC production wells were used in the simulations.

Simulations were performed using the four different models described in PWCC (1999). As mentioned above, these four models, each individually calibrated, use a combination of two different recharge rates and two different upland (non-stream) discharge values simulated using different maximum ET rates. For the model validation tests, only the pumping rates for the period 1997 through 2009 were updated from the 1999 report; no other changes were made to the modeling data sets.

In the following temporal drawdown figures, the drawdown is calculated based on the time of the first available measurement in the indicated well. Errors in the first measurement would affect the calculation of the measured drawdown values. The effects of errors may be greatest at BM-3, which displays considerable variation in water level because of local pumping.

Figures B-1 through B-6 provide comparisons of measured and predicted drawdown for the four models for the BM-series wells through 2009. At BM-1, the agreements of the two models using the full recharge values are better than for the two models using half the full recharge values; the base case provides the best fit to the data. There is a measured long-term trend of declining water levels, with less than 1 foot of decline over more than 30 years. All four of the models predicted more drawdown for the calibration period than was actually observed. Thus, it is expected that they continue to predict more drawdown than has actually occurred.

At BM-2, the predicted drawdowns for the four models are about 15 feet less than the total drawdown observed over the calibration period. The agreement between measured and simulated drawdown appears to have improved after about 1992, and all four models do a reasonably good job of approximating measured drawdown through the end of the calibration period. The base case and low upland discharge models provide the best fit to measured data. In recent years, measured drawdown has been occurring more rapidly than predicted drawdown. The simulations show a small response to the reduction in pumping by PWCC in 2006. The measured values show that the rate of drawdown has decreased but that water levels have not yet started to rise.

The comparison of simulated and measured values is more difficult at BM-3 because the impacts of variable local pumping and the resultant high variability of water levels in the well. The four models approximate the measured water level changes equally well. The low upland discharge model provides better simulation results to an increase in drawdown between approximately 1977 and 1984 than the other three models. Although variability in the measured values makes comparison with the simulated values uncertain, the four models appear to simulate a slightly greater rate of drawdown than the measured values from end of calibration through 2009. Effects of reduced pumpage by PWCC are not apparent in the data. The simulations show a slight decrease in the rate of drawdown.

Little change has occurred in water-level measurements in BM-4. A decline in water levels of approximately 1 foot occurred between 1998 and the beginning of 2003, but levels increased back to pre-1998 levels, and then began to decline again. The cause for the short-term decrease is not known. The models are beginning to simulate a small (<0.1 foot) amount of drawdown at this well.

The most recent 13 years of water level data (since the end of the calibration dataset) at BM-5 are approximated very well by the four models, although the agreement of the full recharge/low ET model is not quite as good as the other three. The rate of drawdown at the well has decreased slightly since PWCC pumping decreased at the end of 2005. Water levels at BM-5 will likely remain depressed due to nearby community pumping centers. The models match this change well.

At BM-6, the full recharge/low ET model simulates about 20 percent less total drawdown than that measured over the calibration period, and less than the other three models. The rates of change calculated by the other three models agree quite well with the measured rate of change, although the base-case (full recharge/ET) and the half-recharge, low upland discharge models provide the best overall fit to the calibration data. The reduction in PWCC's pumping at the beginning of 2006 is apparent in the data and the simulation results, with the models having a slightly earlier and slightly faster recovery than the measurements. From the end of calibration through 2007, the base-case and half-recharge, low upland ET models continue to provide the best fit to the measured drawdown. The agreement between measured drawdown and the predicted drawdowns calculated from these two models over this time period indicates that the two models should reliably predict drawdown for many years.

The four models match the observed water-level changes at the six BM monitoring wells reasonably well. The base-case model provides the best overall fit. The comparisons indicate that model recalibration is not warranted at this time, and support the ability of the models to reasonably predict the effects of pumping by PWCC within the groundwater basin.

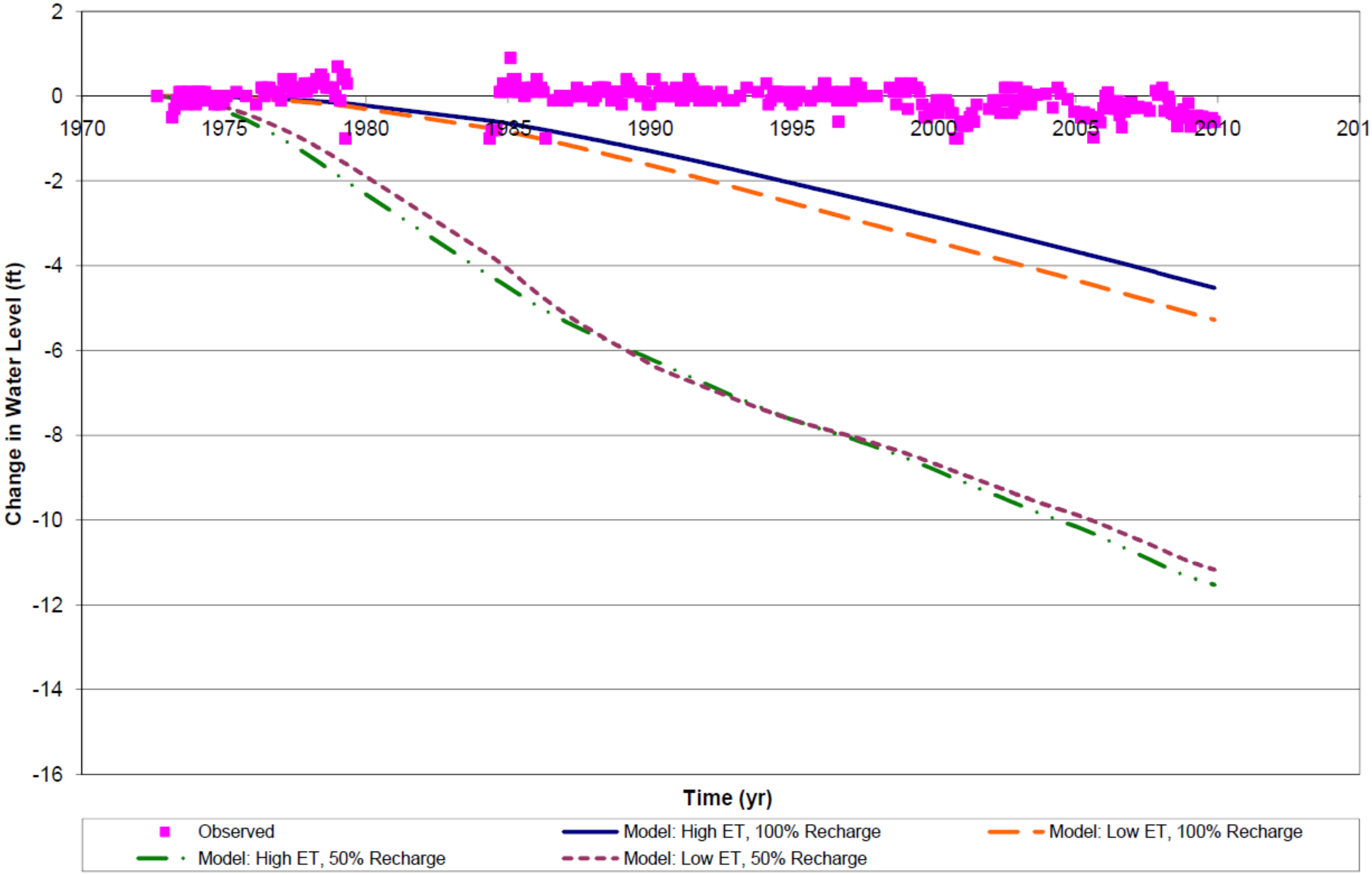


Figure B-1 **Simulated and Measured Drawdown at BM-1**

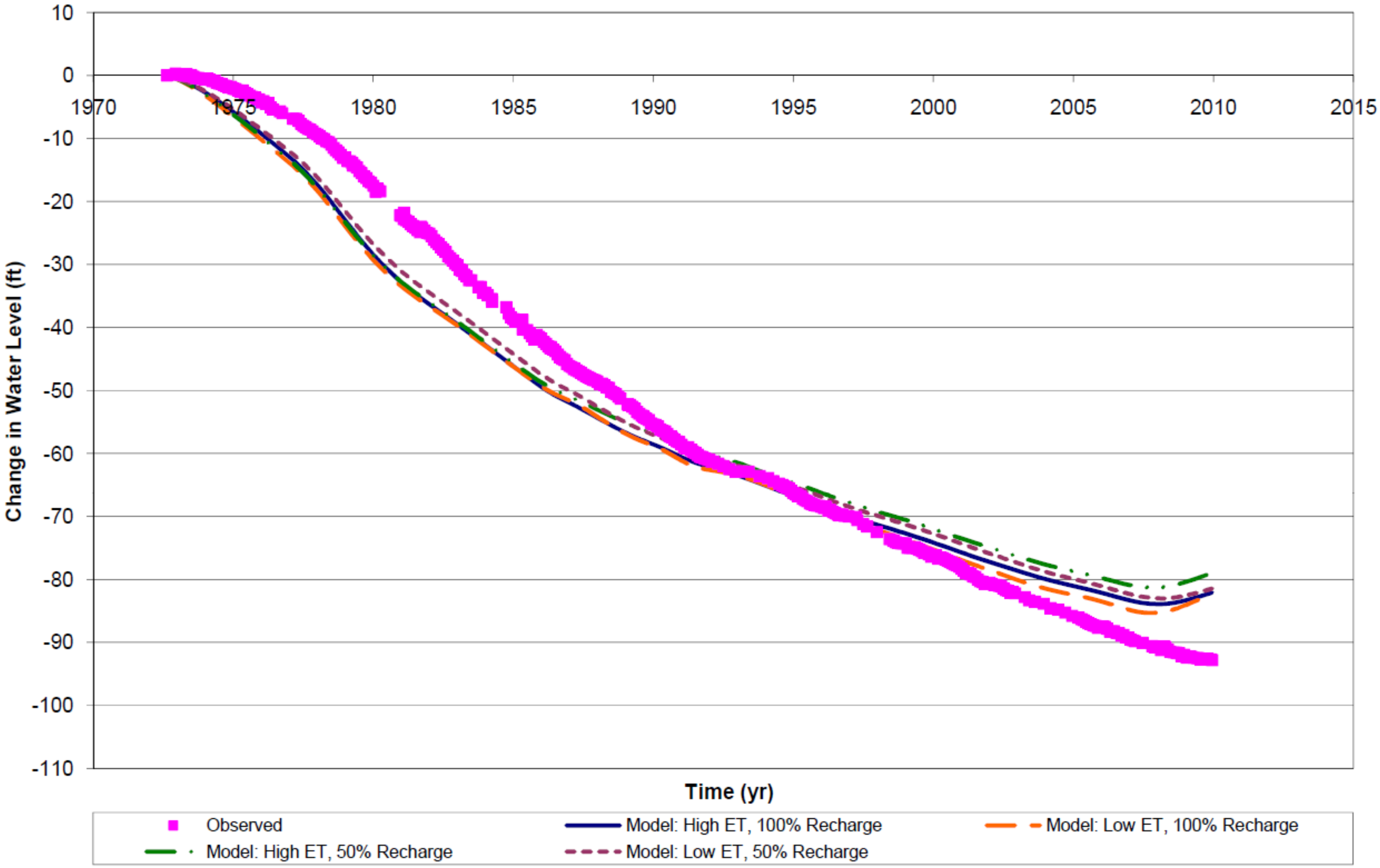


Figure B-2 Simulated and Measured Drawdown at BM-2

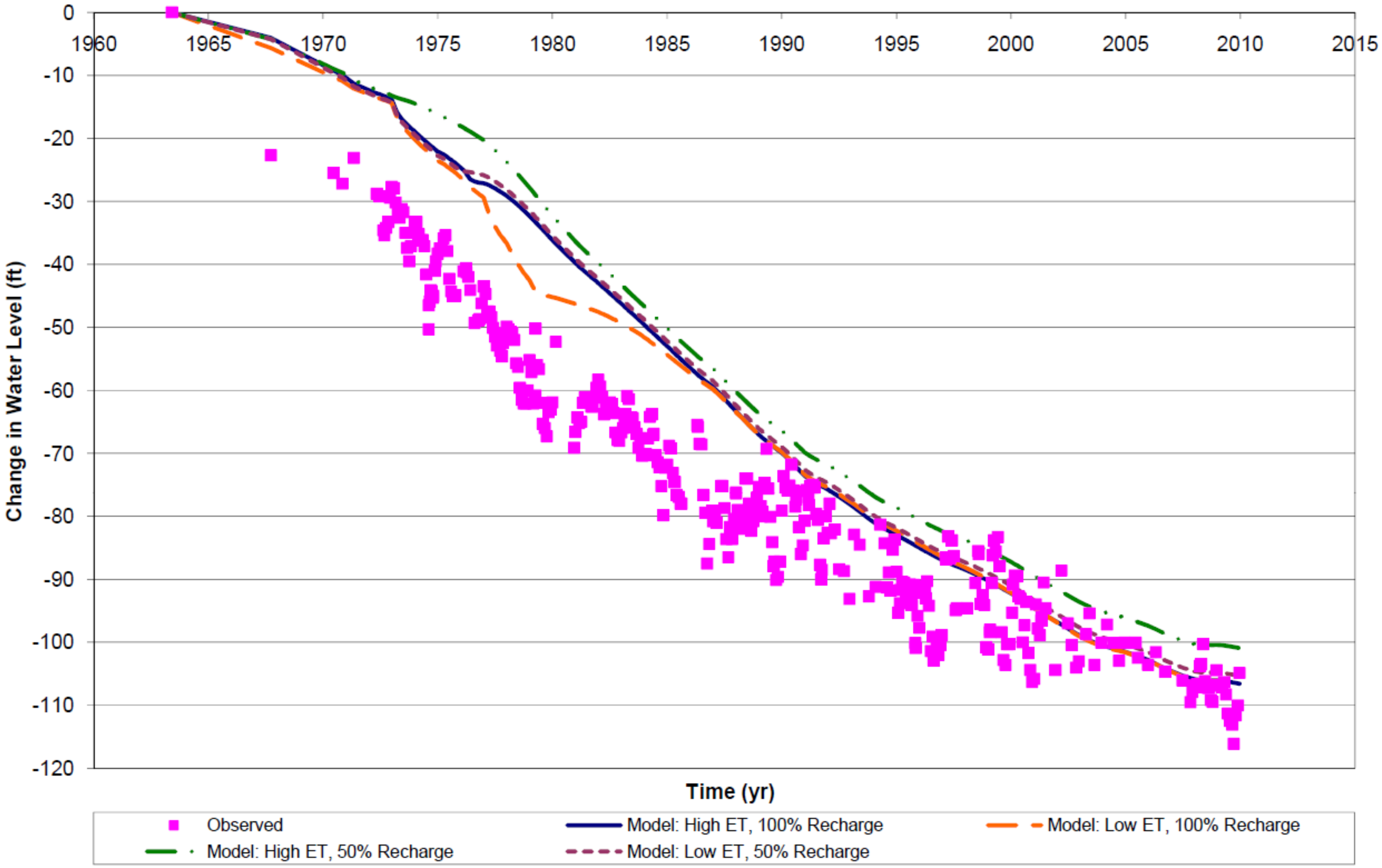


Figure B-3 Simulated and Measured Drawdown at BM-3

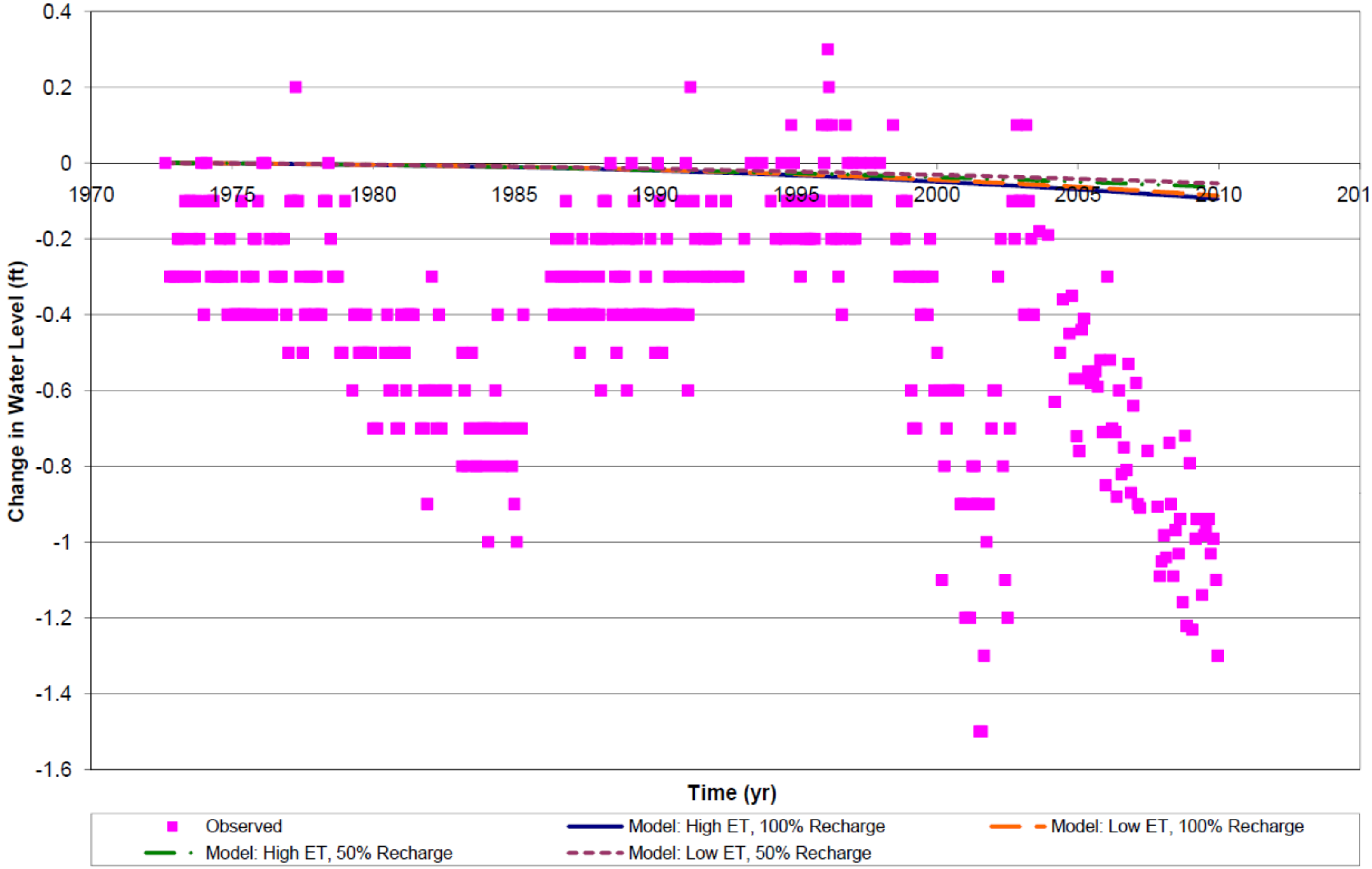


Figure B-4 Simulated and Measured Drawdown at BM-4

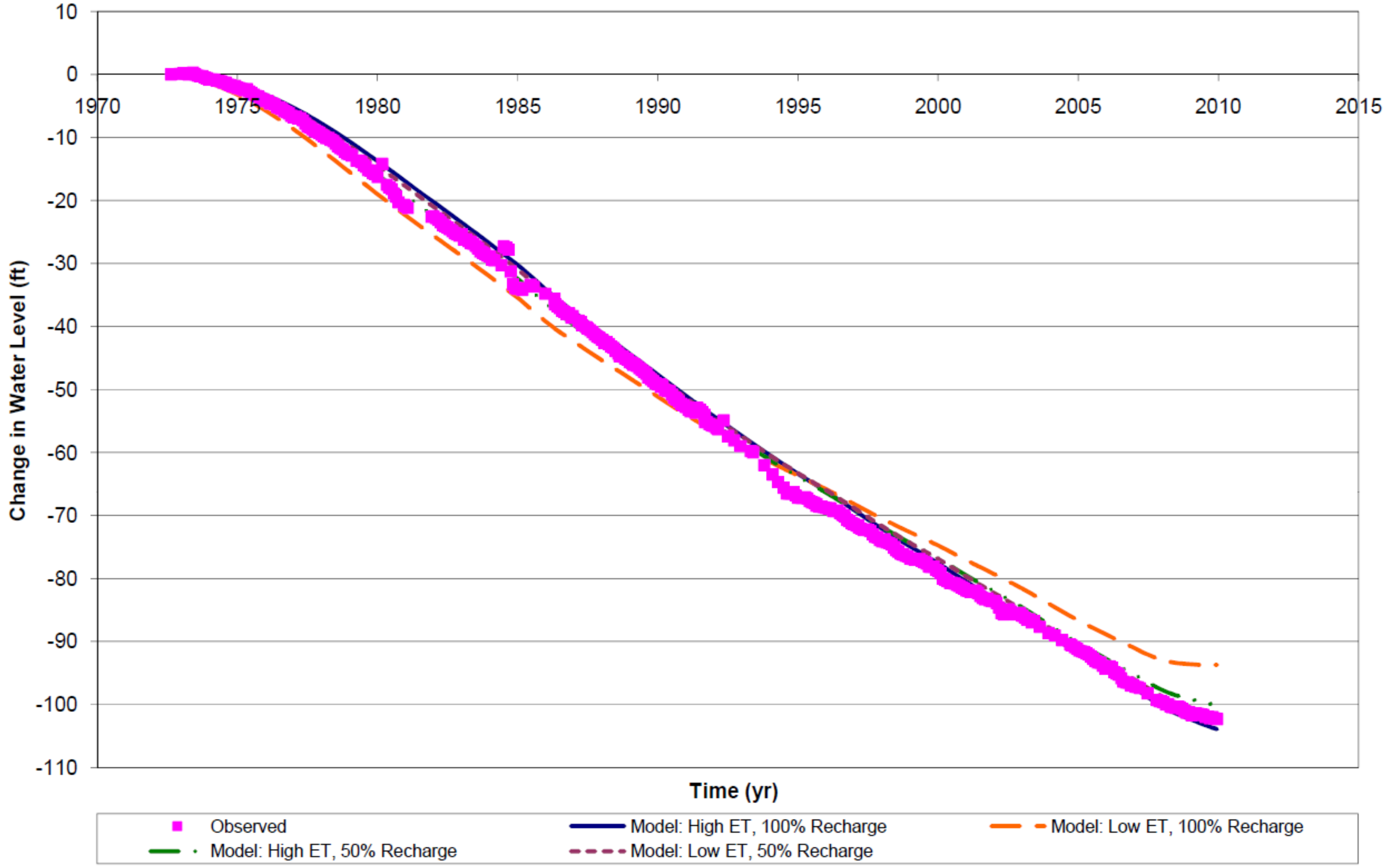


Figure B-5 Simulated and Measured Drawdown at BM-5

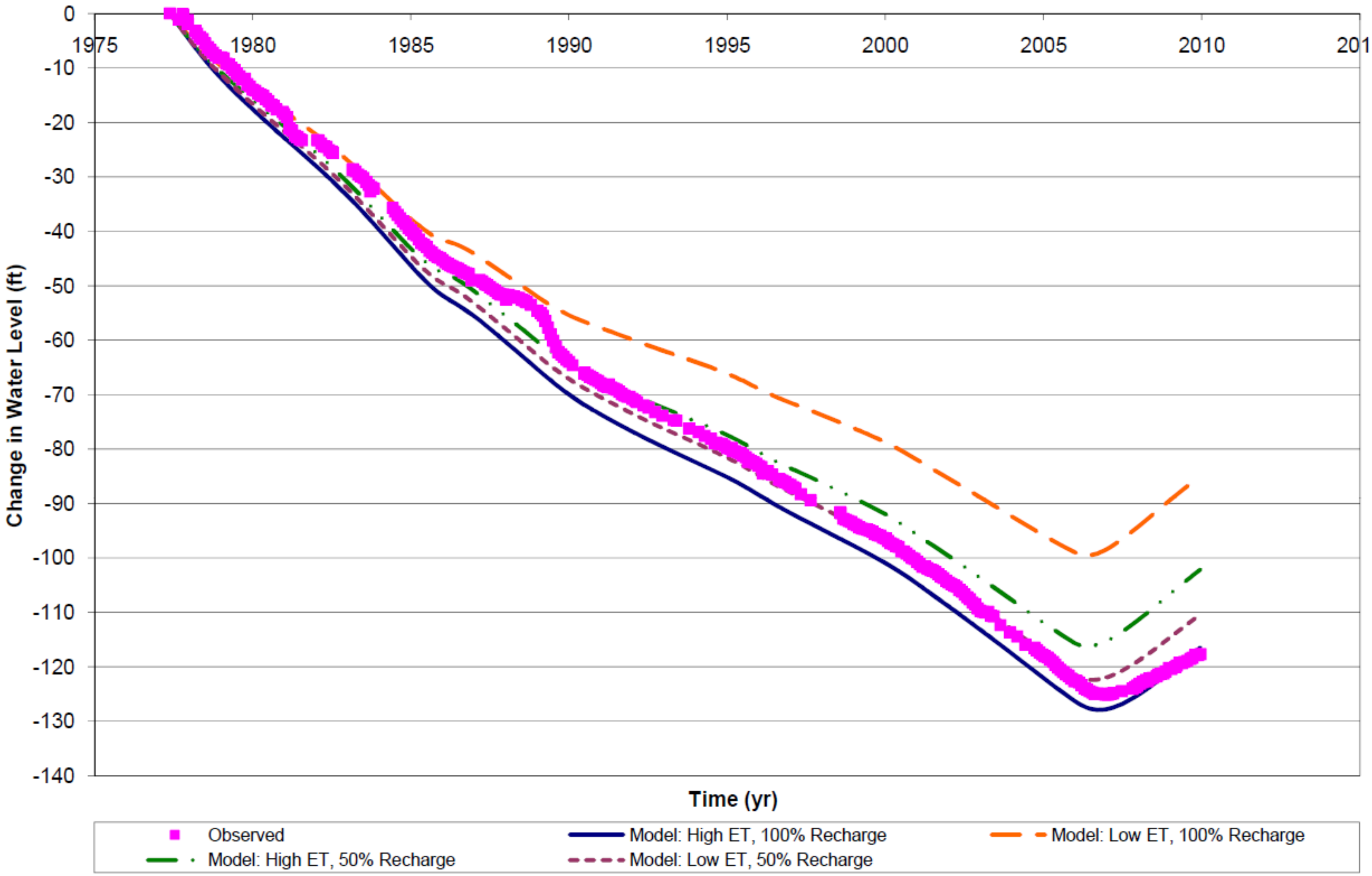


Figure B-6 **Simulated and Measured Drawdown at BM-6**

C. HYDROLOGIC IMPACTS

REGION OF INFLUENCE

C.1.1 Groundwater

The primary region of influence from groundwater pumping is the area that would be impacted by the projected drawdown caused by that pumping. As a practical matter, the area might reasonably be defined as the area within the 0.1-foot drawdown contour under the maximum pumping scenario, as this is the lower limit of what is assumed to be potentially measurable (water levels are often measured to 0.01 foot; however, this is arguably within the measuring error of most commonly used equipment). Furthermore, ambient water-level fluctuations due to tides, barometric pressure, and temperature changes usually exceed 0.01 foot and even 0.1 foot, making it difficult if not impossible to measure changes relative to ambient conditions.

For the N aquifer, the region of influence includes the confined area of the aquifer and extends to the gauges on measured streams and springs located in the unconfined portions of the aquifer. Gauged streamflow data are available for four washes that are supported by N aquifer discharge—Moenkopi Wash, Laguna Creek, Dinnebito Wash, and Polacca Wash. Measured N aquifer springs include Moenkopi School, Pasture Canyon, Burro, and the unnamed spring near Dennehotso (U.S. Geological Survey [USGS] 2005). Location of the washes, springs, and other key features relative to the N aquifer well field are shown on Map D-2.

C.1.2 Surface Water

The region of influence encompasses Moenkopi and Dinnebito Washes at points just below the downstream portion of the Peabody lease area and for each entire basin at their confluence with the Little Colorado River.

C.1.2.1 Key Hydrologic Impacts

Hydrologic impacts can be summarized under three key types. These include:

- impacts of drawdown on the aquifer and other water users;
- diminution of stream and spring flow; and
- changes in groundwater and surface water quality.

C.1.2.2 Impact Levels

In assessing the principal hydrologic impacts it is necessary to assess the severity of an impact. This is accomplished through the assignment of an *impact level* to the identified impact. Impact levels for hydrology are defined below.

- *Major* – Adverse impacts: effects that result in a violation of water-quality standards or that economically, technically, or legally eliminate use of the resource. Beneficial impacts: those that would improve water quality or contribute to or restore water resources capability to the region, such as to greatly increase the potential for human or ecological use.
- *Moderate* – Effects that are outside of the random fluctuations of natural processes but do not cause a significant loss of the use of the resource. Moderate beneficial impacts would simply extend the beneficial use beyond natural variations about the current mean value.
- *Minor* – Changes that would affect the cost or quality but not the use of water or are similar to those caused by random fluctuations in natural processes.
- *Negligible* – Impacts of less magnitude, but still predictable under current technology (e.g., computer models) or measurable under commonly employed monitoring technology.
- *None* – Effects that are not predicted or cannot be measured.

Assignment of the impact levels is based on analysis and professional judgment. In general this study follows the impact evaluation criteria developed for the Bureau of Reclamation's Assessment of Western Navajo and Hopi Water Supply Needs, Alternatives and Impacts (HDR 2003). The analysis and determination of impact levels for each of the key hydrologic impacts are described below. It should be noted that the hydrologic impacts in this section focus on the quantity and quality of surface and groundwater available for municipal, irrigation and industrial uses; it is understood, however, that other uses, such as for fish and wildlife are also important. Impacts on these uses have impact values developed separately (see Section E.1).

C.1.2.3 Impacts of Drawdown on the Aquifer and Other Water Users

The impact of pumping is commonly measured by a projected lowering of the water level in the pumping wells and in wells located within the cone of depression created by the pumping well(s). The lowering of the water level creates five primary effects, as follows:

- Increase the cost of pumping by increasing the lift to get the water to the land surface.
- In unconfined aquifers a reduction in saturated thickness of the aquifer surrounding the well and consequently the transmissivity (ability of the aquifer to transmit water to the well). In severe cases, a well can cease to produce water or "go dry."
- In confined aquifers a reduction in saturated thickness of the aquifer surrounding the well if the water level drops below the top of the aquifer and consequently reduces the aquifer transmissivity.
- Lowering of aquifer water levels in the area of perennial streams and springs. Lowered aquifer water levels can result in a diminution of groundwater discharge and/or depletion of stream base flow and spring flow.

- Migration of man-caused or natural poor quality groundwater toward the well field.
- Extensive long-term pumping can increase the potential for subsidence in unconsolidated aquifer systems due to compression of fine-grained layers and, in some limestone aquifers, can foster sinkhole development due to removal of cavity filling material and dissolution of the limestone.

C.1.2.4 Cost of Pumping

The cost of pumping groundwater is given by the following equation (Campbell and Lehr 1974):

$$Cost\ /\ Hour = \frac{(pumping\ rate\ (gpm))\ x\ (Lift + friction\ (ft))\ x\ (0.746)\ x\ (power\ (K/kW-hr))}{(3960)\ x\ (pump\ efficiency)\ x\ (motor\ efficiency)}$$

The cost of groundwater pumping in the study area was estimated by applying power costs ($0.074 per kilowatt hour) cited by the Navajo Tribal Utility Authority (NTUA) for residential power, and typical Arizona well values for the following parameters (HDR 2003):

- Pump efficiency (75 percent)
- Motor efficiency (90 percent)

There is a cost for lifting the water, and a separate cost for associated with the pressure loss caused by friction in the pump column. The following discussion only addresses the cost for lifting the water, as that cost is a function of the depth to water, and thus the drawdown caused by pumping at the PWCC wellfield. The term “friction” in the above equation is set to zero, so that the calculated cost only reflects the cost to lift the water.

Wells that tap the confined portion of the N aquifer (where the greatest N aquifer pumping impacts occur) are generally deep and limited to industrial (e.g., PWCC) or municipal users. Based on modeling studies, NTUA Forest Lake Well #1 is projected to experience the greatest drawdown due to mine pumping (GeoTrans 2006). Depth to water in this well in 2009 (latest measurement available) was 1,186 feet below ground surface (USGS 2010). Assuming the above unit cost factors and the 2008 average pumping rate of 10.2 acre-feet per year (af/yr), the average cost per hour is $0.154, or $1,356 per year for NTUA Forest Lake Well #1.

Community wells at Piñon produce more water, supplying about 319.1 af/yr in 2008 with a lift of 904.9 feet (measured in 2009). Annual lifting cost of power for these wells is estimated to be $27,526. Wells at Piñon are farther from the mine than Forest Lake and will experience less recovery. For example, under the proposed N aquifer pumpage (1,236 af/yr), the reduced lift resulting from the reduction in PWCC’s pumping is predicted to be 15 feet at Piñon at the end of 2025 (compared to 2010) versus 51 feet at Forest Lake. This translates into an estimated decrease in annual lifting power cost of $456 at Piñon and $49 at Forest Lake, or a 1.7 and 4.4 percent decrease, respectively.

It should be noted that many D aquifer stock-watering wells have windmills and not electric pumps. For these wells, costs do not increase when the water level declines, as long as the decline does not require the pump to be set deeper. The pump setting depth in wells in the area is generally unknown. Assessing the impact of project pumping on these wells relies on available data on the height of the water column in the well (depth of the well minus the static water level) and is evaluated in the same manner as the potential reduction in aquifer saturated thickness, as described in the subsequent subsection, Impacts on Aquifer Thickness (Saturation).

Impact on Pumping Cost

The annual cost of pumping (in 2010 dollars) at Piñon at five different times [pre-mining (1955), reduction in pumping in 2005, present day (2010), proposed action (2015), and proposed action (2025)] are given in Table B-1. All costs assume a constant annual average pumping rate (2009 water use) and 2010 electricity cost. The estimated pumping costs (lift only) due to the effects of PWCC pumping and community pumping are identified.

Table B-1 Estimated Cost of Pumping Years 1955, 2005, 2010, 2015, and 2025

Condition (Year)	Total ($/year)	PWCC ($/year)	Community ($/year)
Pre-mining (1955)	26,612	0	26,612
Reduction in mine pumping (2005)	31,113	2,581	28,532
Present (2010)	31,640	2,806	28,834
Proposed action (2015)	31,756	2,715	29,041
Proposed action (2025)	31,982	2,286	29,696

This analysis shows that the incremental cost of pumping due to drawdown caused by mine-related pumping is between 7 and 9 percent of the community's lift-only pumping cost. Table B-2 provides the impact level and the correlated percent increase in pumping cost. Pressure drop in the pump column is not considered in the cost estimate because that is determined by the depth of the pump, not the lift. The cost caused by pumping at the mine increased slightly between 2005 and 2010, and is estimated to decrease from 2025 and beyond. The estimated cost resulting from drawdown caused by local pumping increases from 2005 to 2025.

The lease agreements with the tribes provide for royalty payments for use of the N aquifer water based on the amount of water withdrawn. The total yearly average of water use fees paid to the Hopi and Navajo by PWCC is $3.2 million. Each Tribe has sole discretion on the distribution of the $1.6 million average yearly fee.

Table B-2 N Aquifer Impact Levels, Increase in Pumping Cost Criteria

Impact Level	Percent Increase in Pumping cost
Major	>51
Moderate	26-50
Minor	11-25
Negligible	1-10
None	0

C.1.3 Impacts on Aquifer Thickness (Saturation)

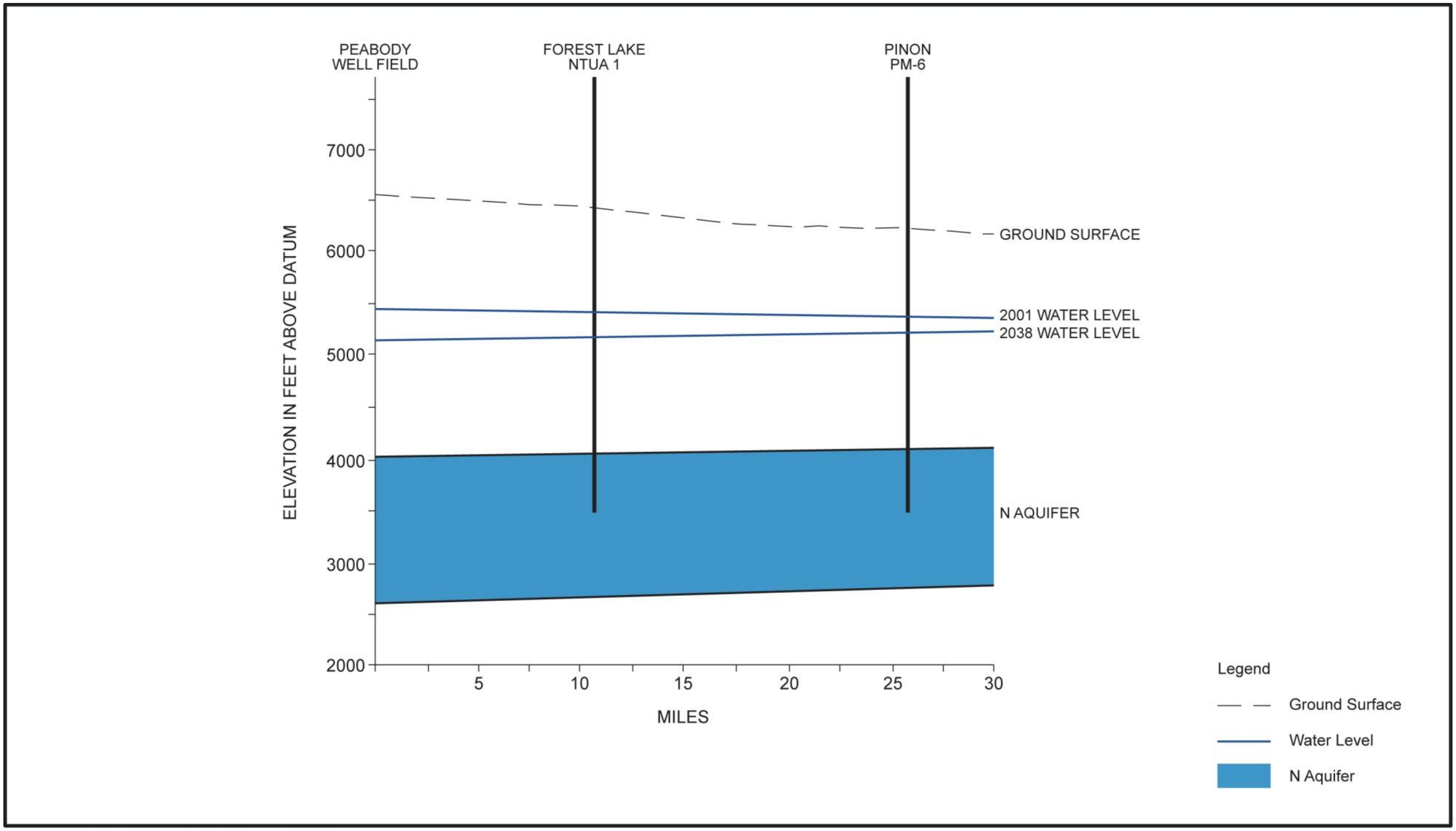
When water levels in the area of influence of the well fields are below (or fall below) the top of the aquifer, the aquifer is potentially subject to dewatering over time (so long as aquifer water levels decline). Dewatering reduces the aquifer's saturated thickness (amount of the aquifer that is full of water) and therefore its ability to yield water to wells (transmissivity) in the area of the well field. For unconfined aquifers, 90 percent of the maximum well yield is obtained at 67 percent of the maximum drawdown (Driscoll 1986). In practice, however, the water level cannot be drawn down to the bottom of the aquifer. In addition, most wells exhibit some well loss (a function of the aquifer, well construction and pumping rate), resulting in the pumping water level inside the well deeper than the water level in the aquifer immediately outside the well. A conservative range of between 20 percent (negligible) and 50 percent (major) reduction in aquifer thickness criterion was selected for this study to account for these expected variations from the theoretical.

In the N and D aquifers, almost all of the wells that are predicted to experience water-level declines due to PWCC-related pumping are located in the confined portion of the aquifer and are not predicted to have their water levels lowered below the top of the aquifer (Figure B-7). In other words, the aquifer remains fully saturated and no reduction in saturated thickness or transmissivity is predicted for the N and D aquifers.

The criteria shown in Table B-3 are applied to assess the effect of aquifer dewatering on a well's ability to sustain its long-term yield.

Table B-3 Impact Levels, Reduction in Saturated Thickness Criteria

Impact Level	Percent Reduction in Saturated Thickness
Major	>51
Moderate	31-50
Minor	21-30
Negligible	1-20
None	0



SOURCE: Southwest Ground-water Resources 2006

Figure B-7 N Aquifer Relationship Between Maximum Project Pumping and Aquifer Saturated Thickness

Effects in N Aquifer

The GeoTrans numerical model is used to assess the impacts of pumping from the N aquifers because it is the most representative of the complexities of this aquifer system. In the simulations, actual pumping rates were used for the PWCC well field through June 2010. From July 2010 through June 2025 (which includes the 5-year period that is the subject of this EA), the pumping rate was assumed to average 1,236 af/y. This period was followed by three years of pumping at 505 af/y (to 2028), and an additional 10 years at 444 af/y (to 2038). The database used to specify the community pumping rates was updated through 2009. However, the future community pumping rates were projected based on an evaluation performed using data through 1986, which found that community pumping would increase at a rate of 2.7 percent on average (GeoTrans. 2006). More recent data show that the rate of growth has decreased over the last 10 to 15 years. The forecast for community water usage was estimated at 4,400 af/y for 2008, but the reported usage was approximately 2,900 af/y (Macy 2010). In 2009, the reported community water usage was slightly lower (Macy, written communication). Thus, the model used higher community pumping rates for the period of 2010 through 2038 than will probably occur unless there is significant community growth.

Figures B-8 through B-10 show the simulated changes in water levels in the N aquifer for July 2015, July 2025, and July 2038. The predicted water levels are shown relative to a July 1, 2010 baseline. The maps (A) at the top of each of these figures show the predicted drawdown in the N aquifer as the result of all pumping (community and PWCC), and the maps (B) at the bottom show the simulated drawdown caused by PWCC's pumping alone. Because PWCC's pumping was reduced in December 2005 after many years of pumping at rates approximately four times higher than has occurred since then, the predicted water levels have risen (indicated as drawdown values that are less than zero) throughout the period of the simulation in the central part of the basin. In 2015, the simulated water level recovery near the PWCC lease area is between 20 and 30 feet during this 5-year time period. [Note that this recovery is the simulated rise in water levels after July 2010; recovery also occurred between December 2005 and July 2010, when the pumping rate was reduced, but is not shown on these figures.] Near some of the PWCC production wells, the simulated recovery is greater. The simulated recovery decreases to small values near the N aquifer boundary between confined and unconfined conditions, as the total drawdown prior to 2005 was also small near this boundary. The greatest differences in simulated drawdowns shown on Figures B-8 through B-10 are near the communities, where local pumping is predicted to cause continued drawdown. [Recall that the community pumping used in the predictions is greater than is likely to actually occur, and that the drawdown caused by community pumping will likely be less than predicted.]

By 2025, the water level recovery is predicted to be more than 30 feet (relative to 2010 levels) within most of the central part of the basin. Recovery will continue until 2038 (and beyond), so that water levels in the central part of the basin are predicted to recover more than 50 feet. These predicted recoveries are in addition to the recoveries that occurred in the period from the end of 2005 to July 2010.

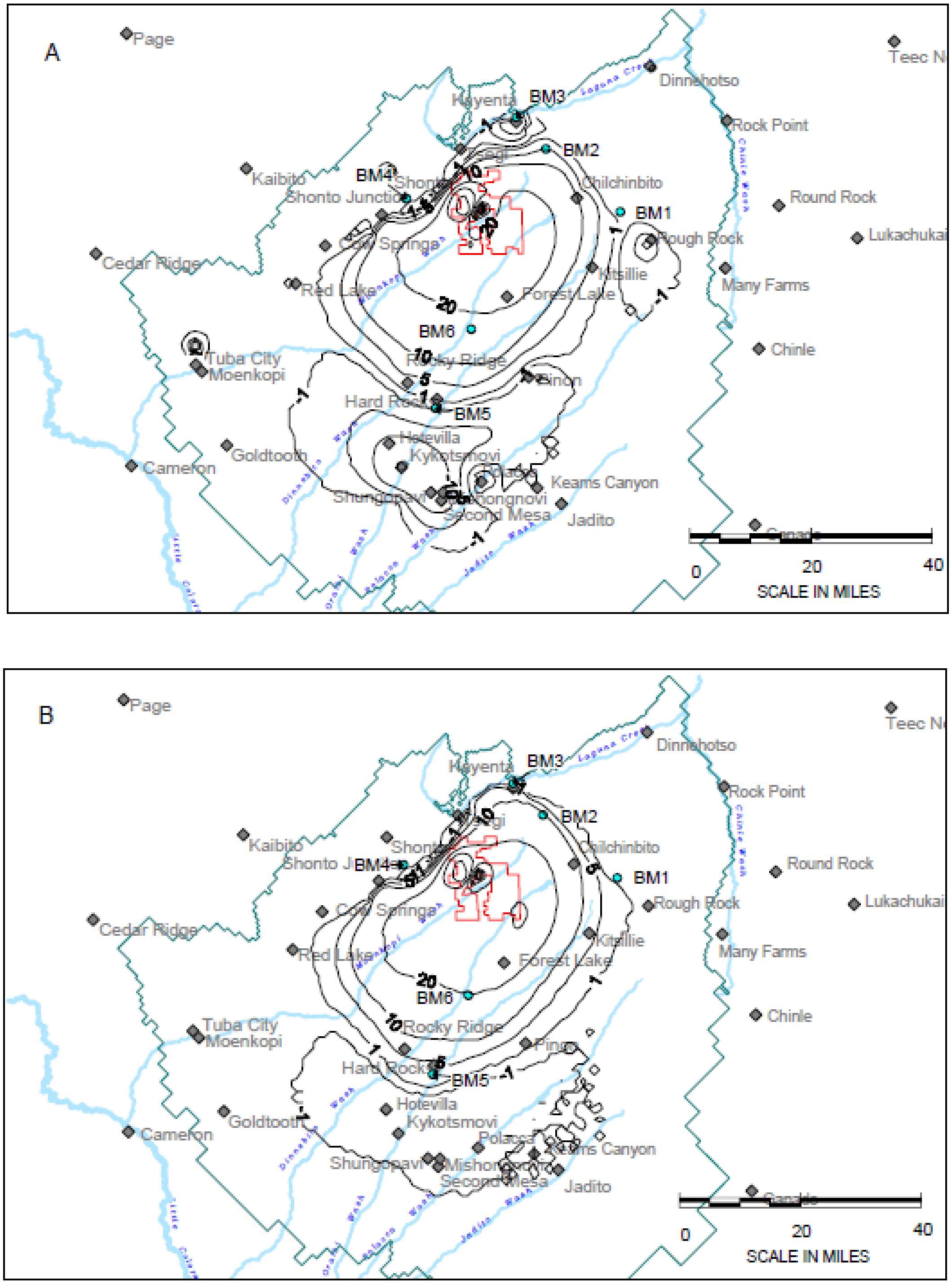


Figure B-8 Simulated Change in N Aquifer Water Levels 2010-2015

NOTE: A: Peabody and community pumping.
B: Peabody pumping only.
The contour interval is 50 feet, with supplemental contours for 1, 5, 10, 20, and 30 feet.

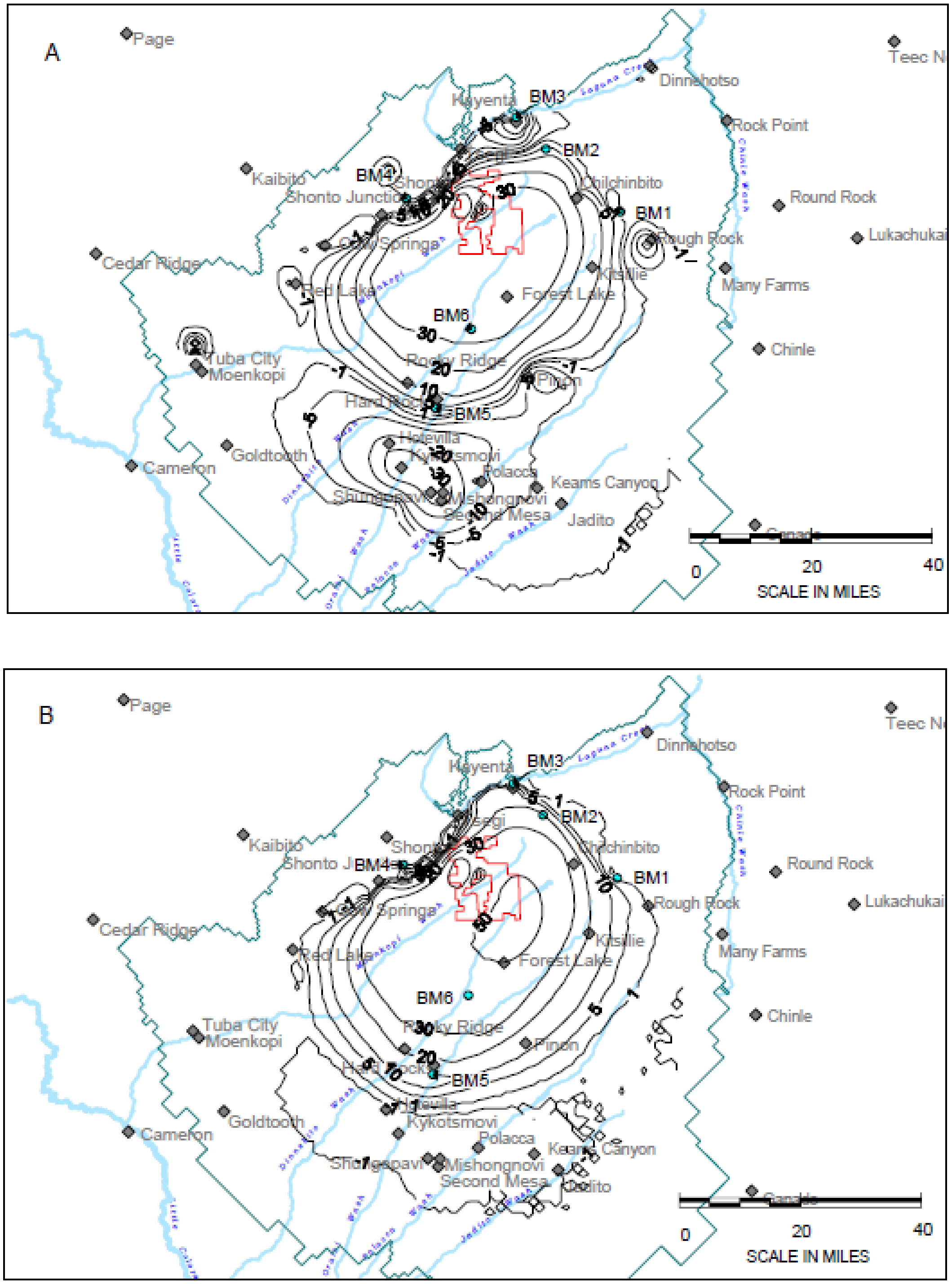


Figure B-9 Simulated Change in N Aquifer Water Levels 2010-2025

NOTE: A: Peabody and community pumping.
B: Peabody pumping only.
The contour interval is 50 feet, with supplemental contours for 1, 5, 10, 20, and 30 feet.

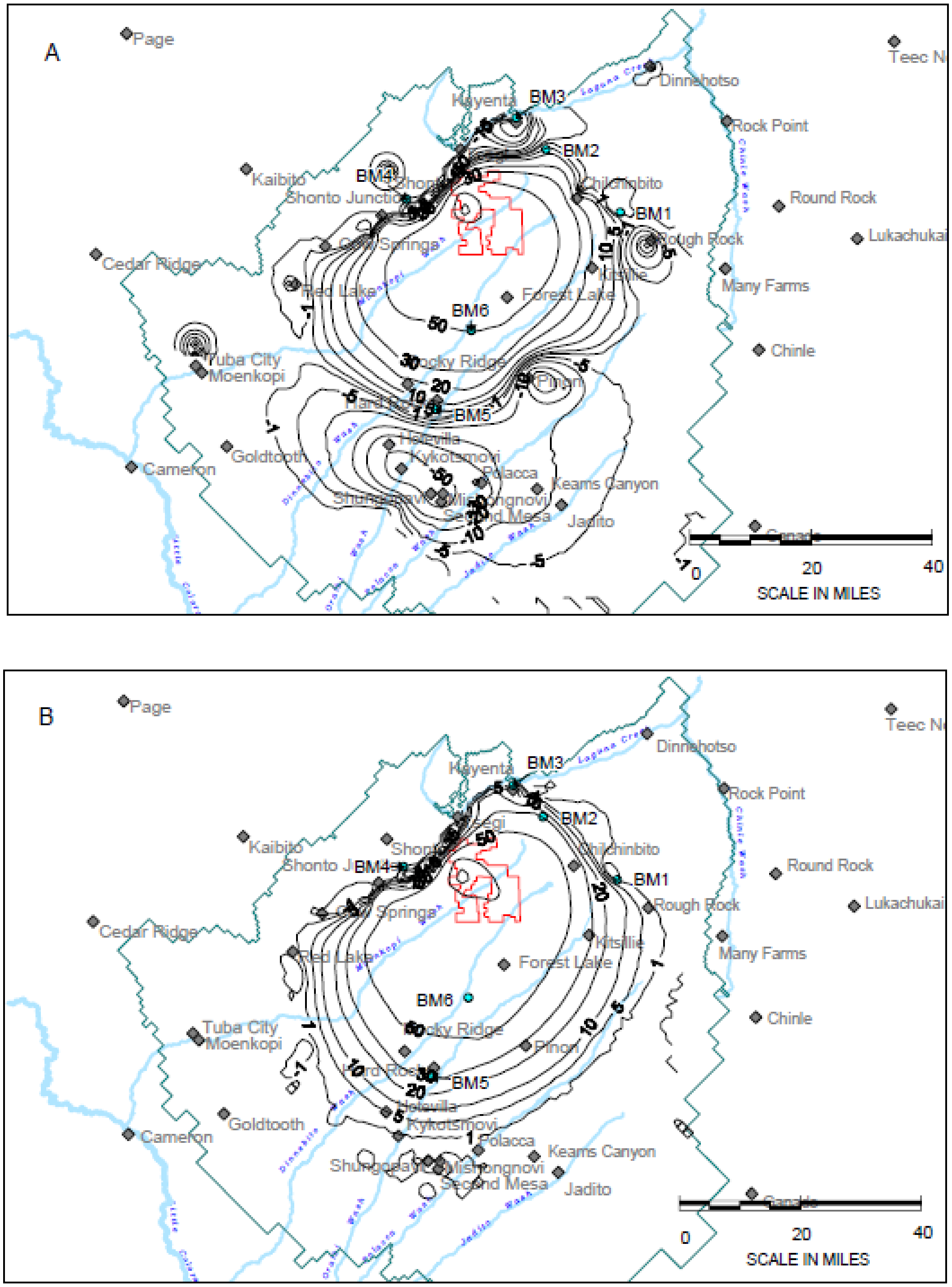


Figure B-10 Simulated Change in N Aquifer Water Levels 2010-2038

NOTE: A: Peabody and community pumping.

B: Peabody pumping only.

The contour interval is 50 feet, with supplemental contours for 1, 5, 10, 20, and 30 feet.

WATER SUPPLY

Table B-4 shows the water level change (relative to a July 2010 baseline) for selected community wells in 2015, 2025, and 2038. In most wells, the simulated drawdown (with both community and PWCC pumping) increases with time. However, the drawdown caused by PWCC's pumping is estimated to decrease with time. The predicted increases in drawdown are caused by local community pumping. In all instances but one, water is predicted to be above the top of the screened intervals by hundreds of feet. At Rough Rock, the water level was only 40 feet above the top of the screen interval when first measured. The model predicted that PWCC's pumping causes only 2 feet of drawdown in this well. Pumping by PWCC has caused drawdown in these wells, but has not limited the ability of these wells to produce water. With the reduction in pumping that occurred at the end of 2005, the effects of PWCC's pumping have become smaller.

Table B-4 Simulated Water Level Change at Selected Community Wells from July 1, 2010

Community	Well	Initial DTW (ft)	Simulated Water Level Change (ft)	PWCC Allocation (%)	PWCC Allocation (ft)	Depth to N or Top of Open Interval	Remaining Excess Water Column (ft)
a. 2015							
Chilchinbito	PM3	405.0	-9	126%	-11	1136	742
Forest Lake NTUA	4T-523	1096.0	-22	116%	-26	1870	800
Kayenta West	8T-541	227.0	14	-47%	-6	700	479
Keams Canyon	PM2	292.5	3	49%	1	900	606
Kykotsmovi	PM1	220.0	23	13%	3	880	657
Pinon	PM6	743.6	3	-79%	-3	1870	1129
Rocky Ridge	PM2	432.0	-3	254%	-6	1442	1016
Rough Rock	10R-111	170.0	1	16%	0	210	40
b. 2025							
Chilchinbito	PM3	405.0	-13	197%	-25	1136	756
Forest Lake NTUA[1]	4T-523	1096.0	-40	128%	-51	1870	825
Kayenta West	8T-541	227.0	37	-37%	-13	700	486
Keams Canyon	PM2	292.5	12	14%	2	900	606
Kykotsmovi	PM1	220.0	53	7%	3	880	657
Pinon	PM6	743.6	10	-152%	-15	1870	1141
Rocky Ridge	PM2	432.0	-9	229%	-21	1442	1031
Rough Rock	10R-111	170.0	2	6%	0	210	40
c. 2038							
Chilchinbito	PM3	405.0	-10	400%	-38	1136	769
Forest Lake NTUA[1]	4T-523	1096.0	-58	141%	-82	1870	856
Kayenta West	8T-541	227.0	69	-25%	-17	700	490
Keams Canyon	PM2	292.5	29	1%	0	900	607
Kykotsmovi	PM1	220.0	96	-1%	-1	880	661
Pinon	PM6	743.6	30	-96%	-29	1870	1155
Rocky Ridge	PM2	432.0	-13	290%	-39	1442	1049
Rough Rock	10R-111	170.0	3	-1%	0	210	40

NOTE: [1] Negative sign (-) indicates rise in water level.

N Aquifer Water Supply

The coal mining considered in this EA will require continued use of water from the N aquifer. The annual usage varies, however, the average annual usage is estimated to be 1,236 af/y. The GeoTrans 3-D model was developed considering the effects of both community and PWCC water usage. The estimated community pumping rates are believed to be higher than will actually occur, and thus the simulation results will likely be conservative.

Municipal (community) and industrial (PWCC) N aquifer annual water usage from 1965 to 2008 as reported by the USGS is provided in Table B-5. Although PWCC's water use was higher than that of the communities in the past, the communities now collectively use more water.

Table B-5 Municipal and Industrial N Aquifer Annual Usage from 1965 to 2008

Use	1965 to 2008 (acre-feet per year)
Community	70 to 3,100
PWCC (started in 1968)	0 to 4,450
Total	**70 to 8,930**

SOURCE: U.S. Geological Survey 1985-2010

Total water-level decline since 1955 (starting date in the model) through 2005 in the closest community well (Forest Lakes NTUA No. 1) was estimated by the model to be approximately 217 feet. The model indicates that approximately 38 feet recovery occurred from 2005 to 2010 because of reduced PWCC pumping, and that the net drawdown (i.e., historical drawdown minus recovery) at Forest Lakes was approximately 179 feet. As shown in Table B-4, modeling predicts that the groundwater level in the N aquifer will rise by another 40 feet over 2010 levels by 2025. The continuing rise over the 2010 to 2025 time period, due to reduced PWCC pumping, is 51 feet; however, continued community pumping is predicted to result in a water-level decline (drawdown) of 11 feet at this well between 2010 and 2025. The net drawdown (compared to 1955 water levels) is estimated to be 139 feet, of which 107 feet is attributed to PWCC pumping from 1968 to 2025.

Wells located farther from the well field would have less PWCC-related drawdown and a lower percentage of total drawdown due to PWCC pumpage. For example, Kykotsmovi Well PM1 is predicted to have a net 2010 to 2025 drawdown of 53 feet, of which about 7 percent, or 3 feet, would be due to PWCC pumping.

C.1.4 Impacts on Stream and Spring Flow

The major streams are fed by groundwater producing baseflow, and by precipitation. In the summer when the demand for water by plants increases, evapotranspiration consumes water discharged from the groundwater system and decreases the flow in the stream. USGS streamflow measurements indicate that the demand by evaportranspiration causes Moenkopi Wash at Moenkopi, Laguna Creek at Dennehotso and Polacca Wash near Second Mesa to be dry during the summer. The flows in Dinnebito Wash at Sand Springs are reduced, but flow typically continues through the summer.

The USGS monitors streamflow in four washes (Moenkopi Wash, Laguna Creek, Dinnebito Wash, and Polacca Wash) that overlie the N aquifer. These washes (and others) were modeled by PWCC to assess potential changes in streamflow due to mine pumping. Of the monitored and modeled washes, Moenkopi Wash is predicted to experience the greatest, albeit small (2.3 af/yr or 0.003 cubic feet per second [cfs]), depletion due to pumping from the N aquifer well field from 2010 to 2025. Begashibito Wash is closest to the PWCC well field and is predicted by the model to have the greatest depletion, but flow in this wash is not monitored (refer to Table B-7). Streamflow in Moenkopi Wash near Tuba City has been measured since 1976. The wash is intermittent with zero flow during many of the summer months. The measured flow during the period November through February was selected by the USGS to best represent the baseflow in the stream. At the Moenkopi gaging station currently being monitored, the median flow rate during this winter period has been approximately 3 cfs (Macy 2010). Assuming that 100 percent of the simulated decline in discharge into Moenkopi Wash affects the flow at the gaging station (i.e., assuming that there are no channel losses or evaporation transpiration losses), the pumping at the PWCC lease area is estimated to reduce the flow at the gaging station by about 0.01 percent of its median winter value.

The USGS has been monitoring N aquifer spring flow from four springs (Moenkopi School, Pasture Canyon Spring, Burro Spring, and an unnamed spring near Dinnehotso) for a minimum of 10 years (some springs have been monitored for much longer but not always at the same location). The closest USGS monitored spring (the unnamed spring near Dinnehotso) is more than 35 miles from the PWCC lease area. The USGS concludes that “for the consistent periods of record at all four springs, the discharges have fluctuated but long-term trends are not apparent” (USGS 1985-2005). It appears that pumping to date has not measurably reduced the monitored N aquifer spring flow. However, modeling of N aquifer groundwater discharge suggests that as future non-mining related groundwater pumping in close proximity to some of these springs increases, flows from springs could be impacted (GeoTrans 2006).

There are other N aquifer springs that are not monitored and past changes to these springs, if any, are unknown. As discussed in a subsequent section of this appendix, numerical models of the N aquifer are not designed to simulate discharge from individual springs (Brown and Eychaner 1988; PWCC 1999). However, the GeoTrans model does simulate groundwater discharge to Begashibito Wash approximately 25 miles west of the lease area. Cow Springs, located at the southwestern extent of Begashibito Wash, is an area of groundwater discharge as expressed by seeps and small springs. Cow Springs is the closest modeled area of seeps and springs to the mine and would therefore experience the greatest impact due to PWCC pumping. Predicted reduction in groundwater discharge into Begashibito Wash due to maximum PWCC-related pumpage (1,236 af/yr) at the end of 2025 is estimated to be 10.5 af/yr, or 0.49 percent of the estimated 2010 groundwater discharge (refer to Table B-7).

Impact levels for the effects on surface water uses in washes, creeks, and springs are defined as shown in Table B-6.

Table B-6 Diminution of Groundwater Discharge (Base Flow) to Streams and Springs

Impact Level	Percent Reduction
Major	>31
Moderate	21-30
Minor	11-20
Negligible	<10
None	0

IMPACT ON SURFACE WATER

Predicted 2015 reduction of groundwater discharge to streams is greatest at Begashibito Wash (refer to Table B-7), the closest point of stream/spring discharge to the PWCC well field (GeoTrans 2006). The total predicted 2010 to 2015 reduction in groundwater discharge is 3.8 af/yr, of which 3.4 af/yr is due to project pumping, and 0.4 af/yr is from community pumping. When pumping to 2025 is simulated, the estimated decrease in groundwater discharge is 12.1 af/yr, of which 1.6 af/yr is from community pumping. The predicted total 2015 and 2025 percent reductions in groundwater discharge to Begashibito Wash are 0.18 percent and 0.56 percent, respectively. Total reduction in groundwater discharge since 1955 is predicted to be approximately 24 af/yr in 2025, a 1 percent reduction in pre-mining groundwater discharge. As with wells, the further the point of groundwater discharge from the PWCC wellfield, the less the reduction in groundwater discharge due to PWCC pumping and the higher the percentage due to community pumping. For example at Pasture Canyon, near Tuba City, the predicted 2025 reduction in discharge from 2010 rates is 45 af/yr, and from 1955 rates is 94 af/yr (not shown in the table), all of which is attributed to community pumping.

The percentage reduction in the discharge to all of the streams and washes predicted for 2025 (based on 1955 discharge rates) is 2.6 percent for the combined PWCC and community pumping, 2.1 percent for community pumping, and 0.5 percent for PWCC pumping. The greatest volumetric reduction (149.4 af/yr) is predicted to occur in the discharge to Laguna Creek, resulting primarily from community pumping (140.6 af/yr). The greatest percentage reduction (22 percent) is predicted to occur at Pasture Canyon, all because of local community pumping.

The total (PWCC and community) diminution of flows at Begashibito Wash, where modeling shows the largest decreases in flows, from pumping of the N aquifer is predicted to be 3.8 af/yr in 2015. This is 0.18 percent of the estimated 2010 discharge of 2,166 af/yr, a negligible effect. The combined effect on Begashibito Wash discharge in 2038 is a reduction of 23.1 af/yr, or a 1.07 percent decline. The decline attributable to PWCC is 0.88 percent, both considered negligible. Because of the distance from the PWCC wellfield to the areas where groundwater discharge occurs, these small, long-term effects are regional in scale, but only occur in small areas.

Table B-7 Predicted Groundwater Discharge (af/yr) to Washes near the Vicinity of the Kayenta Mining Operation After July 2010

	2010		2015		Change Due to Pumping				
Drainage	**All**	**Non-PWCC**	**All**	**Non-PWCC**	**All**	**Non-PWCC**	**PWCC**	**Percent Total All**	**Percent Total PWCC**
2015									
Chinle Wash	498.8	498.8	498.8	498.8	0.0	0.0	0.0	0.00	0.00
Laguna Creek	2440.6	2450.6	2418.3	2427.8	22.2	22.9	-0.6	0.91	-0.03
Pasture Canyon	377.6	377.6	363.1	363.1	14.5	14.5	0.0	3.84	0.00
Moenkopi Wash	4279.6	4302.1	4277.0	4301.4	2.7	0.7	1.9	0.06	0.05
Dinnebito Wash	514.8	515.3	514.6	515.2	0.2	0.1	0.1	0.04	0.02
Oraibi Wash	455.4	456.0	454.4	455.2	1.0	0.8	0.2	0.21	0.04
Polacca Wash	429.8	431.0	427.3	428.9	2.4	2.2	0.3	0.57	0.06
Jaidito Wash	2011.4	2015.6	2007.3	2012.9	4.1	2.7	1.4	0.20	0.07
Begashibito Wash	2166.0	2177.0	2162.2	2176.6	3.8	0.4	3.4	0.18	0.16
2025									
Chinle Wash	498.8	498.8	498.8	498.4	0.0	0.0	0.0	0.01	0.00
Laguna Creek	2440.6	2450.6	2385.8	2395.1	54.8	55.5	-0.8	2.24	-0.03
Pasture Canyon	377.6	377.6	332.8	332.8	44.8	44.8	0.0	11.86	0.00
Moenkopi Wash	4279.6	4302.1	4274.9	4299.6	4.7	2.4	2.3	0.11	0.05
Dinnebito Wash	514.8	515.3	514.2	515.0	0.6	0.3	0.3	0.13	0.07
Oraibi Wash	455.4	456.0	452.6	453.9	2.7	2.1	0.6	0.60	0.14
Polacca Wash	429.8	431.0	422.9	424.8	6.9	6.2	0.7	1.60	0.15
Jaidito Wash	2011.4	2015.6	1999.0	2007.4	12.4	8.2	4.2	0.62	0.21
Begashibito Wash	2166.0	2177.0	2153.9	2175.4	12.1	1.6	10.5	0.56	0.49
2038									
Chinle Wash	498.8	498.8	498.7	498.7	0.1	0.1	0.0	0.02	0.00
Laguna Creek	2440.6	2450.6	2336.7	2347.6	103.8	103.1	0.8	4.26	0.03
Pasture Canyon	377.6	377.6	294.4	294.4	83.2	83.2	0.0	22.02	0.00
Moenkopi Wash	4279.6	4302.1	4273.0	4296.8	6.6	5.2	1.4	0.16	0.03
Dinnebito Wash	514.8	515.3	513.0	514.6	1.2	0.7	0.6	0.24	0.11
Oraibi Wash	455.4	456.0	450.1	451.6	5.3	4.4	1.0	1.17	0.21
Polacca Wash	429.8	431.0	419.0	419.4	11.7	11.6	0.1	2.73	0.03
Jaidito Wash	2011.4	2015.6	1987.1	1998.0	24.3	17.6	6.6	1.21	0.33
Begashibito Wash	2166.0	2177.0	2142.9	2172.9	23.1	4.1	19.0	1.07	0.88

NOTE: 1 Negative sign (-) indicates relative increase in model-predicted stream discharge resulting from reduction in PWCC's pumping since 2005. Non-PWCC = Community pumping sources, PWCC = PWCC pumping sources, All = All combined sources, including PWCC and Non-PWCC sources.

IMPACTS ON GROUNDWATER AND SURFACE WATER QUALITY

C.1.5 Migration of Poor Quality Groundwater

In some situations, extensive long-term groundwater pumping can cause poor quality groundwater to migrate toward a pumping center. Concerns have been raised that pumping from the N aquifer could cause poorer D aquifer water to migrate downward into the N aquifer. Geochemical studies have shown that downward leakage from the D aquifer to the N aquifer has been occurring for thousands of years. Most natural leakage occurs in the southern portion of Black Mesa Basin where the intervening Carmel Formation confining bed is less than 120 feet thick and has a higher sand content than in other areas of the basin (Truini et al. 2005). The areas of known leakage are located more than 20 miles from the PWCC wellfield. While leakage has occurred under natural conditions over a long period of time, water-quality monitoring of the N aquifer for more than 10 years during the period that mining-related and coal-slurry pumping has been occurring has shown no trend in water-quality degradation (USGS 1985-2005). PWCC monitors the quality of water produced from its production wells. Over the more than 20-year period that pumping has occurred, there has been no discernible trend to suggest that water quality is declining. Total dissolved solids, sulfate, and chloride have all remained stable over the life of the wells. If leakage is occurring, it is too small to be detected in the concentration of these constituents.

PWCC conducted an analysis of potential leakage from the D aquifer to the N aquifer using the GeoTrans model and standard mixing calculations. Pumping from the N aquifer was simulated at several different rates, including 6,000 af/yr in one scenario. Results of this analysis indicated a maximum increase in N aquifer sulfate concentration of approximately 0.5 percent in 2038 in the eastern part of the aquifer (PWCC 2005).

C.1.6 Water Quality Impacts on N Aquifer

The USGS suggested that an increase in downward leakage from the D aquifer to the N aquifer would first appear as increased total dissolved solids (TDS) or electrical conductivity (PWCC 2005). The USGS also identified increased Cl and SO_4 concentrations as important indicators of downward groundwater leakage from the D aquifer to the N aquifer. The USGS monitors water quality in the confined N aquifer throughout the Black Mesa region as part of a 1991 Cooperators Agreement among BIA, USGS, ADWR, and PWCC. The USGS monitoring program collects samples at some of the PWCC's pumping wells to validate PWCC's N aquifer water-quality-monitoring program, which began in 1980. USGS' and PWCC's N aquifer water-quality results have shown no apparent increasing or decreasing trends in TDS, Cl, or SO_4 concentrations, although small year-to-year variations in concentrations do occur (USGS 1985-2005). The USGS analyzed TDS data from six wells, including NAV2 and NAV4, and did not detect any increasing trends for TDS (Macy 2010).

Most of PWCC's production wells are partially screened in the water-bearing units composing the D aquifer, as well as being screened in the N aquifer. Hydraulic heads in the D aquifer are about 250 feet higher than in the N aquifer in the area of the well field. When the production wells are not pumping, D aquifer water has the hydraulic potential to flow downward from the D aquifer screened interval to the

N aquifer. Reduction in pumping since December 2005 has resulted in some of PWCC's production wells being turned off for extended periods (weeks), with the potential for D aquifer water to mix with N aquifer water in the immediate vicinity of those wells. However, PWCC's water-quality-monitoring data from 2006 through the first half of 2009 indicate that degradation of the N aquifer in the vicinity of PWCC's production wells is not occurring with the existing wellfield management practices in place. Water-quality samples collected in February and March 2006 from the production wells that had been idle since December 2005 showed no increases in electrical conductivity, TDS, Cl, or SO_4 concentrations compared to the historical data (OSM 2006). A shutdown of the mine well field also occurred in the fall of 1985. In a 1987 USGS report on the Black Mesa monitoring program, no degradation of water quality in the well field was noted (Hill and Sottilare 1987).

PWCC analyzed the potential for groundwater leakage from the D aquifer to the N aquifer through the Carmel Formation confining bed using the GeoTrans model and standard mixing calculations. Results of this analysis indicated a maximum increase in N aquifer SO_4 concentrations beneath the leasehold of 0.05 percent (from 30 mg/L to 30.016 mg/L) by 2038. In some areas, the estimated percentage increase is higher (up to 0.5%), but the increase in SO_4 concentration is estimated to be less than 0.5 mg/L everywhere.

Table B-8 Maximum Predicted Sulfate Concentrations (mg/L) Resulting from PWCC Pumping, 1956-2038.

Subarea	Initial Concentration (mg/L)		Final Concentration (mg/L)	Percent Change
	D Aquifer	Navajo sandstone	Navajo sandstone	
Northeast	250	70	70.056	0.080%
East	850	100	100.498	0.498%
Hopi Buttes	360	50	50.113	0.226%
Forest Lake	1000	100	100.057	0.057%
Kitsillie	75	30	30.002	0.007%
Pinon	200	5	5.006	0.122%
Rocky Ridge	250	10	10.012	0.118%
Preston Mesa	400	10	10.000	0.000%
Leasehold	400	30	30.016	0.054%
Pinon to Kitsillie	1000	20	20.036	0.178%
Surrounding leasehold	100	45	45.002	0.004%
Red Lake to Tuba City	400	50	50.012	0.024%
Hotevilla to Kabito	200	35	35.006	0.016%
Pinon to Rocky Ridge	210	140	140.003	0.002%

SOURCE: Peabody Western Coal Company 2005
NOTE: mg/L = milligrams per liter

SURFACE WATER QUALITY IMPACTS

During 2009, seeps were observed at 12 of the 25 National Pollutant Discharge Elimination System (NPDES) sediment ponds that were inspected by PWCC personnel. Of those 12 sediment ponds, four exhibited seep-water quality that exceeded at least one of the livestock standards (see EA, Section D, Table D-4). Analytical results for both cadmium at BM-A1-S1 and copper at J7-JR-S1 were qualified by the laboratory as being between the method detection limit and practical quantitation limit, effectively yielding inconclusive results with respect to whether values of both trace elements were higher than the standard value. Nitrate levels at BM-A1-SP1 are likely influenced by sheep and other livestock waste in the vicinity, and the selenium value (36 micrograms per liter) was only slightly higher than the standard (33 micrograms per liter). The aluminum value measured at J3-E-S2 was the first value that exceeded the standard at the two seeps monitored below Pond J3-E since monitoring began, and may be anomalous. Finally, the aluminum value that exceeded the standard at Seep N6-F-S1 and the low pH measurements are similar to historical measurements at this site. The embankment at Pond N6-F was removed and reclaimed during the fall of 2009, effectively removing Seep N6-F-S1 permanently. At the remaining eight NPDES sediment ponds, seeps met livestock water-quality standards. Flow rates of the seeps monitored in 2009 were within the historical range of seep flows (ranging from pooled water [no flow] to 9.5 gallons per minute). During 2009, there were fewer NPDES ponds exhibiting poor seep-water quality than in prior years. The constituent results that exceeded water-quality standards were comparable to historical ranges.

Diversions of natural streamflow also are designed to preserve geomorphic stability and prevent uncontrolled or destructive erosion and sedimentation. All diversions on the Kayenta Mine permit area are developed using quantitative hydraulic modeling programs (e.g., SEDIMOT II) that simulate the geometry required to maintain geomorphic equilibrium in a natural channel. Where this is not possible, short, specific structures (such as grade-control structures) are designed and constructed in the channel to correct the problem. Similar to the pond discharges, these channels and structures are regularly inspected and maintained by PWCC staff and reviewed by OSM and tribal inspectors.

Under the current Seepage Management Plan, PWCC dewaters sediment ponds at the earliest practicable opportunity to prevent seeps, and constructs fences around the areas below dams to prevent livestock from accessing those seeps that do not meet livestock water-quality standards. In addition, PWCC has planted willows and cattails in the area below a dam to reduce downstream flow from several seeps. These activities have proved to be effective to some degree. However, fencing provides only a limited measure of protection for livestock access, and does not completely protect the beneficial use of seep water for livestock and wildlife. The U.S. Environmental Protection Agency (USEPA) has recommended other measures to protect water-quality and beneficial uses, such as treating the water, eliminating the sediment pond, sealing the pond, capturing the water and infiltrating it upstream of the pond, or intercepting the seep water and pumping it back into the pond. PWCC has submitted an application to USEPA to renew its NPDES permit (No. NN0022179), and USEPA issued a renewed permit that currently is under review by the USEPA’s Environmental Appeals Board. In the interim, PWCC continues to operate under the terms and conditions of the previous NDPES permit by an administrative extension. The renewed permit requires enhanced seep management measures to improve the effectiveness of the Seepage Management Plan and to ensure compliance with the Clean Water Act. The improved seep management measures would be applied at all NPDES sediment ponds with poor seep water quality, including proposed permanent impoundments. The measures include installing passive treatment systems to treat seep water below two existing impoundments, and reclaiming several existing NPDES sediment ponds with seeps exhibiting poor water quality to comply with requirements under the Western Alkaline Coal Mining effluent limitations (40 CFR Part 434). The Western Alkaline Coal Mining effluent limitations allow operators to remove the embankments of NPDES outfalls if the watersheds above meet certain criteria related to implementation of best management practices under a sediment control plan as approved by USEPA, OSM, and both the Navajo Nation and Hopi Tribe. Removing and reclaiming the embankments of NPDES ponds that have exhibited seeps with poor water quality is expected to eliminate seeps with poor water quality by removing the potential for impounding runoff that otherwise would seep through embankment soils and surrounding geologic formations. The renewed NPDES permit will require continued implementation of a modified Seepage Management Plan, including using existing seep-management measures, performing pond inspections, and reporting the monitoring results.

PWCC also would use design and construction methods that would minimize seeps for new sediment ponds by identifying geochemically inert materials for constructing the embankments, compacting the embankments to meet engineering design standards, and siting embankments at locations with low permeability geologic units to the extent practicable.

SUBSIDENCE AND SINKHOLES

The N aquifer is principally comprised of sandstone, which are indurated and are not subject to significant compaction and subsequent land subsidence. Studies of the lithology and compressibility of the Navajo Sandstone in the Kayenta Mine permit area indicate that it would be subject to compaction of less than 1 percent if the water level was drawn down to the top of the aquifer (GeoTrans 1993). None of the N aquifer pumping scenarios result in the water level being lowered to the top of the aquifer within the Black Mesa Basin. No evidence of casing distress has been noted in any of the surveyed PWCC production wells as might be expected if significant compression of the Navajo Sandstone or overlying units had occurred (OSM 2006).

In 2003 land subsidence features in the form of sinkholes, cracks, and slumps were reported near Forest Lake, about 7 miles south of the PWCC lease area. After investigation by OSM, Navajo Nation Minerals Department, Navajo Nation Water Resources Department, and USGS, all of the subsidence features of concern were determined to be either in or adjacent to unconsolidated alluvial valley deposits and due to surface water entering and eroding desiccation features following an extended period of drought (OSM 2004). These features are unrelated to the mining or water production facilities on the PWCC lease area.

Subsidence and formation of sinkholes in the N aquifer well field area is considered highly unlikely.

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