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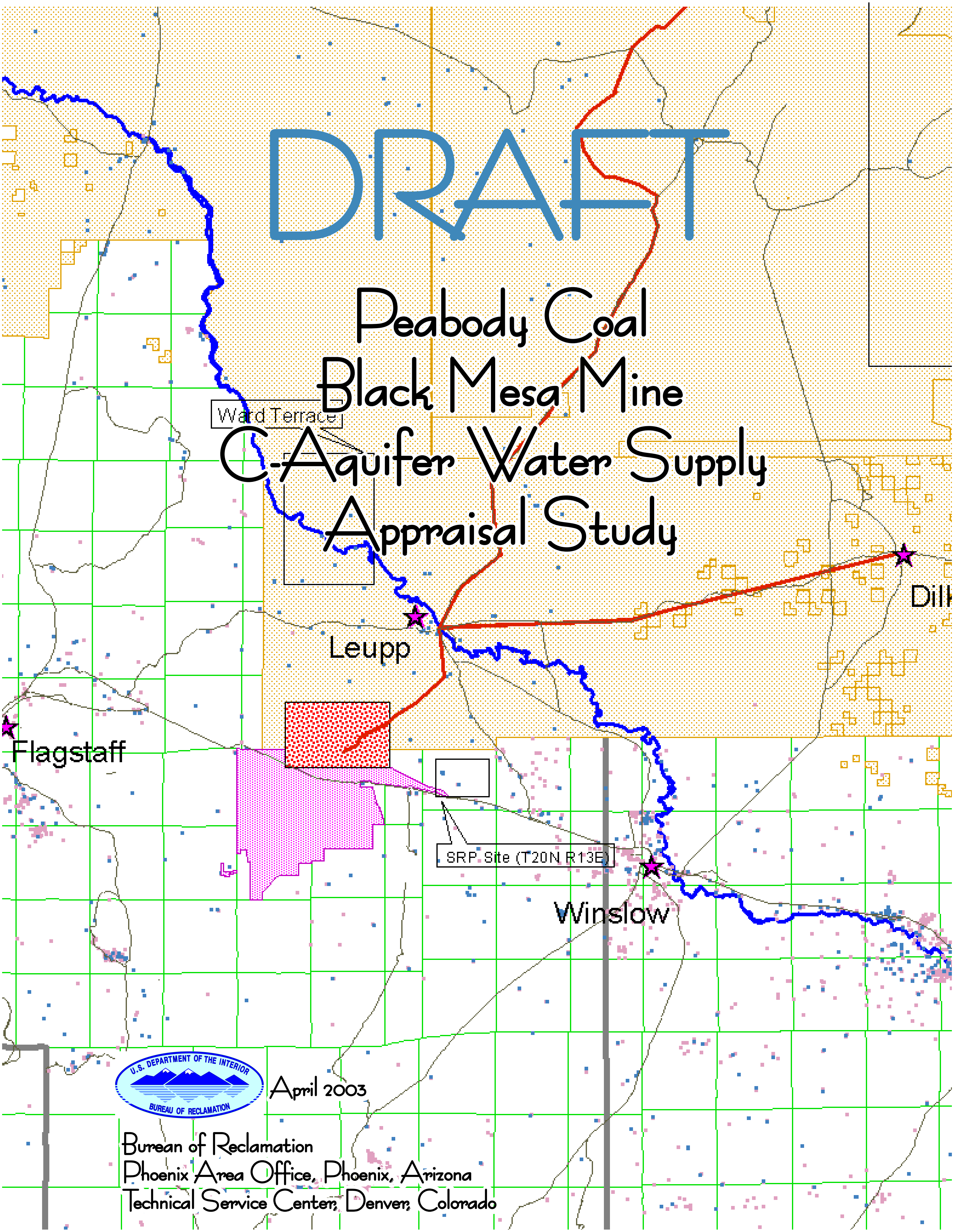
Peabody Coal Black Mesa Mine C-Aquifer Water Supply Appraisal Study



April 2003

U.S. Department of the Interior
Bureau of Reclamation

Bureau of Reclamation
Phoenix Area Office, Phoenix, Arizona
Technical Service Center, Denver, Colorado

Peabody Coal
Black Mesa Mine
C-Aquifer Water Supply
Appraisal Study

Prepared by

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April 2003

Executive Summary

This appraisal engineering study describes the Bureau of Reclamation's (Reclamation) analysis of alternatives utilizing water out of the C-Aquifer to meet the current and future demands of the Peabody Western Coal Company's Black Mesa Mine (Black Mesa Mine) and various communities within the Hopi and Navajo Indian Reservations. Two alternative C-Aquifer wellfields were evaluated (the I-40 wellfield and the Canyon Diablo wellfield), along with the conveyance systems required to deliver the water. The alternative's facilities were developed and analyzed assuming two primary demand scenarios: 1) 6,000 acre-feet per year (af/yr) delivered to the Black Mesa Mine; and 2) 6,000 af/yr delivered to the Black Mesa Mine, along with 2,000 af/yr delivered to the Hopi Tribe and 2,000 af/yr delivered to the Navajo Tribe. In addition, a variation of the second demand scenario included providing 336 af/yr to the Jeddito area and the area not served under the primary demand scenarios. This report describes and evaluates the wellfield requirements, storage facilities, pipeline requirements, power requirements, appraisal cost estimates, hydraulic parameters, and potential biological and cultural resource impacts. The primary objective of this analysis is to determine the presence of "fatal flaws."

Study Need

The Black Mesa Mine currently relies on groundwater pumping from the N-Aquifer for its operation. Alternative supplies are being sought to replace the current use of the N-Aquifer, a regional groundwater supply. This study was undertaken in response to a request from Department of Interior's Water Rights Office in accordance with agreement among the Peabody Coal Company, Southern California Edison, Salt River Project, Navajo Nation, and Hopi Tribe, hereinafter referred to as "the parties."

Alternative Scenarios and Estimated Costs

Reclamation analyzed two primary water demand scenarios to provide the source water to meet the projected municipal and industrial (M & I) demands. Specifically, Reclamation evaluated two C-Aquifer wellfields: 1) the I-40 wellfield, located just south of the Navajo Nation (Township 20 N, Range 13 E), generally located on private land referred to as the Red Gap Ranch; and 2) the Canyon Diablo wellfield, located in the easternmost section of the Canyon Diablo and the southern portion of the Navajo Nation. These wellfield configurations are shown in figure EX-1.

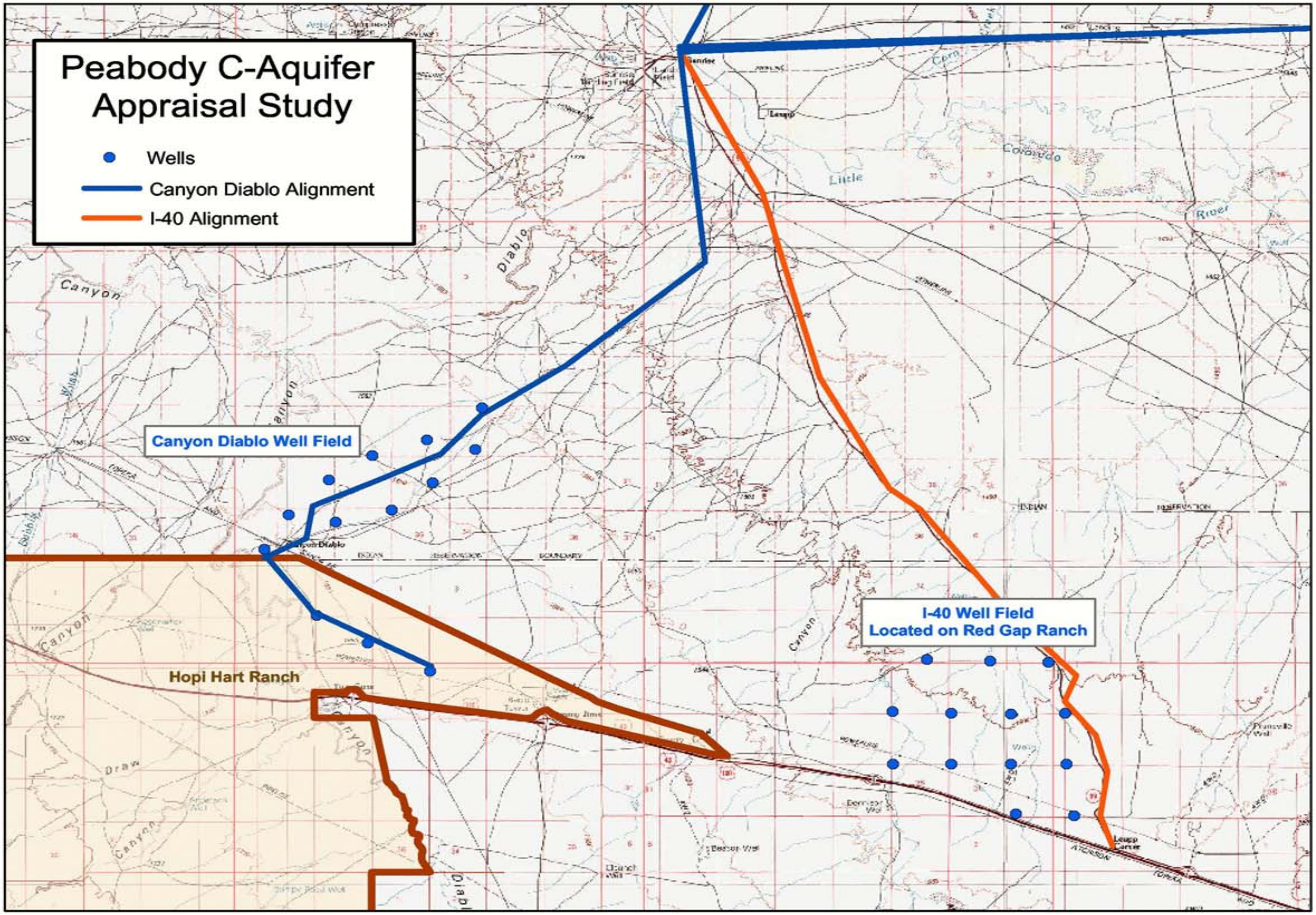

Figure EX-1.—Map of study area.

Reclamation evaluated three pipeline variations to convey the wellfield water to the demand centers. All of the cost estimates for conveyance systems in this report are based on the alignments starting from the I-40 wellfield[1]:

1) Variation 1 is a pipeline conveying 6,000 af/yr from the I-40 wellfield to the Black Mesa Mine. The pipeline would have six pumping plants located along the alignment with no turnouts. This pipeline that directly connects the wellfield and the Black Mesa Coal Mine is called the transmission line.

2) Variation 2 is a pipeline conveying 10,000 af/yr from the I-40 wellfield. Of that amount, 6,000 af/yr would be delivered to the Black Mesa Mine, 2,000 af/yr would be delivered to the Hopi communities of Bacovi (850 af), Shongopovi (420 af), and Keams Canyon (730 af) via the Three Mesa lateral system, and 2,000 af/yr would be delivered to the Navajo communities of Leupp (600 af) and Dilkon (1,400 af).

3) Variation 2A is similar to Variation 2, except that an additional 336 af/yr would be delivered to the Navajo community of Jeddito through the Three Mesa lateral system.

Estimated field construction costs, operation and maintenance (O&M) costs, total costs, and total annualized costs for the above alternatives are shown in table EX-1.

Resources Evaluation

Construction of this proposed project would be subject to Federal environmental laws and regulations. This study provides a reconnaissance-level evaluation of biological and cultural resources, land use, social analysis and environmental justice, and Indian Trust Assets. During the feasibility/EIS state, additional resources would be evaluated in detail, including but not limited to air quality, land use, socio-economic resources, environmental justice, and ITAs

The proposed wellfields are located in an area where there are other tribal and nontribal users of the C-Aquifer (both current and projected). Future pumping from the C-Aquifer would have the potential to create drawdown of the aquifer for these other users. In addition, pumping from the C-Aquifer could potentially reduce the discharge of Blue Springs in the lower Little Colorado River, an important environmental and cultural resource to both the Hopi and Navajo Tribes. Furthermore, the wellfields are located in an area where drawdown could potentially contribute to a decrease of the base flow in Chevelon and Clear Creeks, in areas where this flow provides critical habitat for an endangered species: the Little Colorado River Spinedace.

To evaluate the impacts of the I-40 and Canyon Diablo wellfields on these resources, Reclamation utilized two groundwater models developed for the Hopi-Western Navajo Study:

Variation: I-40 wellfield	Component	Construction field cost	Nonconstruction cost	Total project cost	Annual OMR&E cost
1					
	Wellfield costs	$1,250,000	$325,000	$1,575,000	$186,000
	Pipeline costs	$72,000,000	$18,720,000	$90,720,000	$2,030,000
	Total cost	$73,250,000	$19,040,000	$92,300,000	$2,216,000
2					
	Wellfield costs	$2,700,000	$702,000	$3,402,000	$403,000
	Pipeline costs	$135,000,000	$35,130,000	$170,130,000	$3,410,000
	Total cost	$137,700,000	$35,830,000	$173,500,000	$3,813,000
2A					
	Wellfield costs	$2,910,000	$757,000	$3,667,000	$434,000
	Pipeline costs	$140,000,000	$36,400,000	$176,400,000	$3,570,000
	Total cost	$142,900,000	$37,160,000	$180,100,000	$4,004,000

1) An analytical model that evaluated drawdown, and 2) a numerical model that evaluated impact on Chevelon and Clear Creeks flows, based on projected drawdowns. Modeling runs were performed considering just wellfield operations and wellfield operations with projected demands from other users (both current and projected). The projected demands represent the mid-range demand values estimated for future Indian and non-Indian demands, including "grandfathered" uses and proposed new developments determined in the Hopi Western Navajo Water Supply Study. It is understood that these represent the "worst case scenario," with respect to assumptions adopted in the modeling exercise.

Based on these modeling runs, it was concluded that neither wellfield would exceed a 10 percent reduction in streamflow in Blue Springs (which was used as a "coarse filter trigger" for Endangered Species Act purposes), or have a significant impact on the operation of other wells using the C-Aquifer in this area. It was further concluded that neither wellfield would be likely to impact the seeps and springs that may support two federally protected species, the Navajo sedge or alcove bog-orchid. However, while the impacts of the Canyon Diablo wellfield on base flow in Chevelon and East Clear Creeks were found to be insignificant operation of the I-40 wellfield may have some adverse impacts on the base flow of Chevelon Creek at the Bell Cow Canyon measuring point. The I-40 wellfield alternative appears to have greater potential for streamflow reductions relative to recommending further analysis of the alternative at the feasibility level. It should be noted that this determination was made relative to the criteria used in the Hopi Western Navajo Water Supply Study.

Approximately 30 threatened or endangered species could be associated with the project area. Of those 30 species, in addition to the spinedace and humpback chub, the most likely to be impacted by the wellfield operation are the Navajo sedge and alcove bog-orchid. Since the pipeline alignments generally follow highway rights-of-way (which are already impacted), and since well site locations can be shifted to avoid significant populations of terrestrial species, the potential presence of these other 26 species in the project area is not considered to be a "fatal Flow" relative to recommending any of the alternatives for further analysis at the feasibility level.

Although numerous cultural resources potentially exist in the project area, impacts to these resources either will be reduced or avoided by following existing pipeline/highway alignments. The potential presence of cultural resources in the project area is not considered to be a "fatal flow" relative to recommending any of the alternatives for further analysis at the feasibility level.

Conclusions

Based on this appraisal level study, the C-Aquifer does appear to provide at least one alternative that should be explored at the Feasibility level to replace the Black Mesa Mine's use of the N-Aquifer without causing unacceptable impacts to other resources.

Acronyms and Abbreviations

af	acre-feet
af/yr	acre-feet per year
aka	also know as
APS	Arizona Public Service
ASLD	Arizona State Land Department
ASM	Arizona State Museum
avg	average
Black Mesa Mine	Peabody Coal—Black Mesa Mine
cfs	cubic feet per second
CFR	Comprehensive Facility Review
cmp	corrugated metal pipe
cy	cubic yards
El.	elevation
ESA	Endangered Species Act of 1973, as amended
ft	feet
FWS	U.S. Fish and Wildlife Service
gpm	gallons per minute
HCPO	Hopi Cultural Preservation Office
hdpe	high-density polyethylene
hp	horse power
hr	hour
lb	pound
LCR	Little Colorado River
M&I	municipal and industrial
MNA	Museum of Northern Arizona
MP	measuring points
msl	mean sea level
NESL	Navajo Nation Endangered Species List
NNHP	Navajo Nation Heritage Program
NNHPD	Navajo Nation Historic Preservation Department
O&M	operation and maintenance
OMR&E	operation, maintenance, replacement and energy

Acronyms and Abbreviations

(Continued)

POS	plan of study
psi	per square inch
PMGC	Peter Mock Groundwater Consulting, Inc
PVC	polyvinyl/chloride
PXAO	Reclamation's Phoenix Area Office
Reclamation	Bureau of Reclamation
RRA	Reasonable and prudent alternative
SCADA	Supervisor Control and Data Acquisition
SGC	Southwest Groundwater Consultants, Inc.
SHPO	State Historic Preservation Office
SRP	Salt River Project
swl	surface water level
TCP	Traditional Cultural Properties
tdh	total design head
THPO	Tribal Historic Preservation Officer
TSC	Technical Service Center
V	variation

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Chapter 1

Introduction

1.1 Background, Purpose, and Scope of the Study

Various alternatives have been evaluated to meet the current and future demands of the Black Mesa Mine and various communities within the Hopi and Navajo Indian Reservations. The Black Mesa Mine, Hopi villages, and Navajo communities, located in the lower basin of the Colorado River, currently rely on groundwater. Alternative supplies are being sought to replace the current use of the N-Aquifer, a regional groundwater supply. In a recent study[1]. the Bureau of Reclamation (Reclamation) evaluated methods to meet Black Mesa Mine's demands with surface water from the Colorado River. The Navajo Department of Water Resources published a technical memorandum[2] describing an alternative to replace current use of the N-Aquifer with groundwater from the C-Aquifer. This study expands on the evaluation of alternatives that would meet the Black Mesa Mine demands, with options to include select communities within the Hopi Reservation and southern portion of the Navajo Nation, with C-Aquifer groundwater.

Reclamation conducted this conceptual appraisal engineering study to identify "fatal flaws" associated with two alternative C-Aquifer wellfields (I-40 wellfield, Canyon Diablo wellfield) and the conveyance systems required to deliver the water. These alternatives were further evaluated under two primary demand scenarios: 1) 6,000 acre-feet per year (af/yr) delivered to the Black Mesa Mine; and 2) 6,000 af/yr delivered to the Black Mesa Mine, along with 2,000 af/yr delevered to the Hopi Tribe and 2,000 af/yr delivered to the Navajo Tribe. As a variant to the second demand scenario, additional facilities to provide an additional 336 af/yr to the Jeddito area, were evaluated. This report includes text and figures necessary to conceptually describe the wellfields, facilities, power requirements, pipeline alignment, appraisal cost estimates, hydraulic parameters, and potential environmental impacts at the appraisal level.

1.2 Assumptions

This report represents a cursory review conducted over a period of several weeks. All data evaluated for this study are from interviews, available reports, and databases. Groundwater modeling was performed using a C-Aquifer analytical and numerical model developed for use in

[1] Bureau of Reclamation, "Peabody Coal Black Mesa Mine Water Supply Appraisal Study," October 2002.

[2] Navajo Nation Department of Water Resources, "Conceptual Level Cost Estimates: Ward Terrace to Black Mesa Pipeline and I-40 to Black Mesa Pipeline," January 8, 2003.

the Hopi Western Navajo Water Supply Study. Navajo Nation and Hopi Tribe right-of-way costs are not included. Implementation of any of the alternatives considered will require compliance with Federal environmental statutes and regulations. Therefore, it is assumed in this report that such standards and regulations will apply.

1.3 Study Area

The study area (figure 1) is predominantly within the boundaries of Canyon Diablo and the western half of the Navajo Nation, although one of the evaluated wellfields is located within an area of private land known as the Red Gap Ranch, south of the Navajo Nation.

1.4 Public Involvement and Scoping

General public involvement activities were not conducted at this level of planning but would be required during a feasibility study.

Chapter 2

Alternatives

This chapter presents two alternative C-Aquifer wellfields and the associated conveyance required to provide municipal and industrial (M& I) water, under several alternative demand scenarios, to the Black Mesa Mine and to select communities within the Navajo Nation and Hopi villages.

2.1 Alternative Demand Scenarios

Reclamation analyzed two primary water demand scenarios: 1) 6,000 af/yr to the Black Mesa Mine; and 2) 6,000 af/yr to the Black Mesa Mine along with 2,000 af/yr to the Hopi Tribe and 2,000 af/yr to the Navajo Nation. In addition, a variation of the second demand scenario included providing 336 af/yr to the Jeddito area, an area not served under the primary demand scenarios.

2.2 Alternative Formulation and Engineering Methods of Analysis

To provide the source water to meet the projected M&I demands (discussed further below in section 2.2), Reclamation evaluated two C-Aquifer wellfields: 1) The I-40 wellfield, located just south of the Navajo Nation in T20N, R13E on the Red Gap Ranch; and 2) the Canyon Diablo wellfield, located partially within Canyon Diablo and the Navajo Nation (add a figure reference here). The technical layout of these wellfields is further discussed in section 2.3 below, and the modeling of the wellfields is discussed in section 2.3.3 below, with additional detail in appendix A.

The alignment of the conveyance systems for the two wellfields differs only in their segments from the wellfield to the community of Leupp. The alignment from the I-40 wellfield crosses under the Little Colorado River, and follows the Highway 99 corridor approximately 21 miles north to Leupp. The alignment from the Canyon Diablo wellfield begins with three wells, located within a 10-square-mile section of the Canyon Diablo east of Canyon Diablo, and incorporates 10 wells to meet Black Mesa Mine and Navajo demands within the Navajo Nation southwest of Leupp (figure 1). From Leupp, the alignment for either wellfield proceeds approximately 50 miles along Highway 99 to a point approximately 5 miles south of Dennebito Wash, and then approximately 45 miles along the west side of Dennebito Wash to the Black Mesa Mine.

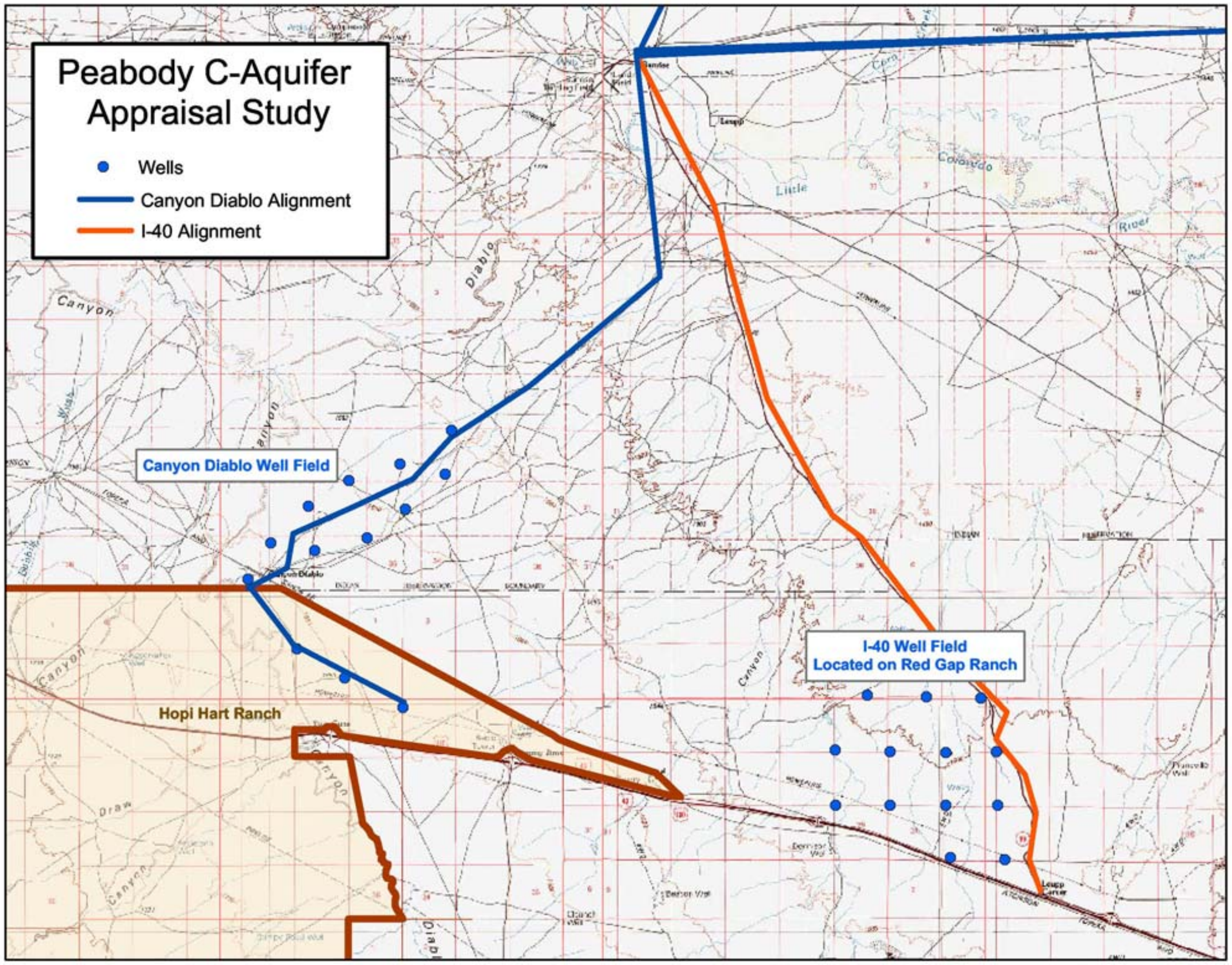

Figure 2.—I-40 and Canyon Diablo wellfields.

2.3 Wellfields

The current Canyon Diablo wellfield is located as shown on figure 1, Black Mesa Mine C-Aquifer Appraisal Study. Based on an identified Black Mesa Mine demand of 6,000 af/yr, and 2,000 af/yr each of Navajo and Hopi M&I demand, the conceptual wellfield layout is illustrated on figure 1. The Canyon Diablo wellfield consists of 13 wells: 3 on the Hopi Hart Ranch parcel, to supply their 2,000 af/yr demands, and 10 wells on the Navajo Nation, to supply the 2,000 af/yr Navajo M&I demand, and for the Black Mesa Mine demand of 6,000 af/yr. All wells would target the regional C-Aquifer, specifically the Coconino Sandstone.

From existing well database and other information, and as used in the Hopi-Western Navajo Water Supply Study modeling work (analytical and numerical models), for the purposes of this study, each well is assumed to pump continuously, yielding 500 gallons per minute (gpm) (807 af/yr) from year 2000 through 2100. This yields an annual total of 6,500 gpm or 10,485 af/yr. Thus, three Hopi wells would provide theoretical yields of 1,500 gpm or 2,420 af/yr to satisfy their anticipated needs, three wells would pump 2,420 af/yr to satisfy the Navajo demand, and the remaining seven wells would pump 3,500 gpm or 5,646 af/yr to meet Black Mesa Mine's needs.

In reality, the wells would be drilled and completed in a phased approach as demands ramped up through time. The Black Mesa Mine life-of-mine ends about year 2030, at which time that demand would be absorbed by one or both tribes or other tribal or nontribal interests. The water supply system is being developed for an average annual peaking demand factor of 2. Water pumped from the Hopi wells, and wells further northeastwards, will flow by gravity to Leupp storage.

2.3.1 Hydrogeologic Characteristics

The C-Aquifer (primarily the eolian Coconino Sandstone) has quartz sand grains generally well lithified (bound together or indurated) and is considered a fractured rock aquifer. Much less groundwater moves through the matrix (around sand grains) as it does via fracture flow. Therefore, wells with their drawdown zones of influence in proximity to water bearing fractures should be much better producers, other factors being equal. The Coconino Sandstone (C-Aquifer) in the wellfield area has a gentle regional dip towards the Black Mesa basin. For appraisal purposes, the top and bottom stratigraphic formational contact elevations for the C-Aquifer are 4950 and 4150 feet above mean sea level (msl), for an average thickness of 800 feet. These numbers are taken from the Hopi Western Navajo Water Supply Study I-40 wellfield modeling work, and they apply to both the I-40 and Canyon Diablo wellfield alternatives.

The three Hopi wells would be drilled from about ground surface elevation 5400 at the Canyon Diablo site. All I-40 wells would begin from about 5000- to 5200-foot ground surface elevation. For the remaining 10 wells of the Canyon Diablo site, the ground surface elevation is about 5400 feet above msl at the Hart Ranch/Navajo Nation boundary, then it drops uniformly to about 5000 feet as one goes northeast from the boundary to the last well site (see figure 1).

Both the I-40 and Canyon Diablo - Hopi wellfield portions are located (spatially) roughly along the strike of the Coconino Sandstone; therefore, the Canyon Diablo - Hopi wellfield is assumed to have a similar depth to base of aquifer as the I-40 wells. Although the top and bottom stratigraphic contact elevations of the C-Aquifer (along the Canyon Diablo - Navajo/ Black Mesa Mine wells alignment) will get increasingly deeper towards the northeast (towards the Black Mesa basin), the ground surface elevations also decrease in that direction, so depth of wells to tap the C-Aquifer are assumed to remain fairly constant.

The regional groundwater flow direction and gradient (other than local pumping gradients) below these sites is north-northwesterly towards the Blue Springs discharge area. Thus, the line of wells (especially on the Navajo Nation) will trend along similar water level contour elevations within the C-Aquifer. This means the depth-to-water (but not necessarily water level elevation) in those wells further northeastward should decline with distance from the tribal boundary, resulting in lower construction and pumping costs.

Assuming confined to semi-confined C-Aquifer conditions and fully penetrating wells, the Hopi wells should be about 1250 feet deep, and the Navajo and Black Mesa Mine wells will range from about 1150 to 1050 feet deep towards the northeast. To keep things simple, the appraisal level well target depths (for both wellfield sites) are normalized to 800-foot depth (the depth used for all analytical and numerical modeling simulations). The depth to static water level is assumed to be 200 feet for both wellfield sites. Aquifer storage properties, conductivities, etc., are similar.

Twelve-inch-diameter wells would be the minimum size necessary to yield 500 gpm. The well casing string could consist of about 300 feet of well screen and 500 feet of blank well casing. A 50- to 75-horsepower (hp) submersible pump is expected using an approximate total design head (tdh) of 350 feet. The field cost estimate for 13 wells is about $2.7 million or $208,000 per well. These costs are summarized in table 1.

Nonconstruction costs were estimated at 26 percent of the constructions costs (See section 2.4.9.4 for additional detail). Nonconstruction costs are summarized in table 19 at the conclusion of this chapter.

Operations and maintenance (O&M) costs were estimated on a per-well basis. It was assumed that for each well, a two-man crew would pull the pump for inspection on a bi-annual basis.

Replacement costs were estimated on a per-well basis on replacing the pump. Each pump coast $15,000. Replacement cost based on computing a future value at 6 percent discount rate and a twenty year life cycle were used to determine the annualized pool of funding required to replace the pumps.

Power costs were estimated consistent with the methodology utilized for estimating pipeline power costs. See section 2.4.9.4.

Total operation, maintenance, replacement, and energy (OMR&E) costs for the wellfields are provided in table 2.

Table 1.–Cost estimate for 13 water production wells in the C-Aquifer–both wellfields

Item No.	Description of work	Estimated quantity	Unit	Unit cost/ lump sum ($)	Total cost ($)
1.	Mobilization/demobilization	13 wells	each	$8,000	$104,000
2.	Drill, furnish, install, and cement 20-inch surface casing	40 ft x 13 wells = 520 ft	ft	$200/ft	$104,000
3.	Drill 8-inch pilot hole, ream to 17-1/4-inch hole air or mud rotary	13 wells x 800 ft = 10,400 ft	ft	$85/ft	$884,000
4.	Standby	16	hr	$250	$4,000
5.	Furnish, install 300-foot, 12-inch well screen	13 wells x 300 ft = 3,900 ft	ft	$160/ft	$624,000
6.	Furnish, install 500-foot, 12-inch blank well casing	13 wells x 500 ft = 6,500 ft	ft	$65/ft	$422,500
7.	Furnish, install 350-foot, (5 cy[4]) gravel pack	13 wells x 5 cy = 65 cy (227,500 lbs)	ton	$500/ton	$56,875
8.	Furnish and install 450-feet of cement to ground surface	13 wells x 450 ft = 5,850 ft	ft	$25 /ft	$146,250
9.	Swab/air lift well to develop	13 wells x 8 hrs = 104 hrs	hr	$250/hr	$26,000
10.	Furnish,and install pump and 4-inch drop pipe, misc. meter, pump test	13 wells x 8 hrs = 104 hrs	hr	400/hr	$41,600
11.	Geophysical well scan	13	ea	$2,500	$32,500
12.	Disinfection	13	ea	$3,000	$39,000
13.	Furnish and install 50-100 hp submersible pump (avg 65 hp)	13	ea	$15,000	$195,000
					$2,700,000

[4] Cubic yard

Table 2.– Wellfield OMR&E costs

	Annual power cost	Annual O&M cost	Annual replacement cost	Total annual OMR&E cost
Per individual well	$27,600	$1,000	$2,400	$31,000
For 13 wells	$359,000	$13,000	$31,200	$403,000

2.3.2 Criteria for Wellfield Site Selection

Criteria include several important factors that, taken collectively, will dictate the best or optimum wellfield site. These factors are:

- Depth to C-Aquifer from ground surface and depth to water. This greatly affects the drilling method used and costs to drill and complete the hole. It also has a bearing on pump selection, pumping costs, and the long-term OMR&E.

- The existing network (density) of municipal and domestic wells tapping the C-Aquifer adjacent to the proposed wellfield sites. A given wellfield may unacceptably overdraft the aquifer or change flow directions, due to the many wells already pumping.

- Average specific yield and current yields of existing C-Aquifer wells.

- Water quality considerations. One wellfield site may have better groundwater quality than another. Quality at one site might suffice for the slurry line but not for potable use.

- Proximity to available electrical power/power line corridors.

- Degree of bedrock faulting. Faulting fractures the bedrock and, depending on its strength, usually improves yields to wells and springs. Fractures normally control the volume and flow direction of groundwater in bedrock aquifers, including the C-Aquifer.

- Hydrologic impacts (e.g., baseflow/subflow impacts), due to pumping the C-Aquifer on hydraulically connected surface water bodies. Additional C-Aquifer pumping could cause additional depletion from the Little Colorado River (LCR) by leakage, or direct streamflow depletion from tributaries such as Chevelon Creek.

2.3.3 Wellfield Modeling

The I-40 and Canyon Diablo wellfields were modeled to predict, out to year 2100, whether the C-Aquifer groundwater system may be able to support an additional (approximately) 6,000 af/yr of Black Mesa Mine demand, and then 10,000 af/yr of cumulative pumping demand (Navajo and Hopi demands added). These 6,000 and 10,000 af/yr demands were in addition to the existing municipal, light and heavy industrial, and agricultural pumping demands by up to 47 tribal and nontribal entities.[4]

An important part of the evaluation was to determine whether this additional 10,000 af/yr of pumping could significantly deplete the current discharge from Blue Springs in the lower LCR, and baseflow from Upper East Clear Creek and Lower Chevelon Canyon tributaries to the LCR. These stream reaches support several critical species dependent on the flows. From the Hopi-Western Navajo Water Supply Study, it was determined that this flow reduction threshold was 10 percent (Alternative 1: local groundwater).

[4] Figure A-2 (demand and pumping center map) in appendix A, lists all the demand centers accounted for in these analyses.

From groundwater modeling work (performed in support of the Hopi-Western Navajo Water Supply Study), Reclamation determined that the vehicle to help make these evaluations would be additional groundwater modeling, using the model input data and/or models from that work. The modeling results would attempt to quantify and at least qualify the impacts to stream and spring flows, and the magnitudes of additional drawdown and resultant cone of depression distribution as a result of pumping either 6,000 af/yr or 10,000 af/yr from the wellfield. Water quality considerations were also considered.

The groundwater modeling subcontractors for the Hopi-Western Navajo Water Supply Study were Southwest Groundwater Consultants, Inc. (SGC) and Peter Mock Groundwater Consulting, Inc. (PMGC), which were consultants to HDR Engineering, Inc. SGC performed the modeling for this analysis. The modeling process and the results of the modeling are described in greater detail in appendix A. The estimated impacts of the pumping on the environmental resources of concern are discussed in section 4 of this report.

2.4 Pipelines

All of the cost estimates for conveyance systems in this report are based on the alignment starting from the I-40 wellfield. The conveyance system from the Canyon Diablo wellfield location only changes the cost for the gravity line from the wellfield to the Leupp Pumping Plant in the construction cost estimate. The pipeline length from the wellfields to Leupp is similar and, while the Canyon Diablo is at a higher elevation and would require smaller pipe, there is also a railroad crossing on this alignment. Therefore, the cost for the pipeline from the wellfield to Leupp would be similar for each wellfield site. Reclamation used a peaking factor of 1.2 for the Black Mesa Mine flows and 2.0 for the tribal flows. The peaking factor is based on information received from Reclamation's Phoenix Area Office (PXAO).

Reclamation looked at three different variations:

1. Variation 1 (V1): 6,000 af/yr delivered to the Black Mesa Mine only. V1 has six pumping plants located along the alignment with no turnouts. The pipeline that directly connects the wellfield and the Black Mesa Mine is called the transmission line.

2. Variation 2 (V2): 10,000 af/yr to deliver 2,000 af/yr to the Hopi, 2,000 af/yr to the Navajo, and 6,000 af/yr to Black Mesa Mine; V2 provides water to the Navajo communities of Leupp and Dilkon. Leupp will receive 600 af/yr and will be supplied by gravity from the wellfield. Dilkon will receive 1,400 af/yr and will be supplied by three pumping plants, and there are no turnouts between Leupp and Dilkon. V2 also provides water to the Hopi communities of Bacovi (850 af/yr) , Shongopovi (420 af/yr) and Keams Canyon (730 af/yr). The pipelines that deliver water to the individual communities from the transmission line are called laterals.

3. Variation 2A (V2A): Same as V2, except that an additional 336 af/yr would be delivered to Jeddito through the Three Mesa Lateral system.

The location of the transmission line and the laterals are shown in figures 2, 3, and 4. Profiles for the various alignments are provided in figures 5 through 8. A schematic of the pipeline system is provided in figure 9.

2.4.1 General

The Technical Service Center (TSC) used National Geographic Topographic Software (TOPO!), which included the area of the locations of the pipe alignments for all of the pipe laterals. The TSC used this software for the layouts of the general plans and profiles for each alternative, which were then used to determine pipe lengths and head classes.

In-line sectionalizing valves would be spaced every 3 miles. Sectionalizing valves would be housed in a corrugated metal pipe (CMP), vault-type structure.

Blowoffs would be located at several low points along the alignment to allow draining and filling of a 3-mile section in 72 hours. Blowoffs would be designed for buried service.

Air valves would be located at all high points, at either side of the sectionalizing valves, and where required to fill and drain the pipeline. Air valves would be designed for buried service.

2.4.2 Hydraulics

The Hazen-Williams equation was used to compute the loss, due to friction in the pipe laterals. As a guideline, the TSC estimated that the design velocity should be about 5 feet per second or less, and the maximum pump lift would be about 450 feet. The minimum system pressure along the pipe laterals was 15 feet. Pipe friction losses were limited to about 25 percent of the total dynamic head for the pumps. Where possible, pumping plant heads were made the same to optimize the use of the pumps between plants.

2.4.3 Pipe Types

When computing the hydraulics, it was assumed that all of the lateral pipe would be mortar-lined steel pipe with full inside diameters. In using a Hazen-Williams Coefficient of 140 and steel pipe with full inside diameters, the resulting friction losses are considered conservative. By limiting the pump lift to about 400 feet of head and adding 30 percent for an upsurge allowance, the head class (pressure class) for the pipe was generally limited to 575 feet (250 pounds per square inch [psi]). However, in areas where the topography results in large decreases in the ground surface elevations, pipe head classes may reach values higher than 575 feet. The pipe head classes, pumping plant locations, pump heads, and pipeline alignments will be more precisely defined in the next level of study.

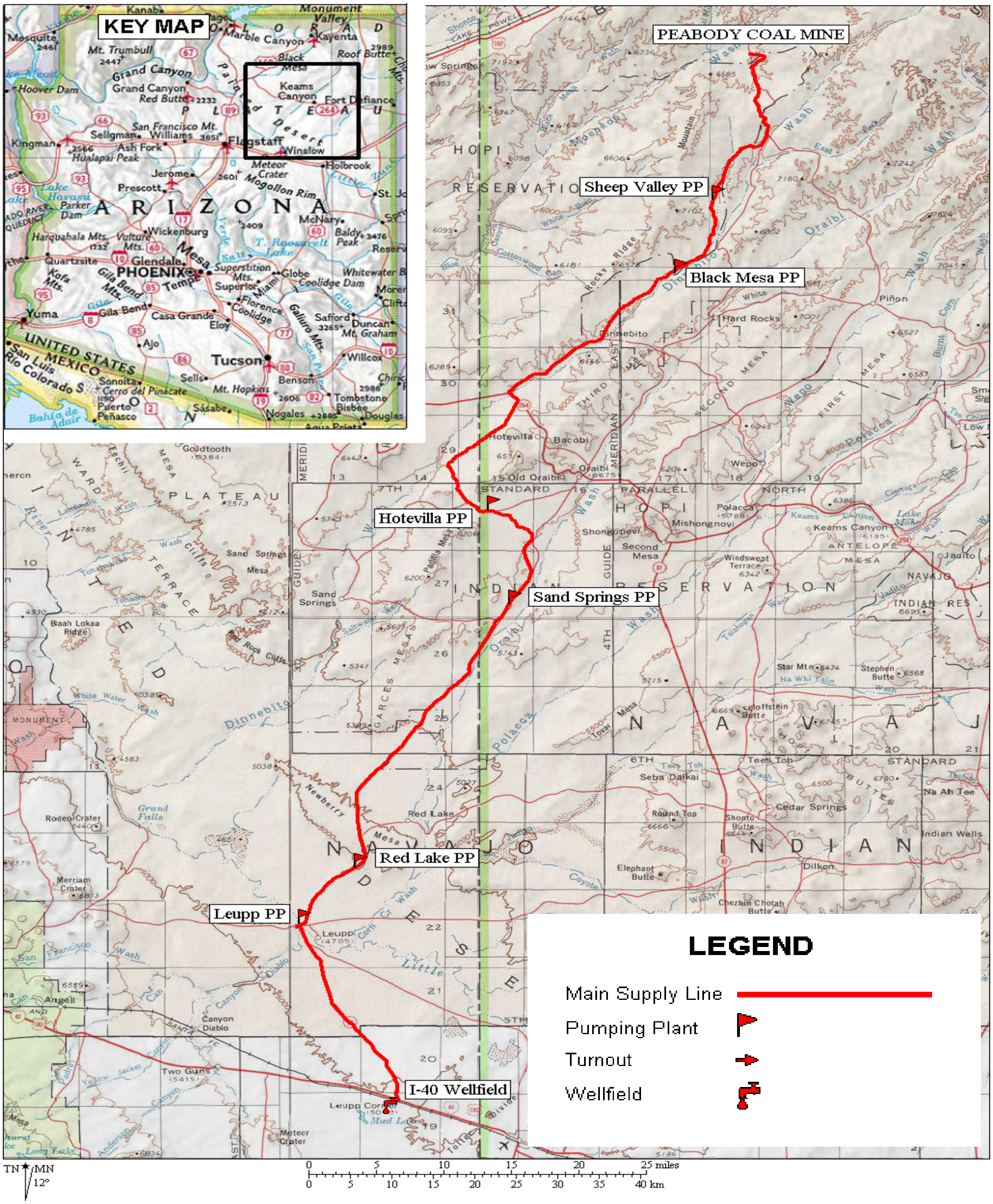

Figure 2.–Proposed water supply pipeline layout from I-40 wellfield, without municipal water supply laterals (V1).

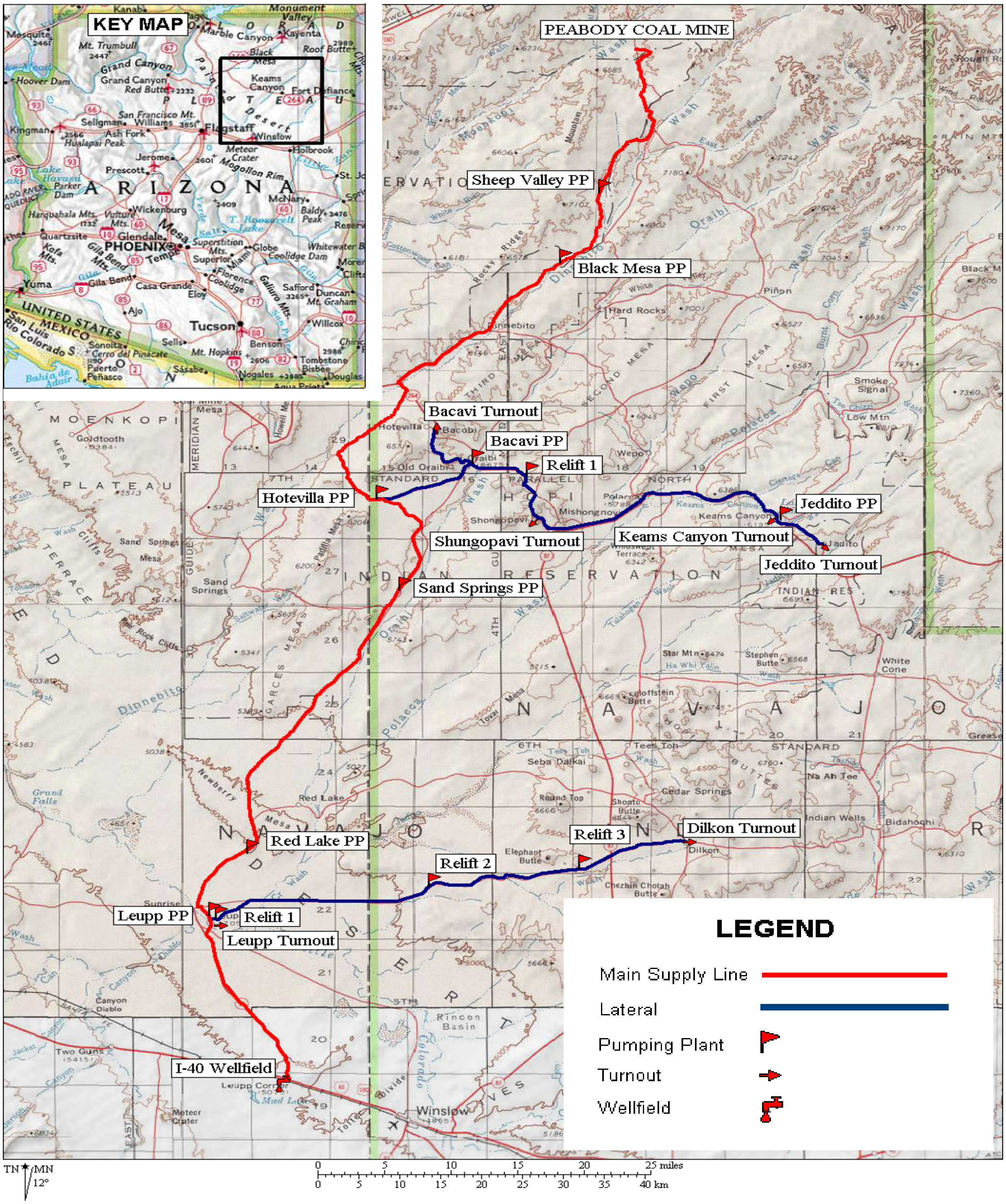

Figure 3.—Proposed water supply pipeline layout from I-40 wellfield, including municipal water supply laterals (V2 and V2A).

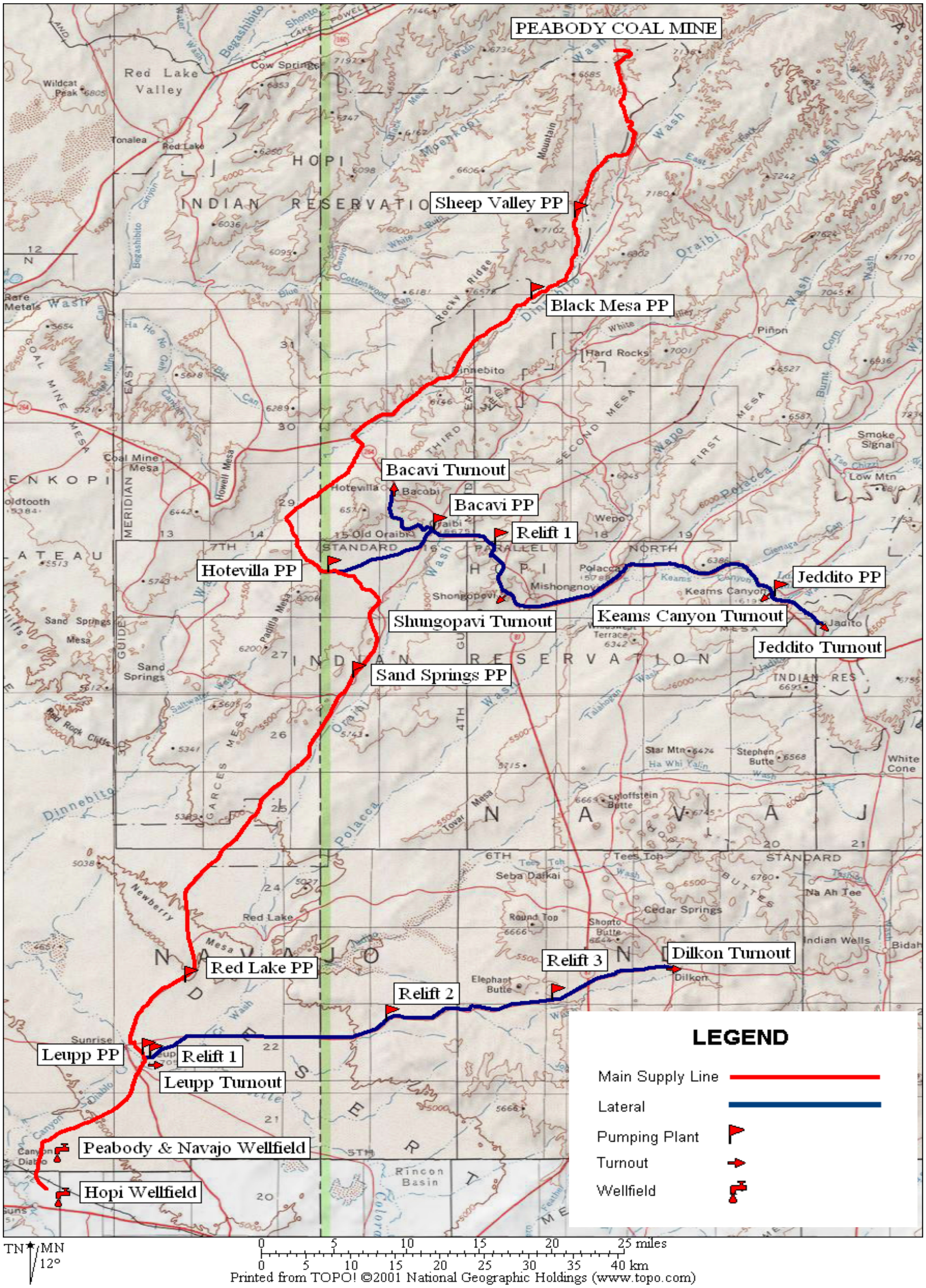

Figure 4.–Proposed water supply pipeline layout from Canyon Diablo wellfield.

Flow = 6,000 AF/YR

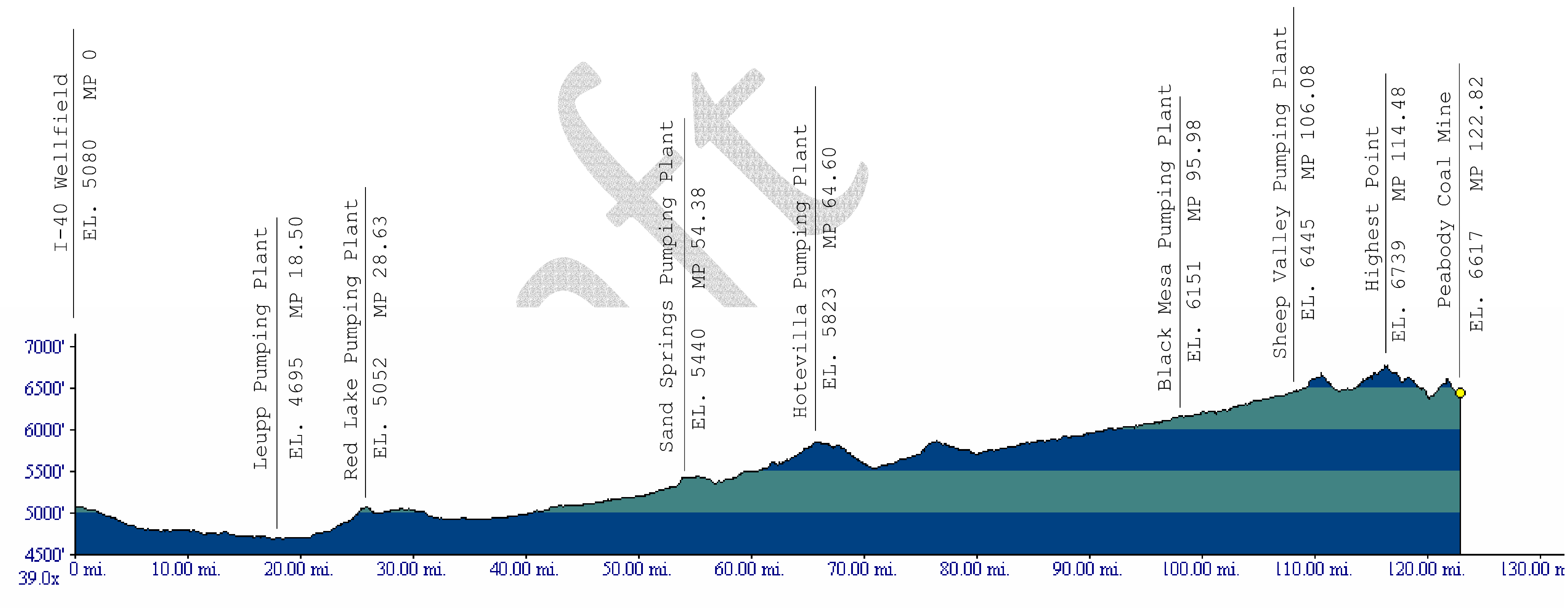

Figure 5.—Profile from the I-40 wellfield to Black Mesa Mine.

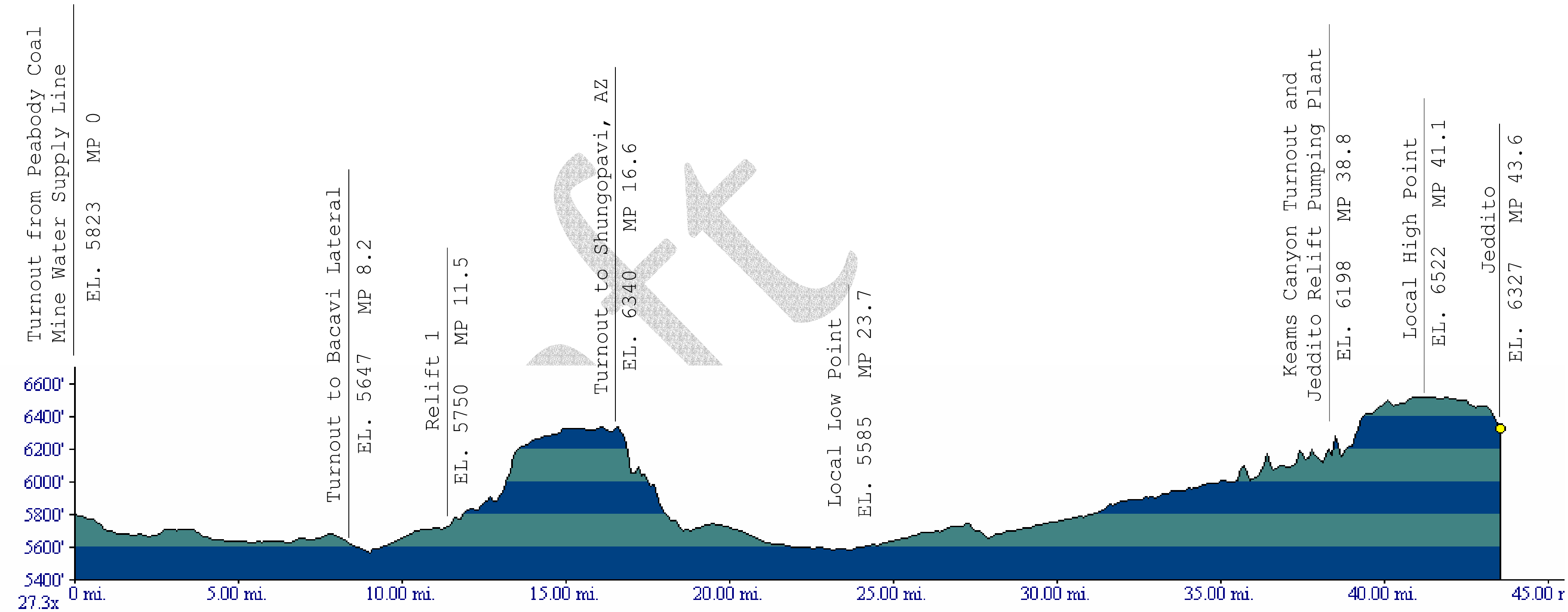

Figure 6.—Profile from Hotevilla Pumping Plant to Jeddito.

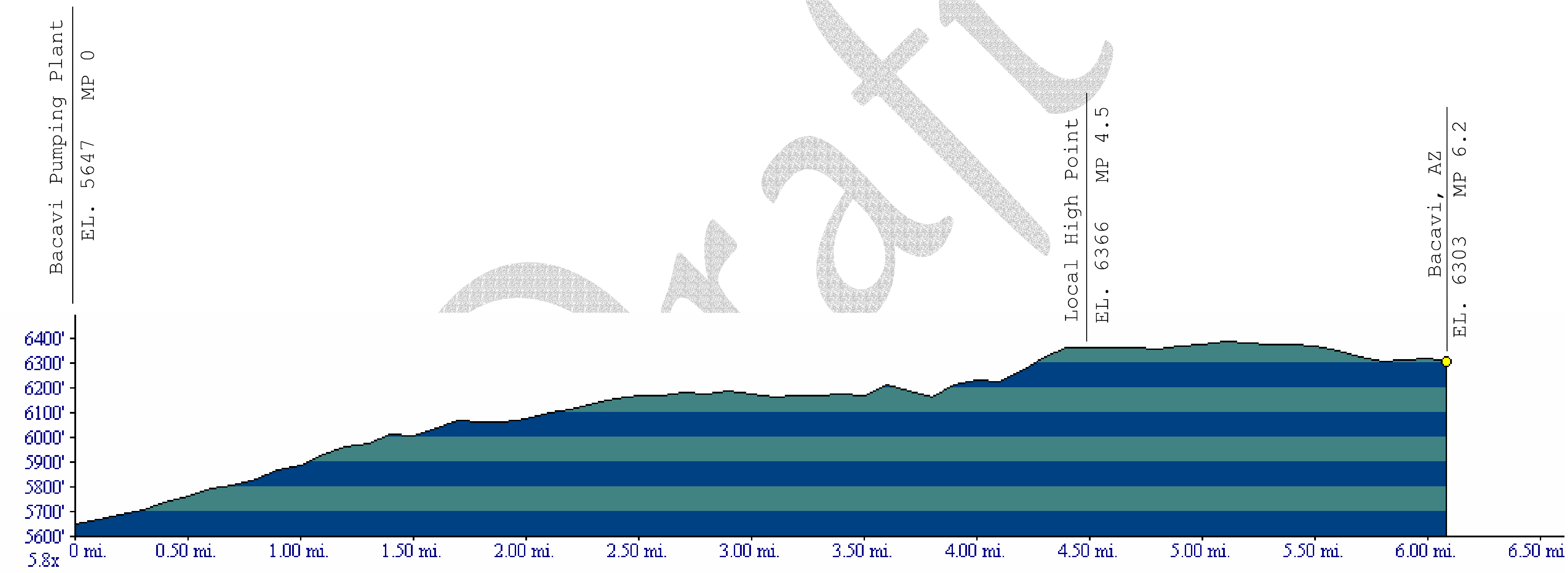

Figure 7.—Profile from Oraibi to Bacavi.

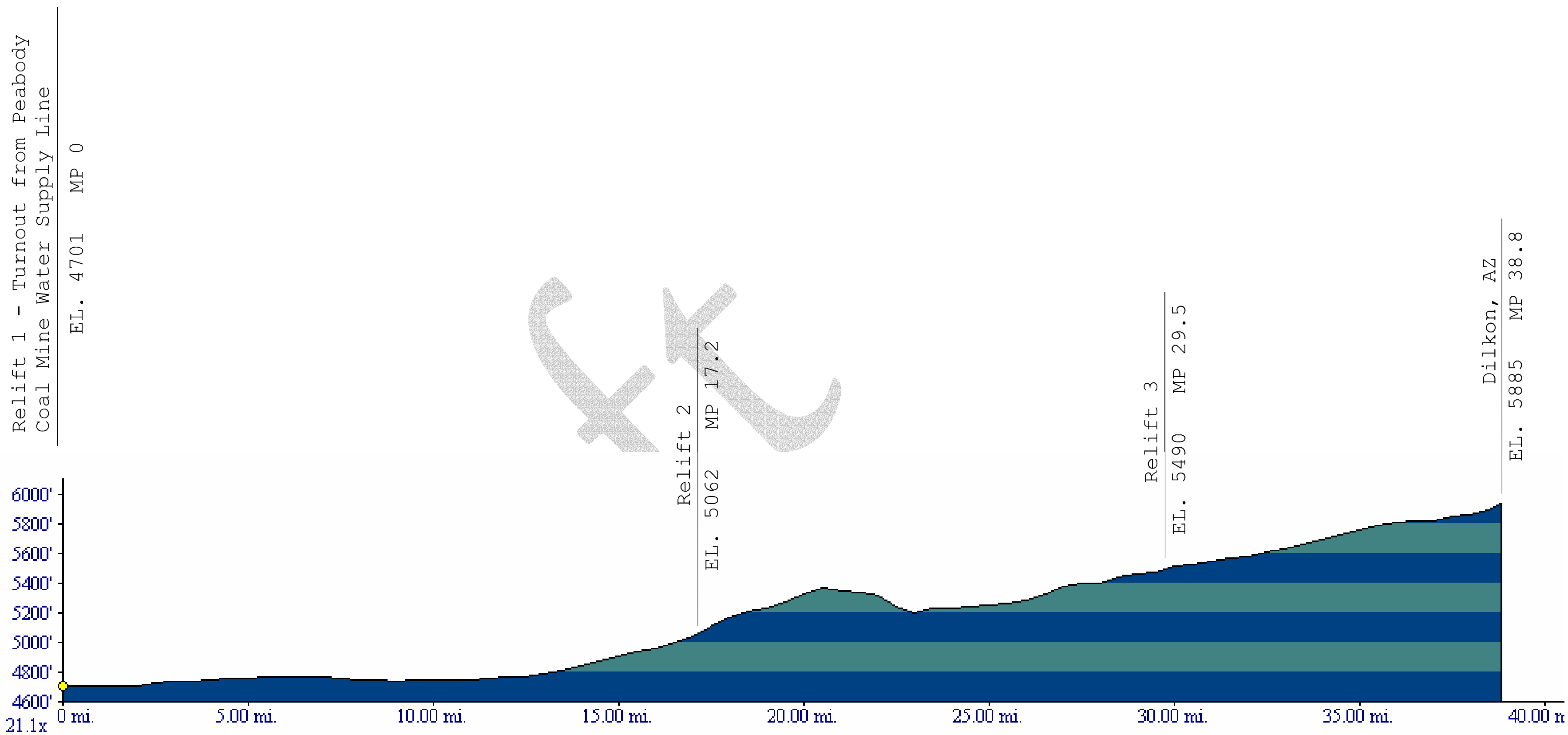

Figure 8.—Profile from Leupp to Dilkon.

Steel pipe can be manufactured in all of the pipe diameters and head class increments that have been estimated for this project. At the present time, some of the newer pipe types are not available in the larger diameters and higher pressure ratings. Polyvinyl chloride (PVC) pipe is currently limited to 30-inch diameter with a 165-psi pressure rating and 24-inch diameter with a 235-psi pressure rating. High-density polyethylene pipe (HDPE) is currently limited to 24-inch diameter with a 160-psi pressure rating, 28-inch diameter with a 128-psi pressure rating, and 30-inch diameter with a 128-psi pressure rating. Fiberglass pipe is currently limited to 24-inch diameter with a 250-psi pressure rating and 30-inch diameter with a 250-psi pressure rating. In some instances, pipe manufactures may have the capability to make larger diameters with higher pressure ratings.

Since cathodic protection is not required for these nonmetallic type pipes, they should at least be considered as an option in most of the pipe diameters in the next level of design for this project. Also, every year, pipe manufacturers are making larger diameter pipes with higher pressure ratings. These nonmetallic type pipes generally have a lower coefficient of friction, but in some instances, do not have full inside diameters, requiring a larger nominal pipe size in order to achieve the required internal diameter. When more precise design data is available in the next level of design, all of these factors should be considered when computing the hydraulics.

Steel pipe prices were used for pipe with pressure requirements outside the rated limits of HDPE. The appurtenant structures and mechanical equipment associated with the pipeline are covered under unlisted items in the cost estimates. These would include such items as air valves, blowoffs, drains, flowmeters, pressure-reducing valves, altitude valves, and sectionalizing valves.

2.4.4 Excavation and Backfill

Quantities for pipe earthwork, including both rock and common excavation, were based on a typical trench section with an average depth of cover of 3 feet. Common and rock excavation areas were based on information from the Navajo Nation Report, in titled "Conceptual Cost Estimates: Ward Terrace to Black Mesa Pipeline and I-40 to Black Mesa Pipeline," dated January 8, 2003. This resulted in a total of 72.88 miles of common excavation and 47.15 miles of rock excavation.

Leupp/Dilkon lateral's earthwork is anticipated to be predominantly common excavation, based on discussions with the Phoenix area office (PXAO) in conjunction with the technical memorandum discussed above. The Three Mesa lateral's earthwork is anticipated to be a combination of common and rock excavation again based on discussions with the PXAO and technical memorandum. The Three Mesa lateral's rock excavation is anticipated for pipeline alignments that intersect Mesa 1, 2, and 3. Rock excavation is anticipated for the Bacobi pipeline, Relift 1 discharge line to Shungopovi, and Gravity C line to Keams Canyon.

A 4-inch-deep layer of select material will be required underneath the pipe. It is assumed that this material will have to be imported to the site. The remainder of the compacted backfill and fill over the top of the pipe can be from trench excavation material or nearby borrow sources.

Table 3 shows the costs for the excavation and backfill for this report.

Table 3.—Pipe trenching costs

Pipe installation Item	Unit cost ($/cy)
Excavation (rock trenching)	9
Excavation (common)	3
Pipe bedding (select material)	30
Backfill	3
Compacted backfill	9

2.4.5 SCADA

The cost estimate includes the cost for a Supervisory Control and Data Acquisition (SCADA) system for the control of the pumping plants. The construction costs for the SCADA system were assumed to be 3 percent of the construction cost.

2.4.6 Corrosion Monitoring and Cathodic Protection

The cost estimate includes the cost for corrosion monitoring and cathodic protection of the steel pipelines where applicable. The construction costs for cathodic protection of steel pipe were assumed to be 1 percent of the construction cost.

2.4.7 Pumping Plants

2.4.7.1 General

The six relift pumping plants are required to lift the water from lower to higher elevations along the transmission line and to overcome the frictional resistance in the pipe.

Tables 4 through 6 summarize the pumping plant data.

Table 4.—Variation V1: Black Mesa Mine lateral

Pumping plant	Flow rate (cfs)	Acre-feet per year	Static lift (ft)	Total lift (ft)	HP
Leupp	9.95	6,000	357	422	597
Red Lake	9.95	6,000	388	443	626
Sand Springs	9.95	6,000	383	448	633
Hotevilla	9.95	6,000	328	395	558
Black Mesa	9.95	6,000	294	358	506
Sheep Valley	9.95	6,000	308	362	510

Table 5.—Variation V2: Black Mesa Mine lateral

Pumping plant	Flow rate (cfs)	Acre-feet per year	Static lift (ft)	Total lift (ft)	HP
Leupp	15.48	6,000	357	439	965
Red Lake	15.48	6,000	388	467	1027
Sand Springs	15.48	6,000	383	466	1025
Hotevilla	9.95	6,000	328	395	558
Black Mesa	9.95	6,000	294	358	506
Sheep Valley	9.95	6,000	308	362	510

Table 6.—Variation V2: Dilkon lateral

Pumping plant	Flow rate (cfs)	Acre-feet per year	Static lift (ft)	Total lift (ft)	HP
Relift 1	3.871	2,000	361	438	241
Relift 2	3.871	2,000	428	483	265
Relift 3	3.871	2,000	395	437	240

Table 7.—Variation V2: Three Mesa laterals

Pumping plant	Flow rate (cfs)	Acre-feet per year	Static lift (ft)	Total lift (ft)	HP
Bacovi	2.34	850	719	739	245
Relift 1	3.19	1,150	590	606	275

Table 8.—Variation V2A: Black Mesa Mine lateral

Pumping plant	Flow rate (cfs)	Acre-feet per year	Static lift (ft)	Total lift (ft)	HP
Leupp	16.40	8,336	357	449	1044
Red Lake	16.40	8,336	388	476	1107
Sand Springs	16.40	8,336	383	476	1106
Hotevilla	9.95	6,000	328	395	558
Black Mesa	9.95	6,000	294	358	506
Sheep Valley	9.95	6,000	308	362	510

Table 9.—Variation V2A: Dilkon lateral

Pumping plant	Flow rate (cfs)	Acre-feet per year	Static lift (ft)	Total lift (ft)	HP
Relift 1	3.871	2,000	361	438	241
Relift 2	3.871	2,000	428	483	265
Relift 3	3.871	2,000	395	437	240

Table 10.—Variation V2A: Three Mesa laterals

Pumping plant	Flow rate (cfs)	Acre-feet per year	Static lift (ft)	Total lift (ft)	HP
Bacovi	2.34	850	719	739	245
Relift 1	3.19	1,150	590	616	360
Jeddito	0.93	336	324	362	48

2.4.7.2 Pumps

The pumps at the pumping plants were assumed to be equal size units with a maximum capacity of 4 cfs each. There is one standby pump unit at each pumping plant. The majority of the pumps would be the horizontal split-case type. Each pump would have a suction and discharge valve with an electric or hydraulic operator, as well as a check valve. The pumps in the relift pumping plants and the turnout deliveries would all require a minimum of 15 feet of head on the suction side. Level switches that sense the water levels in the regulating, forebay, and storage tanks would control the pumps. Pumping plant locations are shown on figures 5 through 8.

2.4.7.3 Air Chambers

All pumping plants were assumed to require an air chamber to prevent upsurge and downsurge. These chambers were assumed to be spherical and have a volume of 3,000 cubic feet. Typical air chamber sizes were estimated, based upon pumped systems for the Navajo-Gallup Water Supply Project, which had similar flows and pressures.

2.4.7.4 Pumping Plant Costs

The TSC used Reclamation's computer program, "PUMPLT," to estimate the field costs of the pumping plants. This program estimates costs of pumping plant construction-based upon historical data for plants with similar flows, heads, and number of pumping units. The program output includes structural improvements, including the structure itself and civil site work, waterways, pumps, motors, electrical access, and miscellaneous equipment.

2.4.7.5 Power

Topographic maps were used to locate nearby powerlines to be used as sources of power for the pumping plants required along the main Black Mesa Mine transmission pipeline. The assumption was made that these powerlines were 69-kilovolts lines, and the associated tap fees required from tapping into two lines were not included. In a previous report for the Lake Powell pipeline, these costs would be about $400,000 per tap. The assumption was made that two taps would be needed for this project, one near Leupp and the other near Black Mesa Pumping Plant. Cost for substations are included in the pumping plant costs. All new powerlines were assumed to be 34.5 kilovolts.

Power for the Three Mesa laterals was assumed to be available at existing wellfields near the cities of Orabi, Shungopovi, and Keams Canyon. Lengths of new powerlines were based on this assumption. No costs were included for tapping into these existing facilities. Cost for substations are included in the pumping plant costs.

Power for the Dilkon laterals was assumed to be available from the planned Leupp Pumping Plant. The powerlines were extended to the relift pumping plants requiring an additional 20 miles of powerline. Cost for substations are included in the pumping plant costs.

2.4.8 Storage Tanks

The size of the initial and terminal gravity tanks on the system were based on 3 hours of storage and were assumed to be 83 feet in diameter and 20 feet tall.

Forebay tanks would be required upstream from each pumping plant to supply water during startup of the pumps and during shutdown to reduce waterhammer effects. Altitude valves would be installed at most sites to prevent the forebay tanks from overtopping. For this appraisal level study, all of the forebay tanks were estimated to be 16,000-gallon capacity; 16 feet in diameter, and 40 feet tall. Tank water surfaces would be the primary control for automatically stopping and starting the pumps. In the next level of study, each of these tanks would be sized on an individual basis.

Storage tanks were provided at the Navajo and Hopi delivery community turnouts, for the Leupp/Dilkon turnout, and for the Three Mesa laterals. These tanks store a 3-day water supply for the community. It was assumed that the height of the storage tanks would range from 20 to 30 feet, and the diameters were computed based on the values for the 3-day storage for the year 2025 demands. Figure 9 shows the tank locations.

2.4.9 Cost Estimates

This section discusses expected construction completion times, estimated construction and nonconstruction cost, estimated annual, OMR&E costs, and summarizes costs for the three alternatives.

2.4.9.1 Construction Completion Times

Reclamation estimated the construction completion time for the main transmission line and laterals for Variation 2 would be 3-4 years.

2.4.9.2 Construction Cost Estimates

Cost estimate sheets are included in appendix B.

2.4.9.3 Nonconstruction Cost Estimates

Nothing is included in the construction cost estimate to cover noncontract costs. Nonconstruction contract activities are usually based on a percentage of construction costs. Table 11 show typical costs.

Table 11.—Typical nonconstruction cost estimate.

Activity	Percent of construction costs
Planning	5.0
Investigations	3.5
Design and specifications	3.0
Contract administration	7.0
Water rights	0.5
Environmental permits	5.0
Right-of-way	2.0
Total	26.0

2.4.9.4 Annual Operation, Maintenance, Replacement, and Energy Costs

The Reclamation computer program, PMPOM, generated annual OMR&E costs for pumping plants. The computer program is derived from information in Eyer, 1965[5]. Estimates of annual OMR&E costs were derived from records of 174 existing electric and hydro-powered pumping plants. The procedures cover direct OMR&E costs for pumps, motors, accessory electrical equipment, and plant structures for plants up through 15,000 total horsepower and consider wage rates and price levels. Price levels were updated from 1965 to 2001 levels. The costs are for the maximum pump discharge using the peak pumping rate.

Power Costs

The annual power costs at each pumping plant were computed using the following formulae:

$hp = QH/8.8$ or $hp = QH/ (8.8 \times Eff)$

Where: hp = horsepower
Q = flow in cfs
H = pump head in feet
Eff = 0.8 (assumed combined pump and motor efficiency)

$kW = 0.746\ hp$

Where: kW = kilowatts of energy

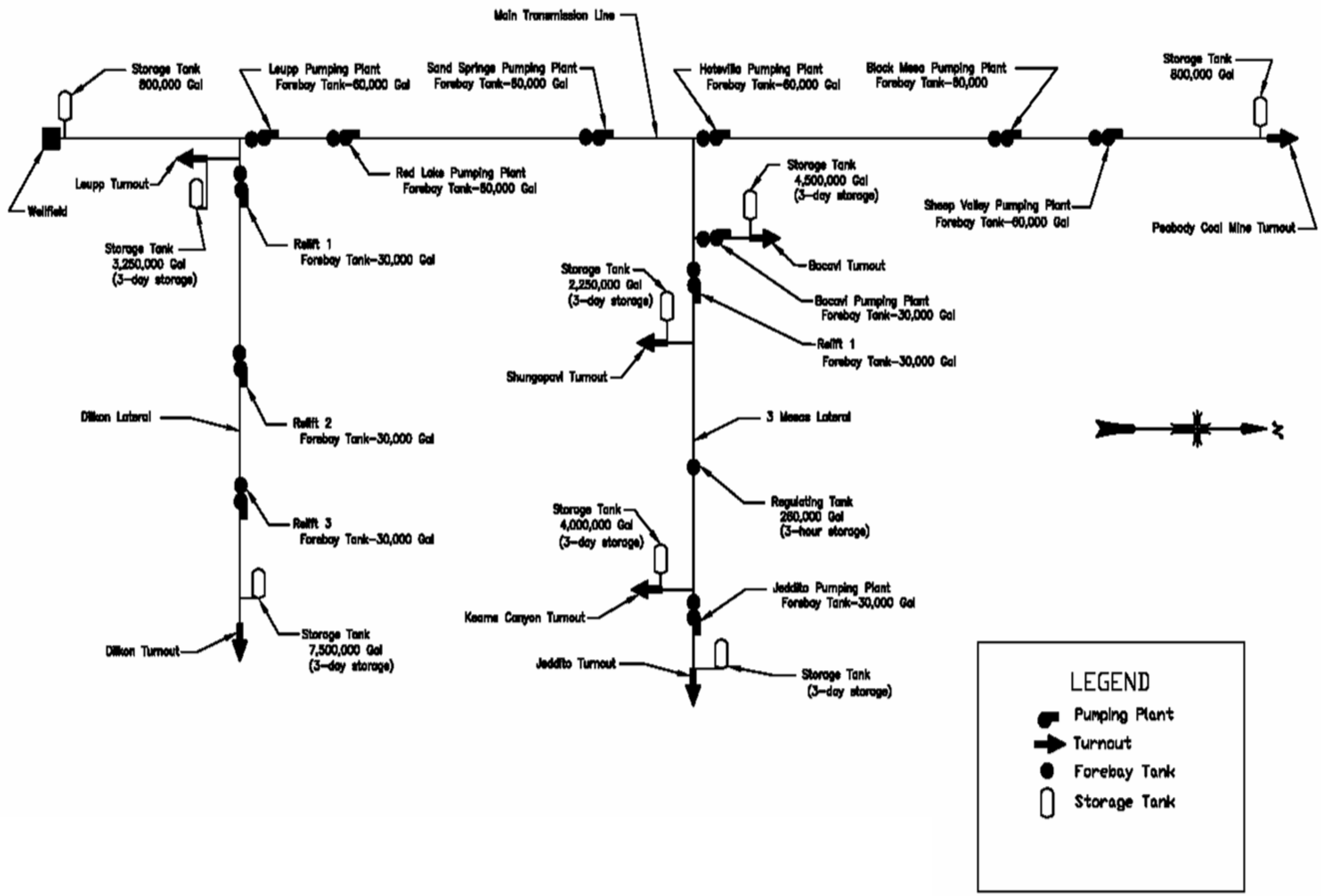

Figure 9.—Black Mesa Mine water supply pipeline schematic.

For each alternative, Reclamation was given the annual diversion in acre-feet per year and the peak flow requirement in cubic-feet per second. After converting the peak flow requirement to acre-feet per year, we determined that the annual diversion could be delivered by pumping at the peak demand for 100 percent of the time (total hours per year). The energy cost was determined using information received from PXAO for commercial energy prices in the area. This gives an average cost of power per kilowatts equal to:

Energy cost ($/year) = $.065 * kW

The pipe diameters, pumping plant locations, and pump heads will be more precisely defined in the next level of study. Also, the required delivery in acre-feet should be known for each month of the year. By knowing the flow in cubic feet per second (cfs) per month, new pipe friction losses and pump heads can then be computed based on the monthly flow requirement. By computing the energy required for each pumping plant for each month of the year, we would be able to compute a more realistic yearly energy cost.

Major Replacement Costs

According to Reclamation estimating guidelines, the replacement costs for pumping plants of less than 7,000 hp are included in the annual maintenance costs. Equipment replacement analysis procedures for pumping plants of more than 7,000 hp do not require replacements over the service life.

Pipelines

Annual O&M costs for pipelines were estimated to be 0.5 percent of the initial pipe cost. Annual OMR&E costs for pumping plants were generated by Reclamation computer program called PMPOM. The computer program is derived from information in Eyer, 1965[6]. Estimates of annual OMR&E costs were derived from records of 174 existing electric and hydro-powered pumping plants. The procedures cover direct OMR&E costs for pumps, motors, accessory electrical equipment, and plant structures for plants up through 15,000 total horsepower, and consider wage rates and price levels. Price levels were updated from 1965 to 2003 levels.

Annual O&M costs for the SCADA system and corrosion monitoring and cathodic protection systems were assumed to be 0.10 percent of the construction costs. The cost for cathodic protection power was estimated to be around $10,000 per year. Because the size and scale of the SCADA system are unknown, it would be difficult to estimate the annual O&M cost for this feature. The 0.1 percent of the construction cost would allow around $50,000-$70,000 for these activities.

Economic Costs

All alternatives were based on a 20-year repayment period for the pumping plants, a 40-year repayment period for the pipelines, and the current repayment interest rate of 6.0 percent. Construction time for the pipelines and pumping plants was assumed to be 3-4 years.

5 *Guidelines for Estimating Pumping Plant Operation and Maintenance Costs,* by John Eyer; 1965, Bureau of Reclamation

Table 12.—Variation V1: Black Mesa Mine lateral

Pumping plant	Flow rate (cfs)	Acre-feet per year	Annual power cost	Annual PP operation cost	Annual PP maintenance cost	Annual pipeline O&M cost	Annual cathodic protection + SCADA cost	Total annual cost
Gravity 1	9.95	6,000				$10,528		$10,528
Leupp	9.95	6,000	$252,688	$9,279	$55,295	$8,025		$325,287
Red Lake	9.95	6,000	$265,753	$9,421	$56,635	$35,360		$367,169
Sand Springs	9.95	6,000	$268,616	$9,421	$56,635	$8,100		$342,772
Hotevilla	9.95	6,000	$237,045	$8,975	$52,465	$43,082		$341,567
Black Mesa	9.95	6,000	$214,812	$8,748	$50,392	$8,010		$281,962
Sheep Valley	9.95	6,000	$216,708	$8,773	$50,622	$6,660		$282,763
Gravity 2	9.95	6,000				$4,840		$4,840
Subtotals							$72,000	$1,956,888
Grand Total								**$2,028,888**

Table 13.—Variation V2: Black Mesa Mine lateral

Pumping plant	Flow rate (cfs)	Acre-feet per year	Annual power cost	Annual PP operation cost	Annual PP maintenance cost	Annual pipeline O&M cost	Annual cathodic protection + SCADA cost	Total annual cost
Gravity 1	9.95	6,000				$15,143		$15,143
Leupp	15.47	8,000	$409,840	$ 13,073	$67,274	$12,034		$502,221
Red Lake	15.47	8,000	$435,412	$13,285	$69,001	$44,880		$562,578
Sand Springs	15.47	8,000	$434,768	$13,278	$68,941	$12,150		$529,137
Hotevilla	9.95	6,000	$237,045	$8,975	$52,465	$43,082		$ 341,567
Black Mesa	9.95	6,000	$214,812	$8,748	$50,392	$8,010		$281,962
Sheep Valley	9.95	6,000	$216,708	$8,773	$50,622	$6,660		$282,763
Gravity 2	9.95	6,000				$4,840		$4,840

Table 14.—Variation V2: Dilkon lateral

Pumping plant	Flow rate (cfs)	Acre-feet per year	Annual power cost	Annual PP operation cost	Annual PP maintenance cost	Annual pipeline O&M cost	Annual cathodic protection + SCADA cost	Total annual cost
Relift 1	9.95	6,000	$102,246	$5,902	$26,373	$10,442		$144,963
Relift 2	9.95	6,000	$112,724	$6,054	$27,452	$7,139		$153,369
Relift 3	9.95	6,000	$101,878	$5,898	$26,349	$5,982		$140,107

Table 15.—Variation V2: Three Mesa laterals

Pumping plant	Flow rate (cfs)	Acre-feet per year	Annual power cost	Annual PP operation cost	Annual PP maintenance cost	Annual pipeline O&M cost	Annual cathodic protection + SCADA cost	Total annual cost
Gravity A	5.53	5,000	$ -	$ -	$ -	$4,763		$ 4,763
Bacovi	2.34	850	$104,102	$5,337	$24,950	$4,087		$138,476
Gravity B	3.19	1,150	$ -	$ -	$ -	$1,566		$1,566
Relift 1	3.19	1,150	$116,463	$5,888	$27,284	$3,376		$153,011
Gravity C	2.03	730	$ -	$ -	$ -	$14,650		$14,650
Subtotals of 3 tables							$135,000	$3,271,116
Grand Totals of 3 tables								**$3,406,116**

Table 16.—Variation V2A: Black Mesa Mine lateral

Pumping plant	Flow rate (cfs)	Acre-feet per year	Annual power cost	Annual PP operation cost	Annual PP maintenance cost	Annual pipeline O&M cost	Annual cathodic protection + SCADA cost	Total annual cost
Gravity 1	21.93	10,336	$ -	$ -	$ -	$15,144		$15,144
Leupp	16.4	8,336	$443,394	$11,708	$67,256	$11,770		$534,128
Red Lake	16.4	8336	$470,088	$11,887	$68,885	$41,480		$592,340
Sand Springs	16.4	8,336	$469,886	$11,887	$68,885	$11,880		$562,538
Hotevilla	9.95	6,000	$237,045	$8,975	$52,465	$38,940		$337,425
Black Mesa	9.95	6,000	$214,812	$8,748	$50,392	$8,528		$282,480
Sheep Valley	9.95	6,000	$216,708	$8,773	$50,622	$6,682		$282,785
Gravity 2	9.95	6,000	$ -	$ -	$ -	$4,840		$4,840

Table 17.—Variation V2A: Dilkon lateral

Pumping plant	Flow rate (cfs)	Acre-feet per year	Annual power cost	Annual PP operation cost	Annual PP maintenance cost	Annual pipeline O&M cost	Annual cathodic protection + SCADA cost	Total annual cost
Relift 1	3.871	1,400	$102,246	$5,902	$26,373	$10,442		$144,963
Relift 2	3.871	1,400	$112,724	$6,054	$27,452	$7,139		$153,369
Relift 3	3.871	1,400	$101,878	$5,898	$26,349	$5,982		$140,107

Table 18.—Variation V2A: Three Mesa laterals

Pumping plant	Flow rate (cfs)	Acre-feet per year	Annual power cost	Annual PP operation cost	Annual PP maintenance cost	Annual pipeline O&M cost	Annual cathodic protection + SCADA cost	Total annual cost
Gravity A	6.46	2,336	$ -	$ -	$ -	$4,763		$4,763
Bacovi	2.34	850	$104,102	$5,337	$24,950	$3,270		$137,659
Gravity B	4.12	1,486	$ -	$ -	$ -	$1,566		$1,566
Relift 1	4.12	1,486	$152,831	$6,640	$31,333	$3,363		$ 194,167
Gravity C	2.96	1,150	$ -	$ -	$ -	$13,478		$13,478
Jeddito	0.93	336	$20,293	$2,873	$1,714	$726		$25,606
Gravity D	0.93	336	$ -	$ -	$ -	$528		$528
Subtotals of 3 tables							$145,000	$3,427,886
Grand Totals of 3 tables								**$3,572,886**

2.5 Summary of Project Costs

Construction costs include 5 percent for mobilization, 15 percent for unlisted items, and 25 percent for contingencies. Table 19 shows the project costs.

Table 19.–Project Costs

Variation: I-40 wellfield	Component	Construction field cost	Nonconstruction cost	Total project cost	Annual OMR&E cost
1					
	Wellfield costs	$1,250,000	$325,000	$1,575,000	$186,000
	Pipeline costs	$72,000,000	$18,720,000	$90,720,000	$2,030,000
	Total cost	$73,250,000	$19,040,000	$92,300,000	$2,216,000
2					
	Wellfield costs	$2,700,000	$702,000	$3,402,000	$403,000
	Pipeline costs	$135,000,000	$35,130,000	$170,130,000	$3,410,000
	Total cost	$137,700,000	$35,830,000	$173,500,000	$3,813,000
2A					
	Wellfield costs	$2,910,000	$757,000	$3,667,000	$434,000
	Pipeline costs	$140,000,000	$36,400,000	$176,400,000	$3,570,000
	Total cost	$142,900,000	$37,160,000	$180,100,000	$4,004,000

2.6 Conclusions

Two wellfield locations were evaluated, as well as the conveyance systems to deliver the water to the demand centers. The pipeline from either wellfield to Leupp is assumed to have similar construction costs.

Five or six pumping plant options were examined for providing water to the Black Mesa Mine. Gravity flow was employed, wherever possible along the alignment. Fine tuning of the number and exact location of pumping plants can be completed in final design, but due to the high static lifts involved in getting water to the mine and the tribal communities, there should not be any significant changes in construction cost or annual OMR&E costs.

Chapter 3

Biological Resources

3.1 Introduction

Given the conceptual nature of the proposed action, the discussion regarding potential impacts to biological resources from the proposed project is presented on a reconnaissance level, and is focused primarily on potential impacts to special status species in the study area from groundwater pumping at either of two wellfield sites: one in T20N, R13E (I-40 Wellfield) and an alternative wellfield site referred to as the Canyon Diablo Wellfield.

This report does not specifically address the construction impacts of the wellfield, mainstem pipeline alignment adjacent to existing road rights-of-way to the Black Mesa Mine, nor any spur alignments to provide water to adjacent communities. Appendix C provides general information on 31 species that should be considered in the scoping of potential fish and wildlife issues associated with the proposed project, especially with regard to land-disturbing activities associated with installation of the wellfield and construction of any pipelines. The list of species was developed through a review of species listed for Coconino and Navajo Counties under the Federal Endangered Species Act (ESA), of 1973 as amended, and the Navajo Nation Endangered Species List (NESL), which was created and distributed by the Navajo Natural Heritage Program, U.S. Fish and Wildlife Service (FWS). The list was originally developed for the Black Mesa Mine Lower Colorado Basin Pipeline Project (which contemplated a diversion off the Colorado River mainstem below Lee's Ferry (entire project area in Coconino County). Some additions or deletions may be appropriate for the currently proposed project, depending upon the final location of the wellfield and pipeline alignments, which have not been considered herein.

The Federal action agency is obligated to abide by the process outlined in Section 7 of the ESA. Generally, once a proposed action is defined and the specific project area is identified, a biological assessment is conducted to determine the potential effects of the project on special status species and any designated critical habitat. The assessment would then be provided to the FWS, which would then prepare a biological opinion on whether or not the proposed project would jeopardize the continued existence of any of the listed species. The anticipated Section 7 process for this particular project is described in more detail below, under in section 3.2, Criteria Used.

In conducting the biological assessment for this project, surveys would likely be needed to determine whether some of the special status species of concern occur within the wellfield boundaries and along the pipeline alignments. Surveys for some species that may potentially occur within the project area can only be conducted during certain times of the year and/or may need to be repeated for consecutive years. After the specific project area is defined, field investigations must be conducted to determine whether or not these surveys will need to be carried out. In addition, should the FWS determine the project may jeopardize the continued existence of a species or adversely impact designated critical habitat, it could identify "reasonable and prudent alternatives" (RPAs) and measures that must be implemented to remove that jeopardy and allow the project to proceed. The RPAs are developed during the formal Section 7 process, and it is during this time that the action agency can assess the necessary costs to implement the RPAs.

For purposes of this reconnaissance-level report, the study focuses on the potential impacts from groundwater pumping from the I-40 wellfield and from the Canyon Diablo wellfield. The proposed project has the potential to lower groundwater tables and/or impact base flows in the Little Colorado River, its tributaries, and existing springs and seeps. The reduction in flows could also affect riparian ecosystems. Six species, that are either federally listed threatened and endangered species or species that are listed on the NESL, are considered in this report, based upon their acute sensitivity to potential impacts from groundwater withdrawals by the proposed project. These species are the federally endangered humpback chub (*Gila cypha*), the federally threatened Little Colorado River spinedace (*Lepidomeda vittata*), the federally threatened Navajo sedge (*Carex specuicola*), the federally endangered southwestern willow flycatcher (*Empidonax trailli extimus*), and the Navajo Nation listed alcove bog-orchid (*Platanthera zothecina*).

This study applies criteria the FWS anticipates using to determine whether or not the proposed project may jeopardize the continued existence of a species or adversely impact designated critical habitat, based upon informal coordination undertaken by Reclamation with the FWS on previous and/or ongoing related studies in the general vicinity. It should be noted very limited data were available specific to the two proposed pumping scenarios considered in this report.

3.2 Criteria Used[3]

FWS is currently being asked to provide guidance on potential impacts to federally listed endangered or threatened species from water supply alternatives included in a Plan of Study (POS) for an effort entitled "Assessment of Western Navajo and Hopi Water Supply Needs, Alternatives, and Impacts." That assessment is being conducted in support of the Little Colorado River water rights negotiations. According to the FWS, it is likely that criteria established for the POS would also apply to the Black Mesa Mine I-40 Wellfield (and Canyon Diablo) Project (Leslie Fitzpatrick, 2003, pers. comm.).

Based upon the criteria in the POS and discussions with the FWS, the following objectives are used as a "coarse filter" to identify those wellfield alternatives that would likely result in a jeopardy to species and probably should not be carried forward to the next level of analysis: (1) groundwater contribution to the base flow in lower East Clear Creek and Chevelon Creek and the Little Colorado River should not be diminished such that habitat for any threatened or endangered species is degraded; and (2) riparian vegetation associated with these streams and other springs and seeps supported by the C-Aquifer, which provide breeding and migratory habitat for the endangered southwestern willow flycatcher and other birds, should not be

[3] This discussion does not take into consideration any consultation needed regarding impacts to species listed on the NESL.

significantly degraded. The degree to which the proposed project meets these two objectives is based upon the following criteria:

- Reductions in groundwater contribution to base flows in lower Chevelon Creek reaches that support Little Colorado spinedace or designated critical habitat do not cause a loss of more than 10 percent of flow, as measured during seasonal low flow periods.

- Reductions in Chevelon Creek do not increase the salinity of the creek by more than 10 percent. The springs that support Chevelon Creek during the low flow periods are saline. Monitoring has shown seasonal change in salinity in the creek when diluting surface waters are not available. Although spinedace may be more adaptable to changes in salinity, their limits of tolerance are unknown.

- Spring flow reductions in Blue Springs do not exceed 10 percent. A reduction in groundwater discharge to Blue Springs could adversely impact habitat for humpback chub populations in the Little Colorado River.

- Reductions in alluvial groundwater levels along the Little Colorado River do not cause a loss of more than 25 percent of riparian habitats in the area affected by the pumping[4].

Successfully passing these criteria, however, does not guarantee that an alternative would not be found "fatally flawed." A critical juncture in completing the feasibility study stage will be the development of a biological assessment and a determination of effects on the listed and proposed species of concern. The Federal action agency has three choices in making their effect determination.

A. No Effect – the appropriate conclusion when it is determined that the proposed action will not affect listed species or critical habitat.

B. May Affect, Not Likely to Adversely Affect – the appropriate conclusion when effects on listed species are expected to be discountable, or insignificant, or completely beneficial. Insignificant effects relate to the size of the impact and should never reach the scale where take of the species occurs. Discountable effects are those effects that are extremely unlikely to occur. Based on best judgment, a person would not: 1) be able to meaningfully measure, detect, or evaluate insignificant effects; or 2) expect discountable effects to occur.

C. May Affect – the appropriate conclusion when a proposed action may pose any effects on listed species or designated critical habitat.

4 How, specifically, a 25 percent reduction in riparian vegetation would be measured has not yet been determined.

In the case of a "no effect" determination, the action agency is not required to submit a biological assessment to the FWS or solicit their concurrence. When the biological assessment or other information indicates that the action may have an effect, but has no likelihood of an adverse effect (including evaluation of effects that may be beneficial, insignificant, or discountable), the FWS provides a letter of concurrence, which completes informal consultation. A "may affect" determination will initiate formal consultation with the FWS.

During formal consultation, the FWS must then consider the impacts of cumulative effects in its jeopardy determination. These include those effects of future State or private activities (but not Federal activities), that are reasonably certain to occur within the action area of the Federal action subject to the consultation. Future Federal actions that are unrelated to the proposed action are not considered in this consultation because they require separate consultations pursuant to Section 7 of the ESA. The effect of the Federal action may be small compared to the State or private activities. However, if those cumulative effects will jeopardize the species, the FWS will conclude that the Federal action will also result in jeopardy.

3.3 Species Accounts

Navajo Sedge.─The Navajo sedge was listed as a threatened species with critical habitat on May 8, 1985 (50 FR 19370). Critical habitat is on the Navajo Nation in Coconino County and contains three groups of springs near Inscription House Ruins. A recovery plan was approved in 1987. The Navajo sedge is listed as "G3" by the Navajo Nation: a species or subspecies whose prospects of survival or recruitment are likely to be in jeopardy in the foreseeable future.

A member of the sedge family (*Cyperaceae*), this grass-like plant reaches a height of 10-16 inches. Numerous stems grow from a rhizome, giving each plant a clumped form. The white flowers appear in June and July (FWS 2000).

Navajo sedge is typically found in seeps and hanging gardens on vertical sandstone cliffs and alcoves from 4600 to 7200 feet in elevation. According to the Navajo Natural Heritage Program (NNHP) (2001), the distribution on the Navajo Nation is from the Navajo Creek drainage in Coconino County, east to the Tsegi Canyon watershed in Navajo County, to the Rock Point/Mexican Water area in Apache County.

Both the FWS (1998) and Navajo Nation (NNHP 2001) identify impacts to the groundwater table as threats to the species.

Little Colorado River Spinedace.─The Little Colorado River spinedace (spinedace) was listed as a threatened species with critical habitat in September 1987 (52 FR 35054, September 16, 1987). A recovery plan was published by FWS in 1997.

The spinedace is a small (less than 4 inches long), silvery minnow that is darker on the back than the belly. Its namesake reflects the presence of a hardened, spinous ray on the dorsal fin, which is characteristic of the tribe, *Plagopterini*, which includes other spinedaces as well as the Gila River basin threatened spikedace. The spinedace inhabits medium to small streams in north-flowing tributaries in the Little Colorado River drainage. The species is characteristically found in pools with water flowing over fine gravel and silt-mud substrates. Many of the streams inhabited by the species are seasonally intermittent, at which time the spinedace persists in deep pools and spring areas that retain water. During flooding, the spinedace redistributes itself throughout the stream system (FWS 1998). Recent studies documented a wide tolerance of the species for a variety of physico-chemical factors (FWS 1997).

The species is found in East Clear Creek and its tributaries (Coconino County), Chevelon and Silver Creeks (Navajo County), and Nutrioso Creek and the Little Colorado River (Apache County). Critical habitat includes 31 miles of East Clear Creek in Coconino County, 8 miles of Chevelon Creek from the confluence with the Little Colorado River upstream to the confluence of Bell Cow Canyon in Navajo County, and 5 miles of Nutrioso Creek downstream from Nelson Reservoir in Apache County (FWS 1998).

During low flow periods, groundwater from springs in Chevelon Canyon is the only source of water to sustain the Little Colorado spinedace. Groundwater pumping from the C-Aquifer could impact base flows in critical habitat of Chevelon Creek and threaten existing populations of this fish.

Populations of spinedace can fluctuate dramatically between years, months, and even days (Minckley and Carufel 1967). Although generally undocumented, spinedace populations are believed to be impacted by: 1) reduction in stream discharge due, to dam construction on the Little Colorado River; 2) alteration in patterns of flows; 3) changes in sedimentation, movement and deposition; and 4) introductions of non-native fishes. Dams have been constructed on Chevelon, Willow, East Clea,r and Silver Creeks, and numerous lakes and diversions have been constructed throughout the watershed. The most obvious impact of these structures is reduction of streamflows and direct loss of habitat (FWS 1997). Interactions with non-native fishes also pose a serious threat to extant populations.

Humpback Chub.─The humpback chub (chub) was listed as an endangered species in March 1967 (32 FR 4001, March 11, 1967) and critical habitat was designated in March 1994 (59 FR 13379, March 21, 1994). The most recent recovery plan was published by the FWS in 1990 and Recovery Goals were published in 2002.

One of the areas designated as critical habitat is the reach of the Little Colorado River between Chute Falls and the Colorado River confluence in the Grand Canyon (a distance of approximately 8 miles). Outflow from Blue Springs, located 13 miles above the Colorado River confluence, provides the perennial source for the lower Little Colorado River; the reach upstream to near Winslow is ephemeral. This reach of critical habitat could be impacted by surface water diversions or groundwater withdrawals from the C-Aquifer. Any significant impacts to the Little Colorado River and its streamflow characteristics, including water quality, could have a significant impact on humpback chub.

The chub is a fairly large (20-inches long) minnow characterized by a narrow, flattened head and a long fleshy snout, large fins, and a very large hump between the head and the dorsal fin (FWS 1998).

Humpback chub evolved in seasonally warm and turbid water and is highly adapted to the unpredictable hydrological conditions that occurred in the pristine Colorado River system (FWS 2002). The chub live and complete their life cycle in canyon-bound reaches of the Colorado River mainstem and larger tributaries that are characterized by deep water, swift currents, and rocky substrates (Valdez et al. 1990). Sub-adults use shallow, sheltered shoreline habitats, whereas adults use primarily offshore habitats of greater depths (FWS 2002).

Some adults from the mainstem Colorado River annually ascend the Little Colorado River to spawn between March and May, but there is also a large resident population in the Little Colorado River. The chub is a broadcast spawner with a relatively low fecundity rate, compared to cyprinids of similar size.

There are six populations of chub currently identified. The population under consideration in this analysis is located in the Colorado and Little Colorado Rivers of the Grand Canyon, Arizona, and is the largest remaining population.

The primary threats to the chub are streamflow regulation, habitat modification (especially thermal), predation by non-native fish species, and parasites and disease transmitted by non-native organisms.

Southwestern Willow Flycatcher.─The southwestern willow flycatcher (flycatcher) was listed as an endangered species in February 1995 (60FR 10694, February 27, 1995). Critical habitat was designated in 1997 (62 FR 39129; July 22,1997) but has been remanded by court order. It is anticipated that the critical habitat designation will be finalized sometime in the future. A Recovery Plan was signed in August 2002.

The flycatcher is a small, migratory bird about 6 inches long, with a grayish-green back and wings, a white throat, a light gray-olive breast, and a pale yellowish belly.

The flycatcher occurs in dense riparian habitats along streams, rivers, and other wetlands where cottonwood, willow, box elder, Russian olive, saltcedar, and other trees and shrub species occur. It has been extirpated from much of its historic range, with fewer than 500 breeding pairs currently documented in the southwest.

In Arizona, populations are known from the upper and middle Gila River, the middle Salt River, the lower San Pedro River, Colorado River, San Francisco River, Hassaympa River, the upper Verde River, Big Sandy River, Santa Maria River, Tonto Creek, and the Bill Williams delta. The southwestern willow flycatcher is endangered primarily due to the reduction, degradation, and elimination of riparian habitat for agricultural and urban development. Other reasons include brood parasitism by the brown-headed cowbird and stochastic events, like fire and floods, that destroy fragmented populations (FWS 1998). .

No breeding or migratory flycatchers have been documented from East Clear Creek, Chevelon Creek, the Little Colorado River, or springs and seeps within the area that might be impacted by the proposed project. However, Chevelon Creek (from the gauging station in T18N, R27E, section 23 to the confluence with the Little Colorado River) has been identified as important to the recovery of the flycatcher in the Little Colorado River management unit (FWS 2002).

Alcove Bog-Orchid.—The alcove bog-orchid is a perennial herb in the Orchidaceae family. The flowers are yellowish-green to greenish and appear from mid-July to late August.

Habitat for the bog-orchid includes seeps, hanging gardens, and moist stream areas from the desert shrub to pinyon-juniper and ponderosa pine/mixed conifer communities. Known populations occur between 4,000 and 7,200 feet in elevation.

The known distribution on the Navajo Nation is from the headwaters of Oljeto Wash, Tsegi Canyon watershed, the Carrizo Mountains, and Chinle Wash(FWS 2001).

The alcove bog-orchid is listed as "G3" by the Navajo Nation: a species or subspecies whose prospects of survival or recruitment are likely to be in jeopardy in the foreseeable future. According to the NNHP (2001), any activity impacting groundwater will need special consideration.

3.4 Results of Groundwater Modeling

The Navajo sedge and alcove bog-orchid are likely to be found at springs and seeps that are not connected to the C-Aquifer (Brad Prudhom, year, pers. comm.). There are no known populations of these plants in the project area. Therefore, neither the I-40 nor Canyon Diablo alternative is expected to affect these species. However, it is recommended that during the feasibility stage for the selected alternative, springs and seeps within the geographic area of the modeled cone of depression be surveyed for these plants.

Tables A-7 and A-8 (appendix A), model streamflow impacts from the wellfield alternatives only, with no other ongoing or future pumping from other sources. Both alternatives indicate there will be no diminishment in flows to Upper East Clear Creek. However, flows will be diminished at Lower Chevelon Canyon, an area where an extant population of spinedace can be found.

Under the I-40 alternative, the model indicates a reduction in flows of approximately 5 percent by 2100 at both measuring points. This would likely result in a "may affect" determination in a biological assessment of impacts to the Little Colorado River spinedace. In discussions with the FWS on April 15, 2003, the FWS did not disagree with this assessment by Reclamation.
It is anticipated that impacts to riparian vegetation would be extremely small, and there would be no affect to the southwestern willow flycatcher. However, surveys may be recommended in the feasibility study phase.

Given this alternative would likely result in a "may affect" determination to a threatened species, formal Section 7 consultation would be required, and the FWS would have to consider the impacts of the Federal action and other cumulative effects as defined above. Table A-3 (appendix A), models impacts to streamflows from a number of M&I users that occur in the

C-Aquifer service area. These future demands were developed for the Hopi Western Navajo Water Supply Study for the evaluation of an all-groundwater alternative

The table indicates that flows in Chevelon Canyon will likely disappear by 2010 at Bell Cow Canyon and by 2030 at measuring points (MP) 1 and 2. Taking into consideration the effects of the Federal action and the cumulative impacts, the FWS could reasonably be expected to conclude that the I-40 wellfield alternative would result in a jeopardy to the spinedace. The FWS would then consult with the action agency to develop a reasonable and prudent alternative that would remove this jeopardy or determine that there are no actions that could be implemented that would remove the jeopardy. Given the importance of this population, it is anticipated the FWS would conclude that there is jeopardy with no RPA.

However, the definition of cumulative effects states that the future effects under consideration must be "reasonably certain to occur." In the feasibility study phase, it may be possible to develop a more accurate M&I demand scenario that would have significantly less impacts to base flows in Chevelon. This could enable the FWS to formulate a reasonable and prudent alternative. Without developing such a demand scenario and entering into formal consultation, it is not possible to determine the magnitude of such a RPA.

According to the model (appendix A), reduction in base flows to Lower Chevelon Creek will only become evident in either 2060 (MP1 and MP2) or 2080 (MP3) under the Canyon Diablo alternative. In either case, the flows will be diminished by approximately 1 percent. The continued viability of the spinedace population in Lower Chevelon Creek is relatively more secure under the Canyon Diablo alternative than the I-40 alternative.
A more refined model and additional data (e.g. test wells, streamflow monitoring) would be needed at the feasibility study level. The biological assessment would integrate these data into its analysis to determine whether the Federal action would be likely to affect the listed species. However, based on the modeling done to date, it appears the project-only pumping would have no effect or would not adversely affect the listed species. In either case, cumulative effects would not need to be addressed by the FWS.

The groundwater modeling associated with the Hopi Western Navajo Water Supply Study indicated that pumping 6,000 af/yr or 10,000 af/yr from the I-40 wellfield would not diminish the flows at Blue Springs in excess of 10 percent. Because the Canyon Diablo wellfield would be located even further west of Blue Springs, it was assumed that modeling of pumping from the Canyon Diablo wellfield would indicate the same results. No additional modeling was performed. Although these limited results indicate that pumping from either wellfield would pass the 10 percent spring flow reductions in Blue Springs "coarse filter," additional modeling would be necessary the additional modeling would be necessary for the humpback chub.

3.5 Recommendations

From a biological resources perspective, the Canyon Diablo wellfield alternative should be carried forward to the feasibility stage. The I-40 wellfield location may be "fatally flawed" because of projected reductions in streamflow in Chevelon Creek which "may affect" the federally threatened Little Colorado River spinedace. Although the I-40 alternative meets the "coarse filter" criteria of 10 percent reduction in base flow, the requirement to formally consult under Section 7, with mandatory consideration of cumulative impacts, would likely result in a jeopardy opinion from FWS.

In addition, a number of specific recommendations are made for further investigation during the feasibility stage. These include:

- Survey springs and seeps within the geographic area of the modeled cone of depression for the Navajo sedge and Alcove bog orchid;
- Depending on the results of additional modeling, recommend surveys for southwestern willow flycatchers in riparian vegetation along Chevelon Creek;
- If the I-40 well-field alternative is carried forward for further evaluation, develop a more accurate M&I demand scenario for consideration of cumulative ground-water impacts in the Section 7 consultation process;
- Obtain a more refined model or additional data (i.e., test wells, streamflow monitoring) to better characterize projected streamflow reductions for the Section 7 process;
- Perform surveys to determine whether some of the terrestrial special status species occur within the wellfield boundaries and along the pipeline alignments.
- Additional modeling to quantify potential impacts on flows from Blue Springs.

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Chapter 4

Cultural Resources

4.1 Background

The purpose of this reconnaissance-level study is to provide a preliminary assessment of potential cultural resource issues and impacts that may be associated with the proposed project. This assessment is based upon a review of two appraisal-level studies in the general project vicinity (one is still in preparation), and the results of a partial archeological site file check conducted for the proposed action's wellfield site.

One appraisal-level study that was used is a study of pipeline alternatives for the Western Navajo-Hopi Water Supply Study (HDR in preparation 2003); the other is the Three Canyons Water Supply Study (Reclamation 1998).

HDR's Western Navajo-Hopi Water Supply Study assessed potential cultural resource impacts associated with the major components of six possible water delivery projects for the western Navajo and Hopi communities and the Black Mesa Mine. These proposed alternatives traverse a vast area of northeastern Arizona and portions of southeastern Utah and northwestern New Mexico (most is within the boundaries of the Navajo and Hopi reservations). Only five alternatives were included in the cultural resource analysis: the Western Navajo-Hopi Pipeline, the Black Mesa Pipeline, the Three Canyons Pipeline, the Loop Pipeline, and the Ganado Pipeline. Because the I-40 wellfield and pipeline alternative was added after HDR had completed the records checks, no specific information was developed for the mainstem pipeline and wellfield. The proposed wellfield associated with the I-40 alternative, and considered in this assessment, lies south of the Navajo Reservation, west of Winslow along I-40 (T20N R13E) in an area of checkerboarded private and State trust land. With the exception of its southernmost extent, the mainstem pipeline follows existing roads across tribal lands to the Black Mesa Mine.

The HDR study describes the proposed I-40 mainstem pipeline alignment as follows:

> *The I-40 pipeline . . . follows the Highway 2 corridor approximately 21.4 miles to the north side of the community of Leupp. The alignment then proceeds 48.4 miles along the Highway 2 corridor west of Oraibi Wash to a point approximately 5 miles south of U.S. Highway 264. The alignment cuts over to the west to the Highway 62 corridor. From this point, the alignment proceeds north 46.6 miles along the Highway 62 corridor west of Dinnebito Wash to the Black Mesa Mine.*

> *Highway 62 corridor. From this point, the alignment proceeds north 46.6 miles along the Highway 62 corridor west of Dinnebito Wash to the Black Mesa Mine.*
>
> *The first reach of the I-40 Pipeline extends generally northward along IR-2 up the west side of Oraibi Wash to SR 264 near the town of Kykotsmovi. Because this segment was added late in the course of the study, a records check for the alignment was not possible. Given the geographical context of this alignment along Oraibi Wash between the Hopi Mesa and the Little Colorado River, it is likely that cultural resources are present; however this cannot be confirmed without additional research.*
>
> *The second reach of the I-40 pipeline extends northward from SR 264 along tribal roads up Dinnebito Wash to the Black Mesa Mine. Given the geographical context of this alignment along Dinnebito Wash on Black Mesa it is likely that cultural resources are present, however this cannot be confirmed without additional research.*

The HDR study was carried out at an appraisal level to determine whether potential impacts to cultural resources, or costs associated with treatment of affected resources, were so extreme that they would threaten the viability of any of the alternatives being considered in the Western Navajo-Hopi Water Supply Study. That study used existing data to "…characterize the broad settlement and land use patterns for the areas affected by the proposed alternative water development plans. Much of the study area has not been previously surveyed for cultural resources, therefore, data derived from surveys in close proximity to the proposed project areas are used to generate baseline assumptions for predicting the density, diversity, and distribution of cultural resources that would likely be encountered (HDR in preparation 2003)."

HDR completed record checks at the Navajo Nation Historic Preservation Department (NNHPD), the Hopi Cultural Preservation Office (HCPO), the AZSITE database housed at the Arizona State Museum (ASM), and the Arizona Department of Transportation. Because HDR's study was carried out at an appraisal level only, in-depth consultations with affected tribes regarding traditional cultural places were not included.

The record checks, conducted by HDR at the various repositories, identified an abundance of linear surveys following the major transportation corridors related to road and utility work. Surveys were also clustered around towns and villages. These surveys were mostly associated with utility work for home sites and tended to be linear in nature but arranged dendritically across the landscape. A few large block surveys, such as the Homolovi State Park, Hopi Buttes, and Black Mesa projects, provided useful data (Gumerman 1988; Lange 1989; Powell and Smiley 2002).

The Three Canyons Study completed by PXAO is one of the studies included in HDR's assessment. That study area encompasses a very large area in northeastern Arizona. The main project area is situated in and around Winslow, Arizona, specifically near the mouths of Clear and Chevelon Creeks. The project extends south into the forests of the White Mountains to Blue Ridge Reservoir, and north to the communities of Dilkon and Leupp on the Navajo Reservation.

Like the HDR study, PXAO's assessment of cultural resources for the Three Canyons Study was not intended to be extensive or exhaustive, but to highlight potentially important issues that could affect the project and to provide basic information on the cost of identifying and mitigating impacts to cultural resources. Site files and records at ASM, the Museum of Northern Arizona (MNA), and the State Historic Preservation Office (SHPO) were checked. That study should be considered a preliminary review of several primary cultural resource site records sources. No formal consultation was conducted with interested tribes regarding information on the location of TCPs and sacred sites (Reclamation 1998).

4.2 Cultural Resources in the Project Area

The record checks conducted at the various repositories for the HDR and PXAO studies revealed a similar pattern of previous work across the study area. Only limited areas within the HDR and PXAO project areas have been investigated, and some of these records are more than 60 years old. Linear surveys were common and generally follow the major transportation corridors. Small surveys were also clustered around towns and villages; these were mostly associated with utility work for home sites and tended to be linear in nature but arranged dendritically across the landscape. Recent, systematic archaeological survey data are available for an area immediately north of the town of Winslow at Homolovi Ruins State Park, on Black Mesa itself, along Chevelon Creek, along State Route 87, and in an area known as the Hopi Buttes south of Dilkon (Gumerman 1988; Lange 1989; Powell and Smiley 2002; Andrews 1983)

Five major periods of human occupation in the study area—Paleo-Indian, Archaic, Early Agricultural, Formative, and Historic—spanning over 10,000 years have been identified in the HDR report (HDR in preparation 2003). Sites attributed to all of these periods were identified in site file checks completed by HDR and PXAO and may be expected to occur in the I-40 pipeline and wellfield project areas.

The types of archeological sites discussed by HDR and PXAO include large, multiroom pueblos, lithic scatters and quarries, petroglyphs, agricultural features and field houses, and sherd and lithic artifact scatters. Some of the latter contain surface features such as upright sandstone slabs, which indicate that buried pit houses may be present. Prehistoric human burials have been identified at a number of these sites.

Homolovi Ruins State Park illustrates the ancestral Hopi occupation along the Little Colorado River. The park includes four major ruins: Homolovi I, II, III, and IV. A large pueblo ruin, located to the east on Cottonwood Creek (on the north side of the LCR), and Chevelon Ruin, situated on Chevelon Creek, are components of the park. Homolovi I contains around 250 rooms, while Homolovi II is estimated to contain at least 700 rooms (Lange 1989). A Class III survey of 13 square miles of the park recorded more than 300 prehistoric sites.

Much of the proposed project area has not been surveyed. The same kinds of sites found at Homolovi Ruins State Park and the Hopi Buttes may be expected in the wellfield area and along much of the pipeline route, especially along drainages and in areas where soil conditions favored prehistoric horticulture; however, their distribution and density is unknown.

4.2.1 Results of Limited Records Check for the Proposed Action, I-40 Wellfield Site

Maps and computerized site files (AZSITE) available at the Arizona SHPO were examined to identify known resources in T20N, R13E. Unfortunately, the results were of very limited use. No block surveys are plotted in this area; a single linear survey along State Route 99 is shown passing just outside and northeast of the wellfield area (Weaver 1990). Although no survey is plotted in this vicinity, a sizeable archeological site is shown near the southeast corner of the wellfield area, and another site is shown just east of this area. These sites may have been located by a survey of the powerline paralleling I-40, roughly one-half mile north of the freeway corridor. No additional information about these sites, identified as AZ J:13:15 and 16 (ASM), is included in the AZSITE database. Finally, another site, AZ J:13:6 (ASM), is plotted in the southwestern portion of the project area. Again, no information about the site was available.

Archeological records at the MNA in Flagstaff may include additional information about the wellfield area. Unfortunately, those records have yet to be added to the AZSITE database. The resources allotted to complete this preliminary assessment were insufficient to permit detailed examination of records located there, at HCPO, or at NNHPD.

Computerized site records in AZSITE do not include information about cultural resources on tribal lands. Site file checks for tribal lands must be performed at tribal preservation offices, which was not possible as a part of this preliminary assessment.

This limited site file check added few specifics to the information about potential project impacts assembled by HDR for the Western Navajo-Hopi Water Supply Study. In the absence of information about how much of the proposed wellfield area may have been systematically surveyed or descriptions of the two previously recorded sites, no refinement of that assessment is possible.

4.2.2 Traditional Cultural Properties and Sacred Sites

An identification of Traditional Cultural Properties (TCPs) and sacred sites, and assessment of project effects on such places, cannot be undertaken without consultation with tribes that claim affiliation with places in the project area. Specific information is not available in archeological site files. Information about properties of traditional cultural value may be maintained in tribal preservation offices; however, it is not readily accessible. ASM personnel have consulted with the Hopi Tribe regarding TCPs in the Homolovi Ruins State Park, where a number of shrines and other areas have been identified as TCPs.

Although the identification of TCPs is specific to a group or community, some generally important types of places or resources have been identified. They include such things as shrines, stands of culturally important plants, deposits of clays used in pottery making, and areas where culturally significant animals are hunted or collected. In addition, specific locations, landforms, or features may be considered traditional cultural properties. Springs and streams are traditionally important and are considered sacred. Impacts to springs resulting from lowering the water table, either locally or regionally, may be considered an adverse effect under the National Historic Preservation Act and 36 Comprehensive Facility Review (CFR) Part 800.

Finally, in consultation about other projects, the Hopi Tribe has indicated that archeological remains are significant in its culture, and these ancestral sites are considered traditional cultural properties. These include village and camp sites, shrines, trails, rock markings, and traditional gathering places.

4.3 Conclusions

The results of this preliminary assessment suggest that cultural resources are likely to be present and will be affected by construction of the proposed I-40 wellfield and pipeline. Because much of the project area has not been surveyed, the numbers and kinds of resources expected can be only roughly projected. In addition, critical issues, such as unmitigatable impacts to TCPs, cannot be identified without in-depth consultation with affiliated tribes.

The possibility of impacting multiroom pueblo sites is moderate to high for the proposed project. It is not unusual for these kinds of sites to contain buried rooms and other features like kivas, with no visible evidence on the surface. Ubiquitous sherd and lithic scatter sites have been documented in the survey data studied for the HDR report, and these often contain buried features. Human remains may be present at many sites and would require special treatment consistent with Hopi and Navajo wishes.

This preliminary assessment consisted of a cursory records review aimed at identifying potential cultural resource issues that could affect the viability of the I-40 alternative. The results are tenuous at best. As a part of ongoing project planning and impact analysis, more in-depth cultural resources studies would be required, including Class I overviews, full-coverage Class III surveys, and formal TCP consultations with the affected tribes.

4.3.1 Projected Site Densities and Mitigation Costs

The HDR study used the results of cursory site records checks to produce projected total numbers of cultural resources likely to be affected by each of five alternatives. These projections formed the basis for rough estimates of costs associated with partial mitigation of impacts to those resources. The "guestimates" are reasonable indications of the mitigation costs of the proposed action; however, it is important to recognize that those estimates are based on only limited data and their predictive value is also limited. Those estimates are as follows:

Western Navajo Pipeline Project	$6,200,000
Black Mesa Pipeline Project	$4,600,000
Three Canyons Pipelines Project	$2,500,000
Loop Pipeline	$1,200,000
Ganado Groundwater Pipeline Project	$1,500,000

As described in the HDR study, the proposed mainstem pipeline associated with the I-40 wellfield alternative is 120 miles long, roughly twice the length of the Loop and Ganado pipelines; extrapolating from those estimates, the cost of mitigation along the I-40 pipeline alignment may be roughly estimated at between $2 million and $3 million assuming site types and densities encountered would be similar to those used in developing the above estimates. Mitigation costs associated with developing a wellfield in T20S R13E cannot be approximated using the available data. If site densities were similar to those recorded around Homolovi Ruin (14 sites per square mile), as many as 500 sites might be located. In any case, not all sites in the wellfield would be affected by construction; avoidance of impacts through relocating individual project elements would lower mitigation costs.

Generally, treatment or mitigation costs in most instances may be estimated at 1 percent of total project costs for project planning purposes. With the proposed project, however, given the extent of consultation required with affected communities and tribal preservation offices, the numbers of sites located along watercourses in the area, increased costs associated with working in relatively remote areas, and other requirements imposed when working on tribal lands, mitigation costs could very quickly exceed what would be considered usual under other conditions.

Realistic treatment cost estimates cannot be determined until the cultural resource survey is completed and consultation with the SHPO and affected tribes has identified the number and extent of significant cultural resource sites (including TCPs) affected by the project. Consultation with interested or affected tribes or other parties, or both, would also be necessary to assess the impact to TCPs and sacred sites, as well as appropriate forms of treatment. While it is highly unlikely that previously unknown large pueblo ruins would be identified and impacted by the project, a number of archaeological sites would be impacted and would require some level of investigation. Again, adverse effects to TCPs are often considered unmitigatable and are, thus, more problematic. Such impacts should be avoided through project redesign whenever possible.

4.4 Strategy for Completing Section 106 Review

At minimum, a Class I survey of the entire project area should be completed commensurate with the appraisal-level studies of other alternatives, and consultation should be initiated with affiliated tribes regarding impacts to TCPs and sacred sites.

Ideally, Class I and Class II surveys of all alternatives under consideration should be completed during the feasibility/planning process and used in their evaluation. Class II survey, at a minimum, should address areas of likely high cultural resource sensitivity and should include in-depth consultation with affiliated tribes regarding traditional cultural concerns; this would substantially reduce the likelihood that places of extreme cultural importance will be discovered very late in the process, when avoidance and treatment are most costly. Class III survey of at least the preferred alignment must be completed before treatment costs can be accurately assessed.

Because most of the proposed project area is located on tribal land, some special considerations arise; these considerations affect the cost of completing surveys and subsequent studies. Key tasks would include examining site files for the affected areas, identifying appropriate consulting parties, and soliciting their input. Multiple meetings with cultural resource advisory groups, communities, and knowledgeable individuals will be needed.

In addition, the I-40 wellfield included in this preliminary assessment includes State trust and private land; as a result, ASM and Arizona State Land Department (ASLD) must be included in the consultation. Survey of State trust land must be conducted under permit from ASM. Impacts to cultural resources on State trust land and treatment of human remains on State and private land are covered by State law. Consultation to meet these requirements must be considered in project timelines.

Incorporating a proactive approach to cultural resource consultations and investigations early in the planning process can reduce cultural resource costs. This is particularly true when considerable consultation with affected tribes will be required, and numerous TCPs and sacred sites may be identified within the area of potential effect. Development of a Programmatic Agreement or Memorandum of Agreement, which will be necessary unless impacts to cultural resources are avoided entirely, is also a lengthy process. Beginning these efforts as soon as possible will reduce the likelihood of project delays, and consultation may identify ways to modify the proposed actions that will avoid or reduce impacts and substantially reduce costs.

Section 106 Consulting Parties.—SHPO, Navajo THPO, the Hopi Tribe, the Navajo Nation, the Pueblo of Zuni, and others as identified through consultation with NNHPD, HCPO. The I-40 wellfield included in this preliminary assessment includes State trust and private land; as a result, ASM and ASLD must be included in the consultation.

Archeological sites and historic buildings and structures.—Tribal lands are not included in existing electronic files of archeological sites maintained by the AZSITE consortium, so records at both the NNHPD and HCPO will have to be checked, in person by either Reclamation staff or its contractor. Most of the records at the MNA are not yet included in AZSITE, and those records too must be examined.

Traditional Cultural Places and Sacred Sites.—Both NNHPD and HCPO work with traditional experts within their cultures to identify properties of significance. Because "show-stopper" cultural resources are likely to be traditional cultural properties which, in many instances, can be identified only through consultation with traditional practitioners, coordination with NNHPD and HCPO—and the communities, advisory groups, and individuals they recommend—will be critical to successfully complete this portion of the study. Adverse effects to TCPs often cannot be mitigated.

Cost Estimates for Class I survey.—The effort and cost of completing a Class I survey internally, including tribal consultation, for two alternatives has been estimated as follows:

Hours	Task
120	site file checks, travel, meetings
32	assessment of impacts
32	produce draft report
16	revise, complete report
200	

Project Archeologists	25 days @ $688	$17,200
Per diem	15 days @ $160	$ 2,400
Total cost		$19,600

Although much of the preliminary work for some of the project area may have been completed by HDR, all site files would have to be revisited. In addition, Bureau of Indian Affairs (BIA) and Indian Health Service have conducted numerous small and large surveys on Hopi and Navajo lands; for the most part, these have been restricted to narrow road and pipeline rights-of-way and the immediate areas to be affected by construction projects. The BIA Roads Department may have surveyed some of the roads along which alternative pipeline routes are proposed, but many of these roads were built or evolved before surveys were required. Records available at these agencies were not included in the HDR assessment, but should be reviewed as a part of the Class I survey. Finally, the process of consulting, to identify traditional cultural places that might be affected by the different alternatives, will affect multiple communities and may involve multiple meetings with some or all of them.

4.4.1 Canyon Diablo Wellfield

Subsequent to completing the preliminary assessment of the I-40 alternative, a new wellfield site has been proposed. This site is west of the area covered by the assessment in the vicinity of Canyon Diablo. Part of the newly proposed wellfield lies on the Navajo Nation; part of it is on private land recently acquired by the Hopi Tribe.

Because this site was not identified until after the I-40 preliminary assessment was completed, it was not included in the review of records included in AZSITE, the computerized database of cultural resources maintained by the AHPO, the ASM, Arizona State University, and the MNA. Cultural resources that might be encountered in the newly proposed wellfield area are likely to be similar to those associated with other alternatives; however, more sites or larger sites may be found in this area relative to the previously assessed wellfield, given the proximity of Canyon Diablo and other water sources.

4.5 References

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Powell, Shirley and Francis E. Smiley (editors) 2002. *Prehistoric Culture Change on the Colorado Plateau: Ten Thousand Years on Black Mesa*. The University of Arizona Press, Tucson.

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Appendix A

Hydrologic Modeling Results Summary

Introduction

The I-40 and Canyon Diablo wellfield sites are two of three alternatives evaluated by Reclamation that would tap the regional C-Aquifer for a municipal and light industrial water supply for the Navajo and Hopi communities, and alternative supply (to the existing N-Aquifer) for the Peabody Western Coal Company's Black Mesa coal slurry pipeline. The Ward Terrace wellfield site is the third site being considered, but it is not included in this evaluation.

The I-40 wellfield is located just off the Navajo Nation southern boundary about 15 miles west of Winslow, Arizona in township T20N, R13E. The Canyon Diablo wellfield is located about six to 10 miles further west with some of the wells on the Canyon Diablo parcel, and the remaining wells on the Navajo Nation. Figure A-1 shows the location of these wellfield arrays.

Purpose

The primary purpose of the evaluations was to predict, out to year 2100, whether the C-aquifer groundwater system may be able to support an additional (approximately) 6,000 acre-feet per year (af/yr) of Peabody Coal demand, and then 10,000 af/yr of cumulative pumping demand (Navajo and Hopi demands added), from one of these two wellfields. This 6,000 and 10,000 af/yr demand is in addition to the existing municipal, light and heavy industrial, and agricultural pumping demands by up to 47 tribal and non-tribal entities. After numerous iterations, a consensus by the stakeholders derived round demand figures of 6,000 af/yr for the Peabody Coal slurry pipeline, and 2,000 af/yr each for Navajo and Hopi communities. Figure A-2, Pumping Centers Map, lists all the demand centers accounted for in these analyses.

An important part of the evaluation was to determine whether this additional 10,000 acre-feet/year of maximum pumping could significantly deplete the current discharge from Blue Springs in the lower LCR, and baseflow from Upper East Clear Creek and Lower Chevelon Canyon tributaries to the LCR. These stream reaches support several critical species dependent on the flows. From the Hopi Western Navajo Water Supply Study , it was determined that a flow reduction threshold of 10 percent would be acceptable for an appraisal level study.

This report section will first explain the modeling methodology and then summarize the demand assumptions and results from Alternative 1, Local Groundwater, as it is the "baseline" from which the two wellfield simulations are being compared and contrasted. Then the I-40 and Canyon Diablo wellfield simulations will be discussed with the demands used, output results, and conclusions. The output results include a series of drawdown contour maps, tables of simulated flows for three selected measurement points on East Clear and Chevelon Creeks at 10-year time steps out to year 2100.

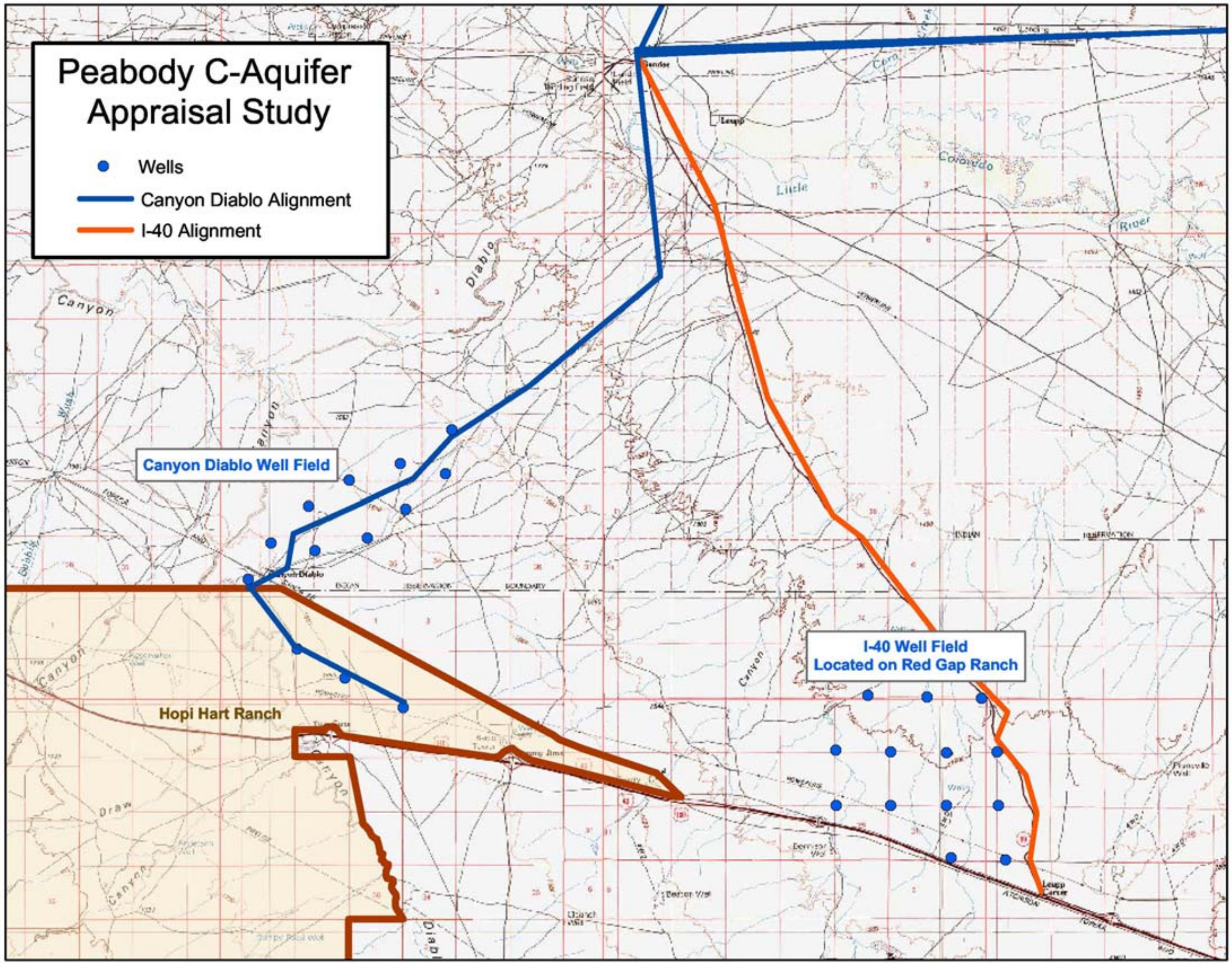
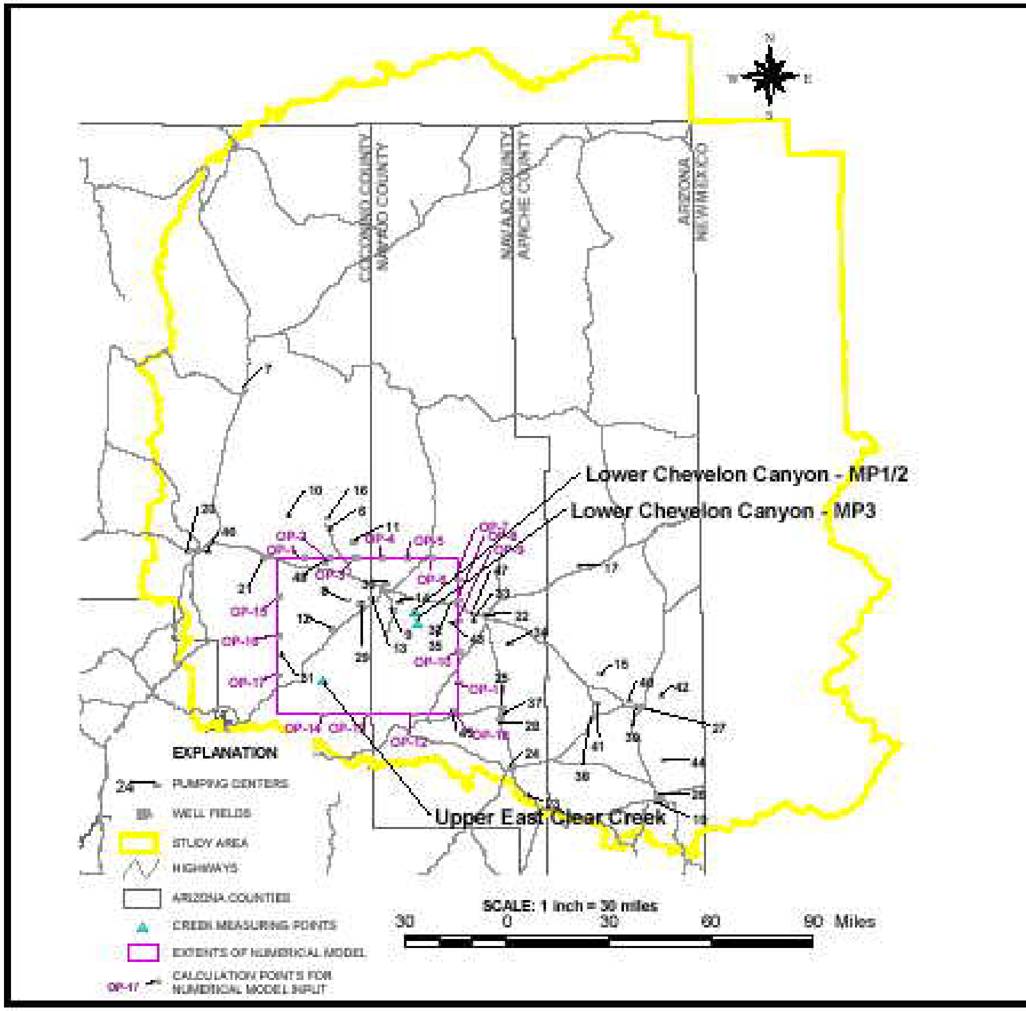


Figure A-1.–Location of C-Aquifer wellfield alternatives.



LABEL	PUMPING CENTER	UTMX (m)	UTMY (m)
1	Many Farms M&I	634036	4033766
2	Chinle M&I	630197	4001806
3	Ft. Defiance M&I	631883	3931433
4	Ganado M&I	632017	3942729
5	Ganado Irr.	630366	3953457
6	Leupp M&I	509951	3904414
7	Cameron M&I	462432	3969664
8	Hopi Ranches - Clear Creek M&I	519938	3870585
9	Hopi Ranches - Aja Ranch M&I	532806	3868600
10	Leupp Irr. (West)	483068	3909029
11	Leupp Irr. (East)	514078	3897949
12	Hopi Ranches Clear Creek #1 Ir	503800	3868800
13	Hopi Ranches Clear Creek #2 Ir	522200	3871000
14	Aja Ranch Irr.	538600	3869800
15	Zuni Heavens (Environmental)	631004	3835300
16	Navajo Power Plant #1	501940	3908041
17	Navajo Power Plant #2	621068	3880524
18	Future Mining (Ward Terrace)	488807	3904067
19	Eager M&I	657579	3775603
20	Flagstaff M&I	435464	3893934
21	Flagstaff Settlement Wells	471722	3888646
22	Holbrook M&I	578889	3860526
23	Pinetop-Lakeside M&I	596824	3778254
24	Show Low M&I	589344	3790577
25	Snowflake M&I	554571	3819285
26	Springerville M&I	658062	3778074
27	St. Johns M&I	658498	3819288
28	Taylor M&I	583435	3813898
29	Winslow M&I	517328	3868734
30	CDI - Winslow	539483	3878308
31	CDI - Canyon Diablo	480069	3844628
32	FW - Joseph City	561013	3864422
33	HOL - Holbrook	576785	3860535
34	HOL - Woodruff	587813	3849446
35	HOL - Joseph City	561013	3864422
36	HOL - Hay Hollow	608108	3830548
37	SNO - Snowflake-Taylor	584068	3816804
38	CON - Concho	627191	3815033
39	STJ - St. Johns	648322	3819946
40	Coronado Power Plant (SRP)	644366	3820017
41	SRP Concho	636833	3821489
42	SRP Patterson	658188	3824565
43	Cholla Power Plant (APS)	586941	3869290
44	Springerville Power Plant (TEP	660918	3794581
45	Abitibi Paper Mill	581051	3818273
46	Little America Refining Co.	445185	3892643
47	Cholla Ready Mix	529733	3880827
48	I-40 Alternative	501038	3887905

PUMPING CENTERS MAP

Southwest Ground-water Consultants, Inc.

March 19, 2003

Project B.692

Figure 2

Figure A-2.–Demand areas pumping centers map.

Table A-1.C-Aquifer Demands by Decade

DEFIANCE PLATEAU

Tribal Municipal and Industrial (M&I)

	2000	2010	2020	2030	2040	2050	2060	2070	2080	2090	2100
Many Farms											
Low	391	593	849	1010	1193	1358	1545	1758	2000	2276	2590
Mid Range	391	615	992	1323	1749	2234	2777	3452	4292	5335	6632
High	391	620	1028	1406	1907	2502	3156	3981	5022	6335	7991
Chinle											
Low	1331	1963	2577	3134	3769	4289	4880	5553	6319	7190	8181
Mid Range	1331	1963	2674	3656	4920	6285	8030	9982	12409	15425	19175
High	1331	1963	2697	3786	5226	6855	8992	11343	14309	18050	22770
Ft. Defiance											
Low	1543	2285	3468	4615	5937	6755	7687	8746	9952	11325	12886
Mid Range	1543	2647	4537	6636	9372	11974	14885	18503	23002	28594	35545
High	1543	2408	4289	6510	9489	12447	15701	19807	24986	31519	39760
Ganado											
Low	824	1203	1887	2609	3426	3899	4436	5043	5744	6536	7437
Mid Range	824	1260	2265	3472	5021	6415	7975	9914	11324	15320	19044
High	824	1425	2518	3782	5477	7184	9062	11432	14421	18192	22948

Tribal Irrigation

	2000	2010	2020	2030	2040	2050	2060	2070	2080	2090	2100
Ganado											
Low	0	2600	2600	2600	2600	2600	2600	2600	2600	2600	2600
Mid Range	0	5200	5200	5200	5200	5200	5200	5200	5200	5200	5200
High	0	5200	5200	5200	5200	5200	5200	5200	5200	5200	5200

OTHER C-AQUIFER AREAS

Tribal Municipal and Industrial (M&I)

	2000	2010	2020	2030	2040	2050	2060	2070	2080	2090	2100
Leupp											
Low	290	403	614	810	1031	1173	1334	1518	1728	1966	2237
Mid Range	290	421	733	1075	1510	1930	2399	2982	3707	4608	5728
High	290	425	762	1146	1647	2161	2726	3439	4338	5472	6903
Cameron											
Low	171	260	371	440	519	590	672	764	870	989	1126
Mid Range	171	269	434	576	760	971	1207	1501	1866	2319	2883
High	171	272	449	613	829	1088	1376	1731	2183	2754	3474
Hopi Ranches - Clear Creek											
Low	0	0	0	1000	1500	2000	2000	2000	2000	2000	3000
Mid Range	0	0	0	1000	1500	2000	2000	2000	2000	2000	2000
High	0	0	2000	2000	2000	2000	2000	2000	2000	2000	2000

OTHER C-AQUIFER AREAS (Continued)

Tribal Municipal and Industrial (M&I) (Continued)

	2000	2010	2020	2030	2040	2050	2060	2070	2080	2090	2100
Hopi Ranches - Aja Ranch											
Low	0	0	0	0	250	500	500	500	500	500	500
Mid Range	0	0	0	400	750	1000	1000	1000	1000	1000	1000
High	0	0	1000	1000	1000	1000	1000	1000	1000	1000	1000

Tribal Irrigation

	2000	2010	2020	2030	2040	2050	2060	2070	2080	2090	2100
Leupp Irrigation (West)											
Low	0	0	0	0	0	0	0	0	0	0	0
Mid Range	0	0	0	0	570	728	905	1125	1399	1739	2162
High	0	0	0	1905	5714	9524	13333	17142	19047	19047	19047
Leupp Irrigation (East)											
Low	0	0	0	0	0	0	0	0	0	0	0
Mid Range	0	0	0	0	430	550	683	849	1055	1312	1631
High	0	0	0	1437	4311	7184	10058	12932	14369	14369	14369
Hopi Ranches Clear Creek #1											
Low	0	0	0	0	200	200	200	200	200	200	200
Mid Range	0	0	500	750	1100	1100	1100	1100	1100	1100	1100
High	0	0	1100	1100	1100	1100	1100	1100	1100	1100	1100
Clear Creek #2											
Low	0	0	0	0	100	100	100	100	100	100	100
Mid Range	0	0	0	300	450	640	640	640	640	640	640
High	0	0	640	640	640	640	640	640	640	640	640
Aja Ranch											
Low	0	0	0	0	250	500	500	500	500	500	500
Mid Range	0	0	0	350	500	730	730	730	730	730	730
High	0	0	730	730	730	730	730	730	730	730	730
Zuni Heavens (Environmental)											
Low	0	500	1000	1500	1500	1500	1000	500	300	200	200
Mid Range	0	500	1000	1500	1500	1500	1000	500	300	200	200
High	0	500	1000	1500	1500	1500	1000	500	300	200	200
Navajo Power Plant #1											
Low	0	8000	8000	8000	8000	8000	8000	8000	8000	8000	8000
Mid Range	8000	8000	16000	16000	16000	16000	16000	16000	16000	16000	16000
High	8000	8000	16000	16000	16000	16000	16000	16000	16000	16000	16000

OTHER C-AQUIFER AREAS (Continued)											
Tribal Industrial (Continued)											
	2000	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**	**2070**	**2080**	**2090**	**2100**
Navajo Power Plant #2											
Low	0	0	0	0	0	0	0	0	0	0	0
Mid Range	0	0	0	0	0	0	0	0	0	0	0
High	0	0	0	0	0	0	16000	16000	16000	16000	16000
Future Mining (Ward Terrace)											
Low	0	0	0	3000	3000	3000	3000	3000	3000	3000	3000
Mid Range	6000	6000	6000	6000	6000	6000	6000	6000	6000	6000	6000
High	6000	6000	6000	6000	6000	6000	6000	6000	6000	6000	6000

Non-Tribal Municipal and Industrial (M&I)											
	2000	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**	**2070**	**2080**	**2090**	**2100**
Eager											
Low	732	861	999	1126	1246	1364	1485	1615	1758	1913	2082
Mid Range	732	886	1056	1216	1369	1523	1682	1859	2053	2268	2505
High	732	911	1115	1312	1503	1700	1906	2137	2397	2687	3013
Flagstaff											
Low	10340	11950	13345	14655	16055	17618	19172	20862	22702	24704	26883
Mid Range	10340	12260	13961	15589	17357	19362	21388	23626	26098	28828	31844
High	10340	12577	14604	16580	18760	21275	23856	26749	29993	33631	37710
Holbrook											
Low	883	938	976	1027	1089	1180	1258	1340	1428	1521	1621
Mid Range	883	948	993	1054	1130	1243	1339	1443	1555	1675	1805
High	883	958	1011	1083	1173	1308	1426	1554	1693	1845	2011
Pinetop-Lakeside											
Low	659	720	735	786	868	1006	1095	1191	1296	1411	1535
Mid Range	659	731	750	811	912	1084	1198	1323	1461	1614	1783
High	659	743	764	836	958	1168	1310	1469	1647	1847	2071
Show Low											
Low	1449	1609	1751	1906	2071	2288	2490	2710	2949	3209	3492
Mid Range	1449	1640	1810	2001	2206	2482	2741	3028	3345	3695	4081
High	1449	1670	1872	2100	2350	2691	3017	3383	3793	4253	4769
Snowflake											
Low	821	881	920	976	1047	1152	1253	1364	1484	1615	1758
Mid Range	821	892	939	1007	1093	1223	1351	1493	1649	1821	2012
High	821	904	958	1038	1141	1299	1457	1633	1831	2054	2303
Springerville											
Low	362	407	455	539	543	588	640	696	757	824	897
Mid Range	362	416	474	578	584	640	707	781	863	953	1053
High	362	425	493	620	627	698	782	877	983	1103	1236

OTHER C-AQUIFER AREAS (Continued)

Non-Tribal Municipal and Industrial (M&I) (Continued)

	2000	2010	2020	2030	2040	2050	2060	2070	2080	2090	2100
St. Johns											
Low	633	647	650	661	681	711	741	774	807	842	878
Mid Range	633	649	653	667	690	725	762	801	842	886	931
High	633	652	656	672	699	740	784	830	880	932	987
Taylor											
Low	607	695	795	884	962	1048	1141	1241	1351	1470	1599
Mid Range	607	712	834	945	1044	1155	1276	1409	1557	1719	1899
High	607	729	875	1011	1133	1272	1426	1599	1793	2011	2255
Winslow											
Low	1711	1828	1923	2035	2160	2332	2485	2647	2821	3006	3202
Mid Range	1711	1849	1964	2099	2251	2464	2655	2861	3083	3322	3579
High	1711	1871	2005	2164	2347	2603	2836	3091	3368	3671	4000

Non-Tribal Irrigation - Low, Mid Range, High

	2000	2010	2020	2030	2040	2050	2060	2070	2080	2090	2100
CDI - Winslow	2738	2738	2738	2738	2738	2738	2738	2738	2738	2738	2738
CDI - Canyon Diablo	2738	2738	2738	2738	2738	2738	2738	2738	2738	2738	2738
HV - Joseph City	120	120	120	120	120	120	120	120	120	120	120
HOL - Holbrook	1739	1739	1739	1739	1739	1739	1739	1739	1739	1739	1739
HOL - Woodruff	1739	1739	1739	1739	1739	1739	1739	1739	1739	1739	1739
HOL - Joseph City	1739	1739	1739	1739	1739	1739	1739	1739	1739	1739	1739
HOL - Hay Hollow	1739	1739	1739	1739	1739	1739	1739	1739	1739	1739	1739
SNO - Snowflake-Taylor	22000	22000	22000	22000	22000	22000	22000	22000	22000	22000	22000
CON - Concho	242	242	242	242	242	242	242	242	242	242	242
STJ - St. Johns	2360	2360	2360	2360	2360	2360	2360	2360	2360	2360	2360

Non-Tribal Industrial

	2000	2010	2020	2030	2040	2050	2060	2070	2080	2090	2100
Coronado Power Plant (SRP)											
Low	12000	12000	12000	12000	12000	12000	12000	12000	12000	12000	12000
Mid Range	12000	12000	12000	12000	12000	16000	16000	18000	18000	18000	21400
High	12000	12000	12000	12000	12000	21400	21400	21400	21400	21400	21400
Cholla Power Plant (APS)											
Low	13500	13500	13500	13500	13500	13500	13500	13500	13500	13500	13500
Mid Range	13500	13500	13500	13500	13500	16000	16000	18000	18000	18000	21500
High	13500	13500	13500	13500	21500	21500	21500	21500	21500	21500	21500

OTHER C-AQUIFER AREAS (Continued)											
Non-Tribal Industrial (Continued)											
	2000	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**	**2070**	**2080**	**2090**	**2100**
Springerville Power Plant (TEPCO)											
Low	20000	20000	20000	20000	20000	20000	20000	20000	20000	20000	20000
Mid Range	20000	20000	20000	20000	20000	20000	20000	20000	20000	20000	20000
High	20000	20000	20000	20000	20000	20000	20000	20000	20000	20000	20000
Abitibi Paper Mill											
Low	13000	13000	13000	13000	13000	13000	13000	13000	13000	13000	13000
Mid Range	13000	13000	13000	13000	13000	16000	16000	18000	18000	18000	20000
High	13000	13000	13000	14000	18000	20000	20000	20000	20000	20000	20000
Little America Refining Co.											
Low	100	100	109	120	131	143	157	171	187	205	224
Mid Range	100	101	112	124	138	153	170	189	210	233	259
High	100	101	114	128	144	163	183	207	233	262	296
Cholla Ready Mix											
Low	20	20	22	24	26	29	31	34	37	41	45
Mid Range	20	20	22	25	27	30	34	37	42	46	51
High	20	20	23	25	29	32	36	41	46	52	59

Modeling Background and Methodology

From groundwater modeling work done in support of the *Assessment of Western Navajo and Hopi Water Supply Needs, Alternatives, and Impacts* Study (Hopi Western Navajo Water Supply Study), Reclamation determined that the vehicle in which to help make these evaluations would be additional groundwater modeling using the model input data and/or models from that work. The modeling results would attempt to quantify and at least qualify the impacts to stream and spring flows, and the magnitudes of additional drawdown and resultant cone of depression distribution as a result of pumping either 6,000 af/yr or 10,000 af/yr for either wellfield.

The *Assessment of Western Navajo and Hopi Water Supply Needs, Alternatives, and Impacts* Study modeling subcontractor was Southwest Ground-water Consultants, Inc. (SGC) and Peter Mock Groundwater Consulting, Inc. (PMGC), the consultants providing the groundwater modeling for the HDR firm.

For the Hopi Western Navajo Water Supply Study, SGC used a modified multi-well analytical model (using the Theis non-equilibrium flow equation) to determine for each C-aquifer well/wellfield demand center the theoretical individual well drawdown and well interference effects. An average drawdown is calculated from the individual well drawdowns. The cummulative yields from each well in a particular wellfield is superimposed on the current C-aquifer flow regime (currently resulting from all existing pumping/recharge within the extent of the particular wellfield(s). Analytical model outputs were also used to establish initial and boundary conditions for the studies' WHN3C Modflow numerical model. (See Assessment of

Western Navajo and Hopi Water Supply Needs, Alternatives, and Impacts, C-Aquifer Analytical Model, December 27, 2002, and Recommended C-Aquifer Model reports for further details).

Reclamation determined it would be more efficient to have SGC/PMGC run the simulations as they already had the Navajo/Hopi region background and most of the input data already assembled, needed for the Reclamation simulations. Based on phone and e-mail discussions with Reclamation representatives on the week of March 3, SGC submitted a Scope of work and cost estimate for modeling evaluations for the I-40 wellfield which was accepted by Reclamation.

Modeling Scope of Work

The I-40 alternative wellfield location (in T20N, R13E), the same location as used in the Hopi Western Navajo Water Supply Study, was evaluated by SGC based on Reclamation's acceptance letter (dated March 11, 2003) of SGC's scope of work proposal and cost estimate, dated March 7, 2003. Preliminary results of those groundwater modeling results in the form of pumping centers map, drawdown tables and contour maps were forwarded to Reclamation via e-mail on March 17, 2003.

During that time frame (and prior to receiving the report of findings from the work) the I-40 wellfield location was revised to a location further west (the Canyon Diablo wellfield site) after the simulations showed flow depletions exceeding the 10 percent criteria in Chevelon and Clear Creeks.

On March 19, 2003 Reclamation asked SGC in a follow-up conference call on the I-40 modeling to postpone submitting the report of findings from that work, and incorporate those findings at a later time in a comprehensive report to include additional modeling/drawdown maps at the I-40 (T20N,R13E) wellfield, and new modeling for the revised Canyon Diablo wellfield location (figure A-3).

Modification to Scope of Work

Reclamation submitted a modification to the March 7 Scope of Work by requesting supplemental modeling runs and deliverables for the I-40 wellfield Alternative work already in-progress, as well as new modeling for the revised Canyon Diablo alternative wellfield.

The modified and new work and deliverables were broken into Phases 1a/1b/1c/1d, and Phase 2 tasks, respectively. All work products were to use the mid-range demands producing tables and drawdown contour maps at the same scales and time periods, and any other supporting tables such as pumping center demands. Reclamation asked that the maps and tables be forwarded to Reclamation after each Phase task.

For both the I-40 and Canyon Diablo modeling, a model run (1 run) was defined as one run of the analytical model and one run of the numerical model with identical pumping applied. Both encompass the same spatial domain. Difference maps were requested to better illustrate the pumping impacts of the two simulated wellfields rather than the coalescing cones of depressions from all existing pumping centers combined with the proposed wellfield. A difference map is defined as the difference in head (or drawdown) between the head (or drawdown) from the Hopi-Western Navajo Water Supply Study Alternative 1, Mid Range results and the head (or drawdown) resulting from the model runs of the two wellfields.

Alternative 1 – Local Groundwater Pumping

The underlying assumption for the Alternative 1 scenario is that all future M&I Navajo and Hopi demands will be met using groundwater pumped from either the C-, or N-Aquifers near the point of use (demand center). No surface supplies are presumed.

Alternative 1, for the purposes of this Appraisal report, is considered to be the "basecase" scenario from which the superimposed I-40 and Canyon Diablo pumping is compared and contrasted. Alternative 1 includes all identified demand centers shown on figure A-2 (excepting point #48, the I-40 wellfield).

Some of these 47 pumping centers are demands which may never foreseeably materialize out into the future. Alternative 1 may represent more pumping than may actually occur, and then it would represent a worst-case scenario for drawdown and streamflow depletions. In particular, the Navajo Powerplant #2 groundwater demand probably will never happen, and some Leupp agricultural pumping may be over-estimated. Thus, it is being informally referred to as the maximum demand or "artificial" scenario.

Alternative1 Modeling Results

The following conclusions are taken from the Hopi Western Navajo Water Supply Study Alternative 1, Local Groundwater report, tables 1 through 4 and 1 through 6, and from page 3 of that report; and from supplemental model runs.

Drawdown.—Modified table 1 through 4 (Alternative1-1 on following page), for the mid-range demand scenario, gives several drawdown impact percentage thresholds as defined in the Hopi Western Navajo Water Supply Study. A sustainable drawdown threshold is no more than 30 percent of the original saturated aquifer thickness at the extent of a particular demand center. In other words, it was considered acceptable for about a third of the present time (current conditions) local saturated aquifer thickness to be dewatered at a given 10-year time increment. It is apparent that Chinle, Ft. Defiance, and Ganado demand center pumping may overtax the C-Aquifer after about year 2030.

The Alternative 1 drawdown contour map is shown in figure A-3. After 100-years, it is apparent the largest coalescing cones of depression and the most drawdown (up to 300 feet at the Snowflake/Taylor area) is simulated to occur east and southeast of Winslow. The Joseph City and Cholla Power Plants area has about 200 feet of drawdown and the 50 –foot drawdown contour is encroaching upon the Lower Chevelon Canyon flow model measurement point "gages" MP1 through MP3. The C-aquifer drawdown at these Chevelon Canyon flow points range from about 30 to 40 feet. Less than 10-feet of C-aquifer drawdown is apparent at the Upper East Clear Creek model measurement point "gage."

Streamflow. —Table Alternative A-2 shows the estimated impacts to the C-aquifer supplied baseflow (baseline flows start at year 2000) for several measuring point "gages" selected on Upper East Clear Creek (UECC) and Lower Chevelon Creek (MP1/2 and MP3; see figures A-1 and A-2).

Flow reductions of 0 to about 5 percent (0.22 cfs over the 100-year timeframe) is shown for Upper East Clear Creek (UECC). Major impacts from pumping occur to Lower Chevelon Creek. At MP1/2, far greater than 10% flow reduction occurs by 2010 and the creek goes dry by 2030. For MP 3 (also known as the Bell Cow canyon point), the creek flow disappears completely by 2010.

Some discussion of the creek measuring points is warranted. How the baseline flows were derived is documented in the *Assessment of Western Navajo and Hopi Water Supply Needs, Alternatives, and Impacts* Study and *Alternative 1: Local Groundwater*. The measuring point locations were selected by the modeling subcontractors in consultation with L. Fitzpatrick of the F&WS (SGC, pers. comm.).

Point MP1/2 was selected to represent the groundwater baseflow contribution (discharge) from the C-Aquifer before it becomes confined or semi-confined by the overlying Moenkopi Formation, an aquitard. From the contact between these units and extending downstream, there is little to no stream/aquifer interaction. The Upper East Clear Creek point was selected where the stream becomes "losing." This means the stream is discharging to the aquifer. The Coconino Sandstone is the primary water bearing unit of the C-Aquifer group.

Alternative 1 Conclusions

All the pumping in Alternative 1 shows unacceptable C-aquifer drawdowns in the Chinle, Ft. Defiance, and Ganado areas. Upper East Clear Creek flows are essentially unaffected over 100 years. The estimated drawdown after 100 years in the C-aquifer below East Clear Creek is 10-feet.

Lower Chevelon creek flows are adversely impacted sometime between 2005 and 2010 and disappear between 2010 and 2030.

No impacts occur to Blue Springs from Alternative 1 pumping demands. This is determined by the modelers' using calculated analytical model drawdowns and assuming uniform groundwater gradients over about 50 miles. The nearest demand center is at Cameron where the projected incremental 10 year demands to year 2100 are relatively low (see table A-1, C-Aquifer Demands by Decade).

Table A-2.—Aquifer Dewatering Impacts: C-aquifer Service Area, Alternative 1
(modified from Alternative 1: Local Groundwater: Dewatering Spreadsheet.xls)

IMPACT DUE TO AQUIFER DEWATERING - ALTERNATIVE 1

MID-RANGE DEMAND SCENARIO

YEAR				**Drawdown (ft)**									
				2010	**2020**	**2030**	**2040**	**2050**	**2060**	**2070**	**2080**	**2090**	**2100**
M&I Demand Center	Drawdown Threshold-30%	Drawdown Threshold - 50%	Maximum Drawdown										
Many Farms	800	900	1150	67	110	147	188	232	284	339	400	471	560
Chinle	400	500	750	145	214	294	378	463	560	666	Dry	Dry	Dry
Ft Defiance	205	305	555	36	55	81	108	136	169	207	251	307	394
Ganado	132	220	440	6	35	58	98	133	177	233	310	472	Dry
Hopi Ranches-Aja	195	325	650	0	1	8	16	24	29	33	38	42	47
Hopi Ranches-Clear Creek	195	325	650	3	6	20	30	38	44	49	54	58	78
Leupp	195	325	760	27	72	99	120	139	158	177	196	217	241
Cameron	545	705	1105	3	5	7	9	12	16	20	25	31	39

Table A-3.—Impacts to C-Aquifer Supplied Creek Flows and Blue Springs, Alternative 1
(modified from Alternative 1: Local Groundwater: Table 1-6)

Mid Range Demand Scenario	**Impacts to Baseflow of Clear and Chevelon Creeks (cfs)**										
	2000	2010	2020	2030	2040	2050	2060	2070	2080	2090	2100
East Clear Creek Creek	4.62	4.55	4.54	4.51	4.49	4.47	4.45	4.44	4.43	4.41	4.40
Percentage reduction from base		*-2%*	*-2%*	*-2%*	*-3%*	*-3%*	*-4%*	*-4%*	*-4%*	*-4%*	*-5%*
Lower Chevelon Creek, measuring points 1&2	4.04	0.74	0.31	-	-	-	-	-	-	-	-
Percentage reduction from base		*-82%*	*-92%*	*-100%*	*-100%*	*-100%*	*-100%*	*-100%*	*-100%*	*-100%*	*-100%*
Lower Chevelon Creek, at Bell Cow Canyon	1.01	-	-	-	-	-	-	-	-	-	-
Percentage reduction from base		*-100%*	*-100%*	*-100%*	*-100%*	*-100%*	*-100%*	*-100%*	*-100%*	*-100%*	*-100%*

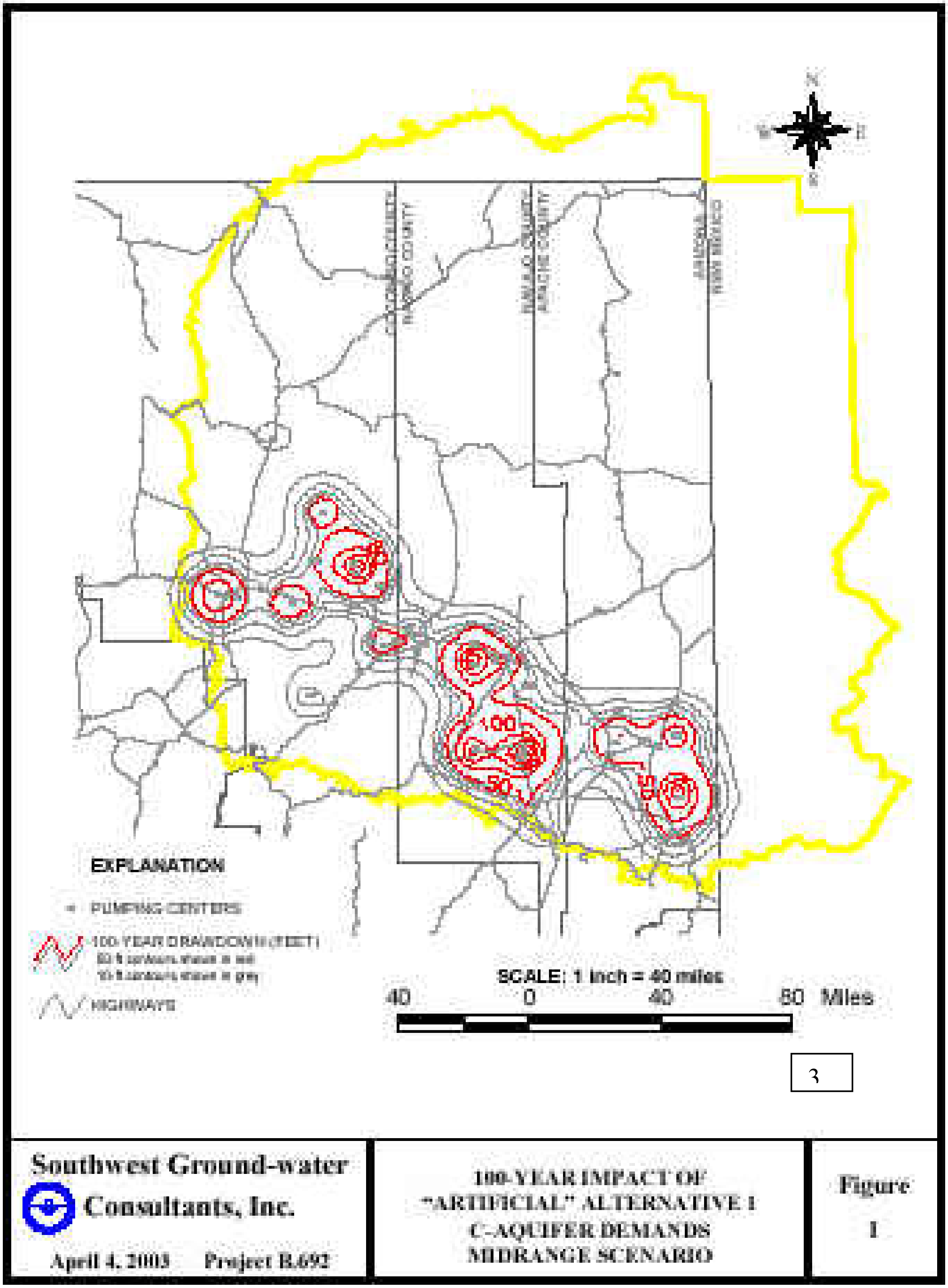


Figure A-3.—Alternative 1 drawdown contour map.

Alternative I-40 Wellfield

This alternative wellfield location was selected in consultation with the Navajo Nation Department of Water Resources (NNDWR), Hopi Tribe, Peabody Coal, SRP (who suggested the I-40 location be off the Navajo Nation in T20N, R13E), and other stakeholders. This I-40 wellfield location is no longer being considered after SGC's preliminary modeling data showed 10 percent or more impacts to flows in Chevelon Creek (discussed under the AlternativeI-40 Modeling Results section below). It also coincides with the privately held Red Gap Ranch. The I-40 alternative wellfield site has since been relocated to the revised Canyon Diablo site (see figure A-1). This section documents the demand assumptions and modeling results and shows why this alternative location was revised to the Canyon Diablo site.

In the (Reclamation) I-40 wellfield simulations, as run by SGC, all demand center pumping (as shown on figure A-2 and table A-1) used in the Alternative 1 "Basecase" is included in the Alternative I-40 wellfield simulations with minor changes. Added to this basecase demand is either 6,000 af/yr or 10,000 af/yr of additional pumpage from the C-aquifer within the I-40 Alternative wellfield site in T20N, R13E. Not shown in demand table A-4 are the Defiance Plateau demands (same as in table A-1). However, table A-4 does show the "Other Areas" demands as used for this I-40 run.

One model run used the Peabody Western Coal Black Mesa Mine, Kayenta Mine, and slurry pipeline demand at 800 af/yr, 800 af/yr, 500 af/yr for coal washing, and 3,700 af/yr for the slurry line to make 6,000 af/yr. The other run used 10,000 af/yr which includes the mine's projected industrial demands above, and SRP's suggested 2,000 af/yr each for the Navajo and Hopi tribes (except not Moenkopi) using the 2025 demands out of the Hopi Western Navajo Water Supply Study. The stakeholders suggested projected tribal demand figures are a little different than 2,000 af/yr but round figures were used. Ward Terrace pumping is not included, and the Leupp M&I pumping comes from the I-40 wellfield rather than the Leupp area.

In this wellfield, the hypothetical wells are spaced at 5000-foot intervals in a regular grid. All wells pump from the C-aquifer at a steady 500 gpm (about 800 af/yr).

AlternativeI-40 Modeling Results

The following conclusions are based on the I-40 wellfield mid-range model results e-mailed to Reclamation by SGC on March 17, 2003.

Streamflow.–Table A-6 shows the simulated impacts to the three creek flows for the I-40 Alternative wellfield under the 6,000 af/yr and 10,000 af/yr demand options. Table A-7 shows the simulated flow impacts if only 6,000 af/yr or 10,000 af/yr were pumped from the I-40 wellfield without any other pumping whatsoever. Thus, it helps demonstrate the model pumping sensitivity.

For Upper East Clear Creek, the I-40 Alternative does not adversely impact the creek flows (less than 10 percent flow reduction). There is about a five percent flow reduction (0.23 cfs over the 100 years) from year 2000 (4.62 cfs) to year 2100 (4.39 cfs) under either the 6,000 af/yr or 10,000 af/yr added pumping. In fact the flows are identical which suggests that the upper reaches of East Clear Creek flows (at least at the measurement point) are well outside the radius of pumping influence, and possibly that more Mogollon Rim precipitation (higher elevations) replenishes the aquifer here compared to the Lower Chevelon Creek reaches.

For Lower Chevelon Creek MP1/2, flows are not reduced below 10 percent until year 2020 (from 4.04 cfs to 3.60 cfs), and the streamflow does not disappear under either pumping scenario until year 2090. These flows are the output resulting from an adjustment to the time discretization for the transient numerical model (Modflow 2000).

For Lower Chevelon Creek MP3, flows are not reduced below 10 percent until year 2020 under either the extra 6,000 af/yr or 10,000 af/yr pumping stress added at the I-40 wellfield. The model computed flows go dry by year 2060.

Table A-7 shows the simulated flow impacts if only 6,000 af/yr or 10,000 af/yr were pumped from the I-40 wellfield. There is no impact to flows at the Upper East Clear Creek from either pumping regime. At MP1/2 on Lower Chevelon Creek, the flow reductions are quite similar under the two pumping regimes and even at 10,000 af/yr, the flow reduction at 2100 is only 4 percent. For MP3, flows don't drop until about 2050 from a baseflow of 1.01 cfs to 1.0 cfs. By 2100, flows have only declined 5 percent.

Drawdown. –It was not readily apparent looking at SGC's (March 19) modeling drawdown maps (the 6,000 & 10,000 af/yr I-40 drawdown contour maps; see figures A-4 and A-5) the "differences" this additional pumping makes on the C-aquifer over the "baseline" Alternative 1 demand scenario discussed in the previous section (see figure A-3). Therefore, SGC was asked under the modified Scope of Work to produce these. These difference maps are included as figures A-5 and A-6.

The inclusion of 6,000 af/yr pumping at the I-40 wellfield does not significantly alter the regional C-aquifer flow regime after 100-years, especially the aquifer drawdown distribution east of Winslow. In the demand areas around Leupp and the Navajo Powerplant #1 the year 2100 50-foot drawdown contour does expand to slightly south of I-40 coalescing with the Flagstaff Settlement wells cone of depression. Figure A-6 shows about 50 to 60 feet additional drawdown over Alternative1 by pumping 6,000 af/yr.

Under 10,000 af/yr of pumping by 2100, the 50-foot drawdown coalesces with the cone of depression around the Hopi Ranches Clear Creek and Winslow M&I centers. In both pumping cases, the estimated C-aquifer drawdowns below the Lower Chevelon Creek MP1/2 and MP3, are still about 30 to 40 feet (as in Alternative1) , the difference at these gages being less than one–foot as shown on figures A-6 and A-7. The drawdown below Upper East Clear Creek is also estimated at 2100 to be less than one additional foot under both pumping regimes. An additional 80 to 100-feet of drawdown by 2100 is estimated when pumping 10,000 af/yr at the I-40 wellfield (figure A-7).

Figures A-6 and A-7 also show a well defined cone of depression of about 100 feet of drawdown around an unidentified pumping center which is most likely the 2,000 af/yr of Hopi demand. This cone of depression doesn't seem to change magnitude or extent from 6,000 af/yr to 10,000 af/yr of pumping at the I-40 wellfield.

Alternative I-40 Wellfield Conclusions

With reference to table A-5 pumping 6,000 af/yr in Alternative I-40 estimates 122 feet of drawdown at the wellfield by 2100. Water level decline per year varies from 0.8 to 3 feet. For the 10,000 af/yr rate, this maximum drawdown is 178 feet by 2100. The water level decline varies from 1-foot to 4 feet per year.

Pumping 6,000 af/yr at the I-40 wellfield does not significantly alter the regional C-aquifer flow regime after 100-years, especially the aquifer drawdown distribution east of Winslow. There is about 50 to 60 feet additional drawdown (at the I-40 wellfield) over Alternative1 by pumping 6,000 af/yr, and an additional 80 to 100-feet of drawdown by 2100 when pumping 10,000 af/yr at the I-40 wellfield.

In both pumping cases, the estimated C-aquifer drawdowns below the Lower Chevelon Creek points MP1/2 and MP3 are about 30 to 40 feet as in Alternative 1 without the I-40 wellfield. The drawdown changes as a result of the I-40 pumping is estimated to be less than one–foot as shown on figures A-6 and A-7. The drawdown below Upper East Clear Creek is also estimated at 2100 to be less than one additional foot under both pumping regimes.

East Clear Creek flows are essentially unaffected over 100 years under either pumping regime. Lower Chevelon creek flows are adversely impacted (exceed the 10 percent criteria) sometime between 2010 and 2020 and flows disappear entirely at 2090 (under 6,000 af/yr) and 2060 under the 10,000 af/yr stress.

Looking at only I-40 pumping as a sensitivity run (no other pumping in the model), the MP1/2 on Lower Chevelon Creek flow reductions are quite similar under the two pumping regimes and even under 10,000 af/yr, the flow reduction at 2100 is only 4 percent. It is about 5 percent for MP3 at either 6,000 or 10,000 af/yr from the 2000 base to 2100 (1.01 to 0.96 cfs).

Therefore, at the flow measurement stations on Lower Chevelon Creek, points MP1/2 and MP3, and on Upper East Clear Creek, the I-40 pumping alone whether at 6,000 or 10,000 af/yr does not appear to adversely impact flows. The cumulative impacts of all actual pumping plus the I-40 pumping superimposed does adversely impact Lower Chevelon Canyon flows. Upper East Clear Creek and Blue Springs flows are not impacted by the I-40 wellfield alternative.

The MP3 measurement point is approximately 3 miles upstream of MP1/2, and using a 7.5-minute quadrangle, roughly 50 feet higher in elevation than MP1/2.

No impacts occur to Blue Springs from Alternative 1 pumping demands. This is determined by the modelers' using calculated analytical model drawdowns and assuming uniform groundwater gradients over about 50 miles. The nearest demand center is at Cameron where the projected incremental 10 year demands to year 2100 are relatively low (see table 1, C-Aquifer Demands by Decade).

Table A-4.—C-Aquifer Mid-Range Demand Changes Used for I-40 Alternative

OTHER C-AQUIFER AREAS											
Tribal Municipal and Industrial (M&I)											
	2000	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**	**2070**	**2080**	**2090**	**2100**
Leupp											
Mid Range	290	421	733	1075	1510	1930	2399	2982	3707	4608	5728
Cameron											
Mid Range	171	269	434	576	760	971	1207	1501	1866	2319	2883
Hopi Ranches - Clear Creek											
Mid Range	0	0	0	1000	1500	2000	2000	2000	2000	2000	6000
Hopi Ranches - Aja Ranch											
Mid Range	0	0	0	400	750	1000	1000	1000	1000	1000	1000
Tribal Irrigation											
	2000	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**	**2070**	**2080**	**2090**	**2100**
Leupp Irrigation (West)											
Mid Range	0	0	0	0	570	728	905	1125	1399	1739	2162
Leupp Irrigation (East)											
Mid Range	0	0	0	0	430	550	683	849	1055	1312	1631
Hopi Ranches Clear Creek #1											
Mid Range	0	0	500	750	1100	1100	1100	1100	1100	1100	1100
Clear Creek #2											
Mid Range	0	0	0	300	450	640	640	640	640	640	640
Aja Ranch											
Mid Range	0	0	0	350	500	730	730	730	730	730	730
Zuni Heavens (Environmental)											
Mid Range	0	500	1000	1500	1500	1500	1000	500	300	200	200
Tribal Industrial											
	2000	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**	**2070**	**2080**	**2090**	**2100**
Navajo Power Plant #1											
Mid Range	8000	8000	16000	16000	16000	16000	16000	16000	16000	16000	16000
Navajo Power Plant #2											
Mid Range	0	0	0	0	0	0	0	0	0	0	0

OTHER C-AQUIFER AREAS (Continued)

Tribal Industrial (Continued)

	2000	2010	2020	2030	2040	2050	2060	2070	2080	2090	2100
Future Mining (Ward Terrace)											
Mid Range	0	0	0	0	0	0	0	0	0	0	0

Non-Tribal Municipal and Industrial (M&I)

	2000	2010	2020	2030	2040	2050	2060	2070	2080	2090	2100
Eager											
Mid Range	732	886	1056	1216	1369	1523	1682	1859	2053	2268	2505
Flagstaff											
Mid Range	10340	12260	13961	15589	17357	19362	21388	23626	26098	28828	31844
Holbrook											
Mid Range	883	948	993	1054	1130	1243	1339	1443	1555	1675	1805
Pinetop-Lakeside											
Mid Range	659	731	750	811	912	1084	1198	1323	1461	1614	1783
Show Low											
Mid Range	1449	1640	1810	2001	2206	2482	2741	3028	3345	3695	4081
Snowflake											
Mid Range	821	892	939	1007	1093	1223	1351	1493	1649	1821	2012
Springerville											
Mid Range	362	416	474	578	584	640	707	781	863	953	1053
St. Johns											
Mid Range	633	649	653	667	690	725	762	801	842	886	931
Taylor											
Mid Range	607	712	834	945	1044	1155	1276	1409	1557	1719	1899
Winslow											
Mid Range	1711	1849	1964	2099	2251	2464	2655	2861	3083	3322	3579

Non-Tribal Irrigation - Low, Mid Range, High

	2000	2010	2020	2030	2040	2050	2060	2070	2080	2090	2100
CDI - Winslow	2738	2738	2738	2738	2738	2738	2738	2738	2738	2738	2738
CDI - Canyon Diablo	2738	2738	2738	2738	2738	2738	2738	2738	2738	2738	2738
HV - Joseph City	120	120	120	120	120	120	120	120	120	120	120
HOL - Holbrook	1739	1739	1739	1739	1739	1739	1739	1739	1739	1739	1739
HOL - Woodruff	1739	1739	1739	1739	1739	1739	1739	1739	1739	1739	1739
HOL - Joseph City	1739	1739	1739	1739	1739	1739	1739	1739	1739	1739	1739
HOL - Hay Hollow	1739	1739	1739	1739	1739	1739	1739	1739	1739	1739	1739
SNO - Snowflake-Taylor	22000	22000	22000	22000	22000	22000	22000	22000	22000	22000	22000

OTHER C-AQUIFER AREAS (Continued)											
Non-Tribal Irrigation - Low, Mid Range, High (Continued)											
	2000	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**	**2070**	**2080**	**2090**	**2100**
CON - Concho	242	242	242	242	242	242	242	242	242	242	242
STJ - St. Johns	2360	2360	2360	2360	2360	2360	2360	2360	2360	2360	2360
Coronado Power Plant (SRP)											
Mid Range	12000	12000	12000	12000	12000	16000	16000	18000	18000	18000	21400
Cholla Power Plant (APS)											
Mid Range	13500	13500	13500	13500	13500	16000	16000	18000	18000	18000	21500
Springerville Power Plant (TEPCO)											
Mid Range	20000	20000	20000	20000	20000	20000	20000	20000	20000	20000	20000
Abitibi Paper Mill											
Mid Range	13000	13000	13000	13000	13000	16000	16000	18000	18000	18000	20000
Little America Refining Co.											
Mid Range	100	101	112	124	138	153	170	189	210	233	259
Cholla Ready Mix											
Mid Range	20	20	22	25	27	30	34	37	42	46	51

Table A-5.—C-Aquifer Mid-Range Demand Drawdowns for the I-40 Alternative Wellfield

BUREAU OF RECLAMATION MODEL RUNS DRAWDOWN

I-40 DEMAND = 6,000 AF/YR(3720 gpm) SCENARIO

YEAR		s (ft)										
		2000	2010	2020	2030	2040	2050	2060	2070	2080	2090	2100
M&I Demand Center	Depth to SWL (ft)											
Cameron	500	0	3	5	7	9	12	16	20	25	31	39
Leupp	120	0	27	73	100	123	145	165	186	207	231	257
Hopi Ranches-Aja	150	0	0	1	8	16	24	29	33	38	42	47
Hopi Ranches-Clear Creek	150	0	3	6	20	31	40	47	53	59	65	71
I-40 Wellfield	200	0	30	55	66	74	82	90	98	106	114	122
	DTW=	200	230	255	266	274	282	290	298	306	314	322
	Ft/yr of s	0.0	3.0	2.5	1.1	0.9	0.8	0.8	0.8	0.8	0.8	0.8

I-40 DEMAND = 10,000 AF/YR(6200 gpm) SCENARIO

YEAR		s (ft)										
		2000	2010	2020	2030	2040	2050	2060	2070	2080	2090	2100
M&I Demand Center	Depth to SWL (ft)											
Cameron	500	0	3	5	7	9	12	16	20	25	31	39
Leupp	120	0	27	73	101	125	147	169	191	214	238	267
Hopi Ranches-Aja	150	0	0	1	8	16	24	29	33	38	43	47
Hopi Ranches-Clear Creek	150	0	3	6	20	32	42	49	56	62	69	76
I-40 Wellfield	200	0	43	82	100	114	126	137	147	158	168	178
	DTW=	200	243	282	300	314	326	337	347	358	368	378
	Ft/yr of s	0	4	4	2	1	1	1	1	1	1	1

Table A-6.—Impacts to Creek Flows from I-40 Alternative Wellfield Simulations

Upper East Clear Creek Flow (cubic feet per second)

Alternative	Demand Scenario	2000	2010	2020	2030	2040	2050	2060	2070	2080	2090	2100
BOR6000	Mid-Range	4.62	4.62	4.61	4.60	4.59	4.57	4.56	4.55	4.53	4.52	4.51
BOR10000	Mid-Range	4.62	4.62	4.61	4.60	4.59	4.57	4.56	4.55	4.53	4.52	4.51

Lower Chevelon Canyon Flow - MP1/2 (cubic feet per second)

Alternative	Demand Scenario	2000	2010	2020	2030	2040	2050	2060	2070	2080	2090	2100
BOR6000	Mid-Range	4.04	3.60	2.90	2.17	1.48	0.94	0.63	0.39	0.12	0.00	0.00
BOR10000	Mid-Range	4.04	3.60	2.89	2.17	1.48	0.93	0.62	0.37	0.10	0.00	0.00

Lower Chevelon Canyon Flow - MP3 (cubic feet per second)

Alternative	Demand Scenario	2000	2010	2020	2030	2040	2050	2060	2070	2080	2090	2100
BOR6000	Mid-Range	1.01	0.91	0.69	0.46	0.23	0.06	0.00	0.00	0.00	0.00	0.00
BOR10000	Mid-Range	1.01	0.91	0.69	0.46	0.23	0.06	0.00	0.00	0.00	0.00	0.00

Table A-7.—Impacts to Creek Flows: Pumping Only at the I-40 Alternative Wellfield

TASK 1C BOR I-40 WELLFIELD ONLY

Upper East Clear Creek Flow (cubic feet per second)

Alternative	2000	2010	2020	2030	2040	2050	2060	2070	2080	2090	2100
BOR I-40 6,000 ONLY	4.62	4.62	4.62	4.62	4.62	4.62	4.62	4.62	4.62	4.62	4.62
BOR I-40 10,000 ONLY	4.62	4.62	4.62	4.62	4.62	4.62	4.62	4.62	4.62	4.62	4.62

Lower Chevelon Canyon Flow - MP1/2 (cubic feet per second)

Alternative	2000	2010	2020	2030	2040	2050	2060	2070	2080	2090	2100
BOR I-40 6,000 ONLY	4.04	4.04	4.04	4.04	4.03	4.02	4.00	3.98	3.97	3.95	3.93
BOR I-40 10,000 ONLY	4.04	4.04	4.04	4.03	4.02	4.00	3.97	3.95	3.92	3.89	3.86

Lower Chevelon Canyon Flow - MP3 (cubic feet per second)

Alternative	2000	2010	2020	2030	2040	2050	2060	2070	2080	2090	2100
BOR I-40 6,000 ONLY	1.01	1.01	1.01	1.01	1.01	1.00	1.00	0.99	0.99	0.98	0.98
BOR I-40 10,000 ONLY	1.01	1.01	1.01	1.01	1.00	1.00	0.99	0.98	0.98	0.97	0.96

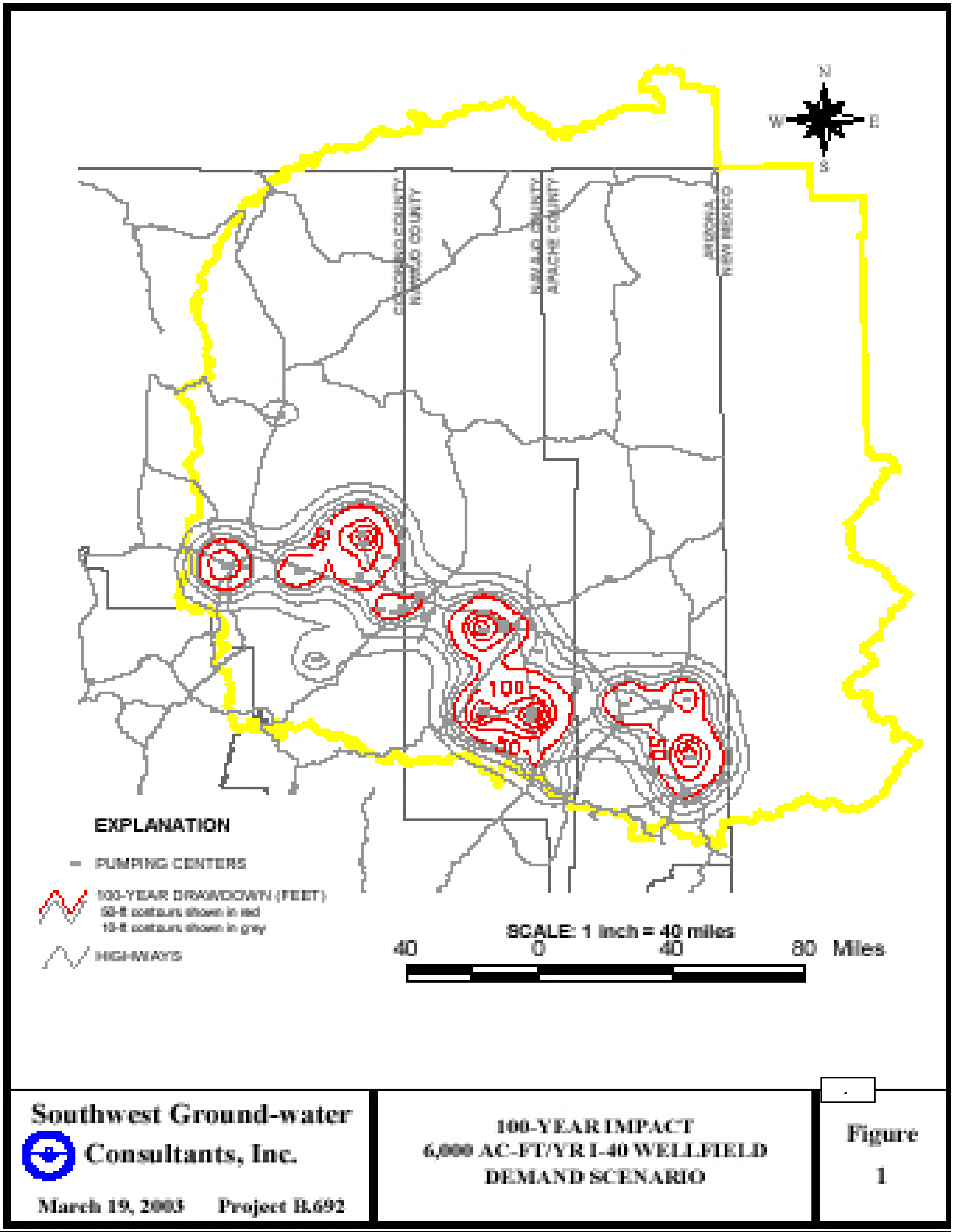


Figure A-4.–Alternative I-40 wellfield drawdown contour map – 6,000 af/yr.

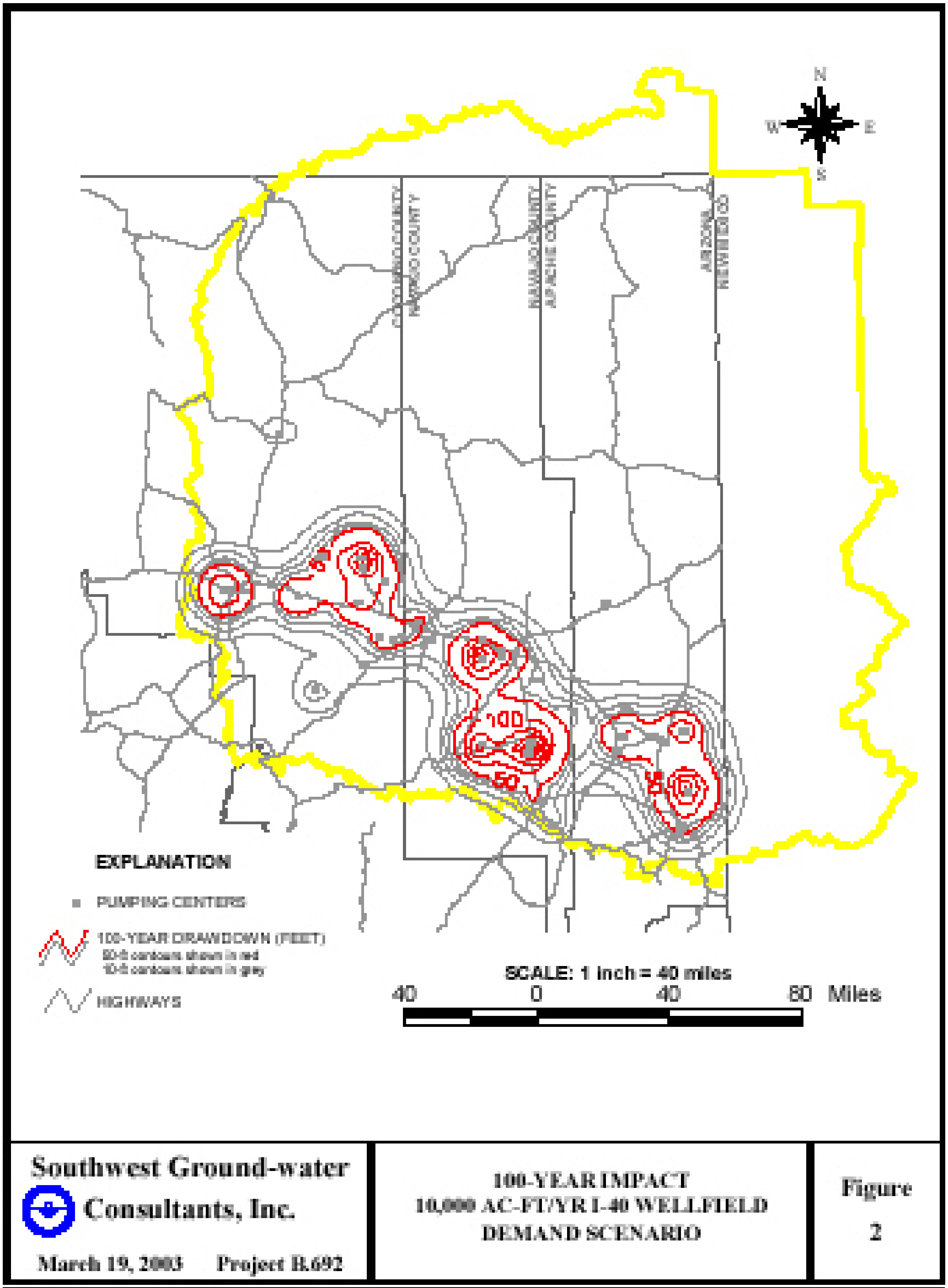


Figure A-5.—Alternative I-40 wellfield drawdown contour map – 10,000 af/yr.

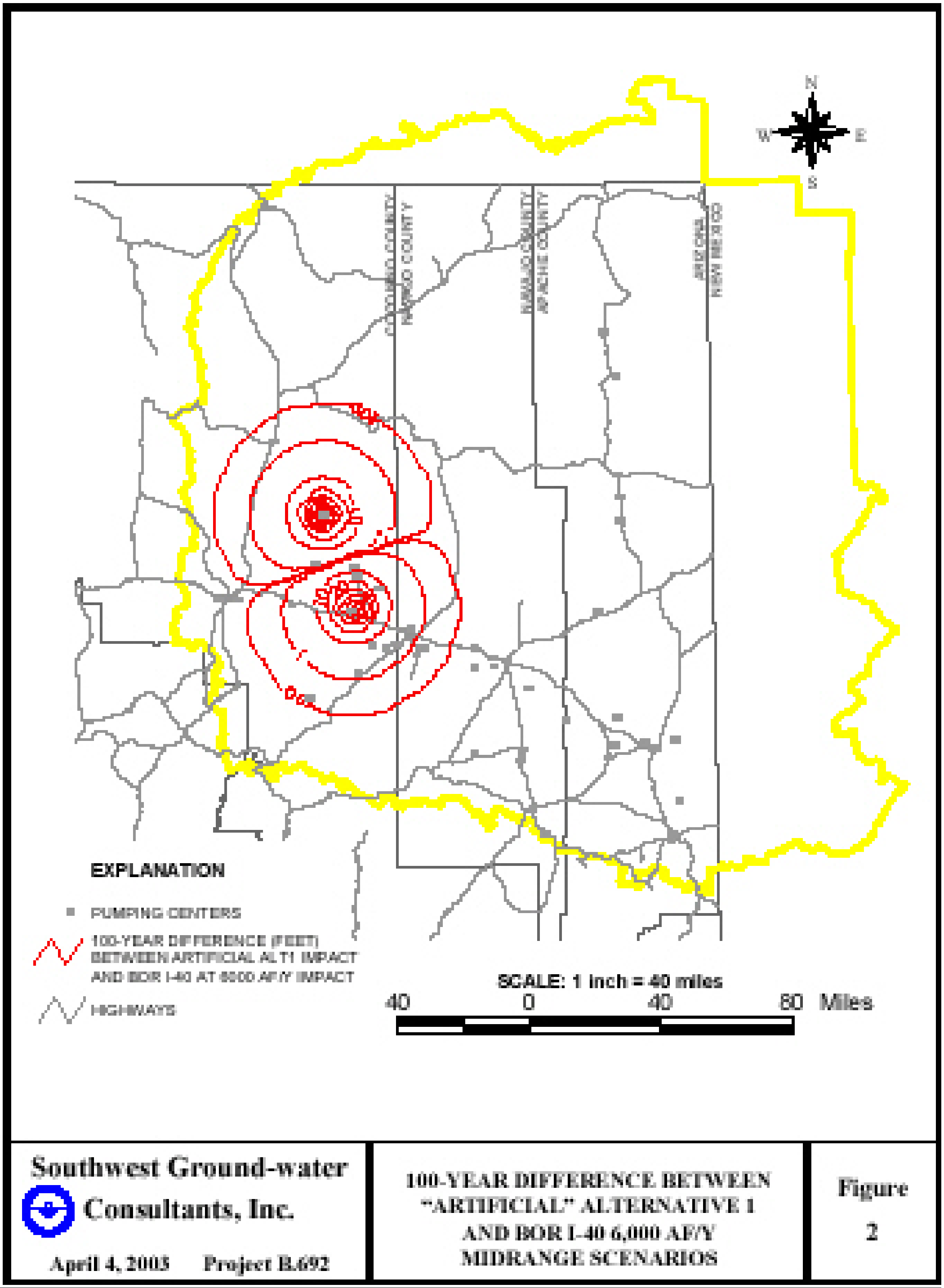


Figure A-6.—Alternative I-40 Wellfield Difference Contour Map – 6,000 af/yr.

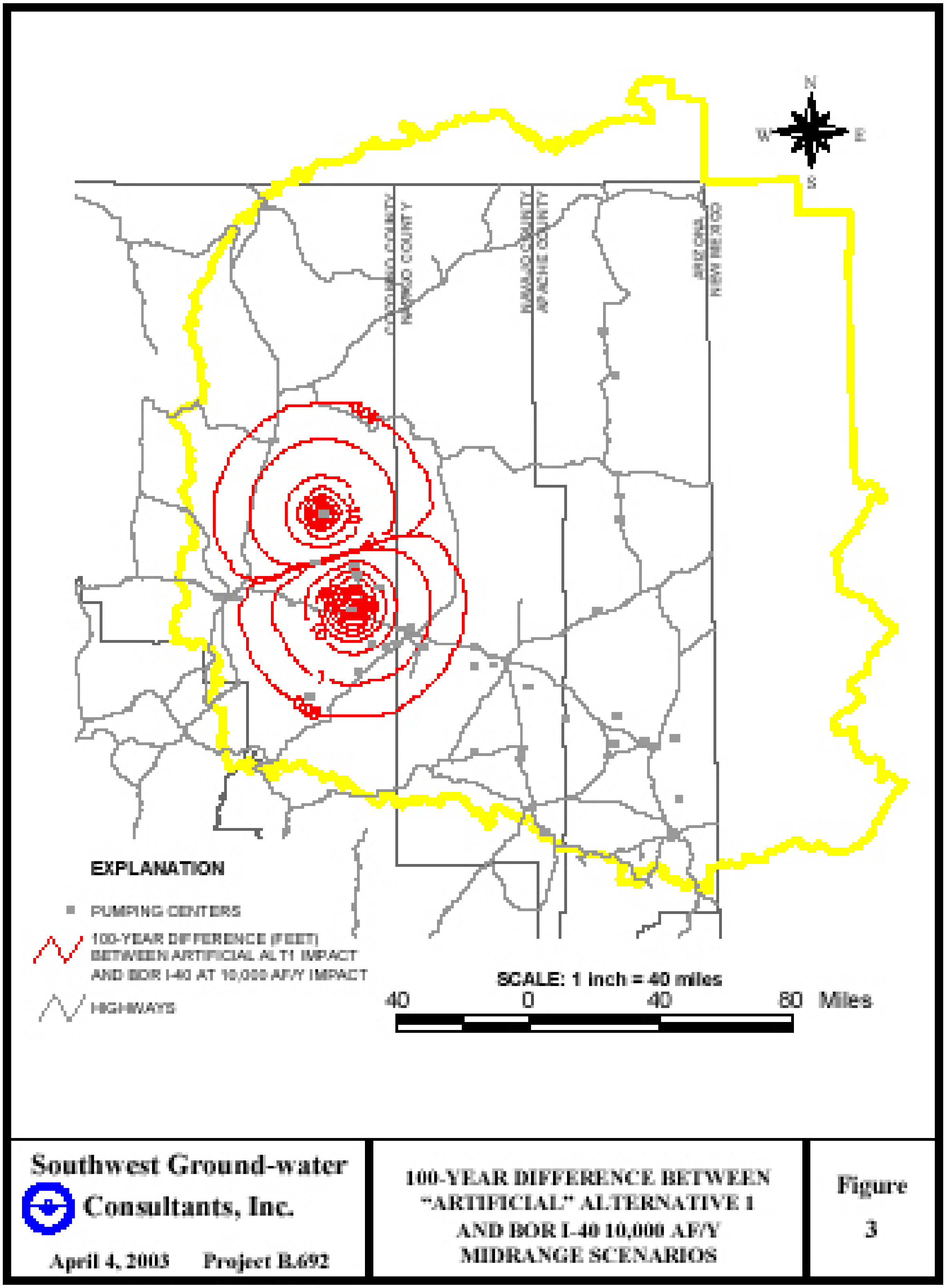


Figure A-7.—Alternative I-40 Wellfield Difference Contour Map – 10,000 af/yr.

Canyon Diablo Alternative Wellfield – Maximum (Artificial) Demand Scenario Pumping

This alternative wellfield location was selected cooperatively between Reclamation, SGC, and input from the tribes. It started out as the Canyon Diablo wellfield (see figure A-1) tentatively located just east of Canyon Diablo, and north of Interstate I-40 in a portion of the Canyon Diablo property in T20N, R12E. However, SGC pointed out that the wells (with their 5000-foot spacing) would be very close to those in the I-40 wellfield so the location was revised. Discussions with SGC resulted in attempting to locate the wellfield within the domain of the WNH3C numerical model but on the Navajo Nation.

Reclamation determined that the wellfield should be situated completely off the Red Gap Ranch but with a portion (three wells) within the Canyon Diablo parcel, below the railroad tracks, and the remaining 10 wells on the Navajo Nation. (see figure A-1). This section documents the demand assumptions and modeling results from this latest Canyon Diablo wellfield iteration.

The Canyon Diablo modeling scenario 1D uses the same 6,000 af/yr (for Peabody Western Coal) and 10,000 af/yr pumping demands (Peabody Coal plus 2,000 af/yr for each of the Navajo and Hopi tribal demands) as the I-40 alternative used, as well as all remaining "artificial" pumping center demands. The only change is the wellfield is 3 to 6-miles further west of the I-40 wellfield, and overlaps both Canyon Diablo property and the Navajo nation boundary.

Thus, another pumping center demand table is not included here since table A-4 applies to this scenario. The same wellfield spacing, layout, and well construction attributes as for the I-40 wellfield apply.

Canyon Diablo Alternative Modeling Results

The following statements and conclusions are based on the mid-range pumping demand data results for this Canyon Diablo alternative e-mailed to Reclamation by SGC on April 10, 2003.

Streamflow.—Table A-8 shows that the Canyon Diablo wellfield by itself, under either 6,000 af/yr or 10,000 af/yr pumping, does not deplete the baseline year 2000 flows significantly at the measurement points in either Upper East Clear Creek or Lower Chevelon Creek. This is a sensitivity analysis which demonstrates the Canyon Diablo pumping by itself does not drawdown the C-aquifer to a point which causes adverse flow depletions. Comparison of table A-7 for the I-40 wellfield and table A-8 shows almost identical simulated flows for each 10-year period except the flows from Canyon Diablo for MP1, MP2, and MP3are just slightly higher. The SGC's Phase 2 work products will use the "Best Guess" demand center pumping plus the Canyon Diablo wellfield pumping to estimate the flow depletions in the creeks.

Pumping Lift/Drawdown. —Table A-8 shows the mid-range lifts (pumping level to the surface) for the Canyon Diablo wellfield pumping at 10,000 af/yr plus all existing "artificial" demand center pumping. At 2100, the Hopi portion (which has 3 wells each pumping at 500 gpm or 2,000 af/yr) shows 68 feet less drawdown (99 feet drawdown) than the Navajo wellfield (at 167 feet drawdown) which has 10 wells. The I-40 wellfield at 10,000 af/yr, by comparison, had 178 feet of drawdown. Looking at only the Canyon Diablo drawdowns alone, tens of feet more drawdown at each 10-year period is expected with the 10,000 af/yr rate over a 6,000 af/yr rate. Furthermore, 22 percent more drawdown is simulated to occur by 2100 in the Navajo wellfield (under 6,000 af/yr) with all entities pumping as opposed to pumping only 6,000 af/yr at the Canyon Diablo wellfield exclusively. For 10,000 af/yr , this 2100 drawdown difference is 14 percent. For the three Hopi wells (under the 6,000 af/yr (three wells), 24 percent more drawdown is estimated at 2100 for all demand center pumping including the three Hopi wells as compared to a 9 percent difference with the Hopi wells alone pumping.

Figures A-8 through A-11 are drawdown contour maps for the Canyon Diablo "artificial" simulation. Figure A-8 shows the 100-year drawdown contour distribution under 10,000 af/yr. The drawdown cone of depression distribution is similar to that of figure A-5 – the I-40 run of 10,000 af/yr. The 50-foot contour of figure A-8 does not coalesce with the Winslow M&I area cone of depression as it does with figure A-5. Otherwise the two simulations show very similar drawdown trends and differences (with the Alternative 1 baseline shown in figure A-9) by 2100 (still about 30 to 40 feet of C-aquifer drawdown is estimated below Lower Chevelon Canyon points MP1/2 and MP3).

Figures A-10 and A-11 show 100-year drawdowns from Canyon Diablo pumping alone at 6,000 af/yr of 40 to 50 feet, and 60 to 90 feet when pumping 10,000 af/yr.

Canyon Diablo Alternative Wellfield Conclusions

Creek flow impacts were estimated using only the Canyon Diablo pumping rates of 6,000 af/yr and 10,000 af/yr exclusively so the flows do not reflect all the additional pumping centers. This sensitivity run does show that the creek flows at all measuring points are not depleted (below 10 percent) by either pumping regime at only the Canyon Diablo wellfield.

Drawdown effects, distribution, and magnitudes are quite similar to the I-40 Wellfield although in general the Canyon Diablo pumping results in slightly less C-aquifer drawdown than for the I-40 alternative. Drawdowns below Lower Chevelon Creek and Upper East Clear Creek are similar (about 30 to 40 feet) to those of the I-40 wellfield.

The 2,000 af/yr Hopi pumping center shows 92 feet more drawdown from either the I-40 or Canyon Diablo scenarios when compared (heads subtracted) with the Alternative 1 basecase (see figures A-6 and A-9). Around the I-40/ Canyon Diablo wellfield area the I-40 difference at 10,000 af/yr by 2100 is a maximum of 106 feet (e.g., Alternative 1 had 106 feet more drawdown). For the Canyon Diablo run, this difference is 80 to 100 feet less drawdown than Alternative 1.

Table A-8.—C-Aquifer Mid-Range Demand Pumping Lifts or the Canyon Diablo Alternative Wellfield

CANYON DIABLO 6,000 AFA AND 10,000 AFA AND CANYON DIABLO 10,000 AFA PLUS "ARTIFICIAL" DEMANDS

Canyon Diablo Wellfield Demand = 10,000 AF/YrPlus "Artificial" Wellfields

YEAR		LIFT (ft)									
		2010	2020	2030	2040	2050	2060	2070	2080	2090	2100
M&I Demand Center	Depth to SWL (ft)										
Cameron	500	503	505	507	509	512	516	520	525	531	539
Leupp	120	148	194	224	250	273	296	319	342	368	397
Hopi Ranches-Aja	150	150	151	158	166	174	179	183	188	192	197
Hopi Ranches-Clear Creek	150	153	156	170	180	189	195	200	206	211	217
Canyon Diablo Navajo Wellfield	200	237	261	279	293	307	319	331	343	355	367
Canyon Diablo Hopi Wellfield	200	214	231	241	249	258	266	274	282	291	299

Canyon Diablo Wellfield Only - Demand = 6,000 Ac-Ft/Yr

YEAR		LIFT (ft)									
		2010	2020	2030	2040	2050	2060	2070	2080	2090	2100
M&I Demand Center	Depth to SWL (ft)										
Cameron	500	500	500	500	500	500	500	500	500	500	500
Leupp	120	120	121	123	125	127	129	131	133	134	136
Hopi Ranches-Aja	150	150	150	150	150	150	150	150	150	150	150
Hopi Ranches-Clear Creek	150	150	150	150	150	150	150	151	151	151	151
Canyon Diablo Navajo Wellfield	200	230	252	261	267	272	276	279	282	284	286
Canyon Diablo Hopi Wellfield	200	201	205	210	214	217	220	222	224	226	228

CANYON DIABLO 6,000 AFA AND 10,000 AFA AND CANYON DIABLO 10,000 AFA PLUS MAXIMUM DEMANDS

Canyon Diablo Wellfield Only - Demand = 10,000 Ac-Ft/Yr

YEAR		LIFT (ft)									
		2010	**2020**	**2030**	**2040**	**2050**	**2060**	**2070**	**2080**	**2090**	**2100**
M&I Demand Center	Depth to SWL (ft)										
Cameron	500	500	500	500	500	500	500	500	500	500	500
Leupp	120	120	122	125	128	132	135	137	140	143	145
Hopi Ranches-Aja	150	150	150	150	150	150	150	150	150	150	150
Hopi Ranches-Clear Creek	150	150	150	150	150	150	151	151	152	153	153
Canyon Diablo Navajo Wellfield	200	237	260	274	283	291	297	302	306	310	314
Canyon Diablo Hopi Wellfield	200	214	230	240	247	253	258	262	266	270	273

Table A-8.–Impacts to Creek Flows from Canyon Diablo Alternative Wellfield Alone

Upper East Clear Creek Flow (cubic feet per second)

Alternative	2000	2010	2020	2030	2040	2050	2060	2070	2080	2090	2100
CANYON DIABLO 6,000 ONLY	4.62	4.62	4.62	4.62	4.62	4.62	4.62	4.62	4.62	4.62	4.62
CANYON DIABLO 10,000 ONLY	4.62	4.62	4.62	4.62	4.62	4.62	4.62	4.62	4.62	4.62	4.62

Lower Chevelon Canyon Flow - MP1/2 (cubic feet per second)

Alternative	2000	2010	2020	2030	2040	2050	2060	2070	2080	2090	2100
CANYON DIABLO 6,000 ONLY	4.04	4.04	4.04	4.04	4.04	4.04	4.04	4.03	4.03	4.02	4.02
CANYON DIABLO 10,000 ONLY	4.04	4.04	4.04	4.04	4.04	4.04	4.03	4.03	4.02	4.00	3.99

Lower Chevelon Canyon Flow - MP3 (cubic feet per second)

Alternative	2000	2010	2020	2030	2040	2050	2060	2070	2080	2090	2100
CANYON DIABLO 6,000 ONLY	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.00
CANYON DIABLO 10,000 ONLY	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.00	1.00	1.00

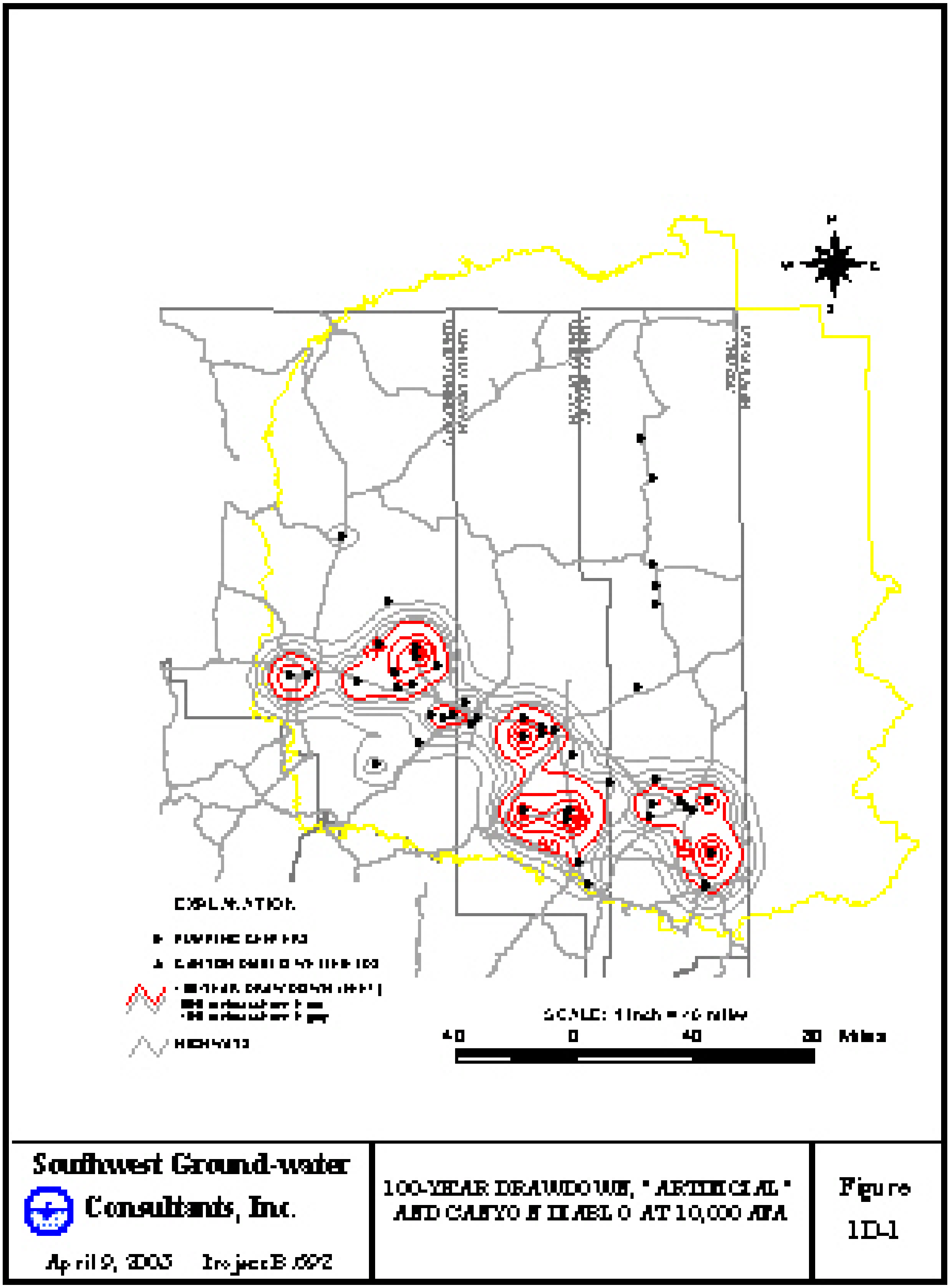


Figure A-8.–Canyon Diablo Alternative drawdown contour map – 10,000 af/yr.

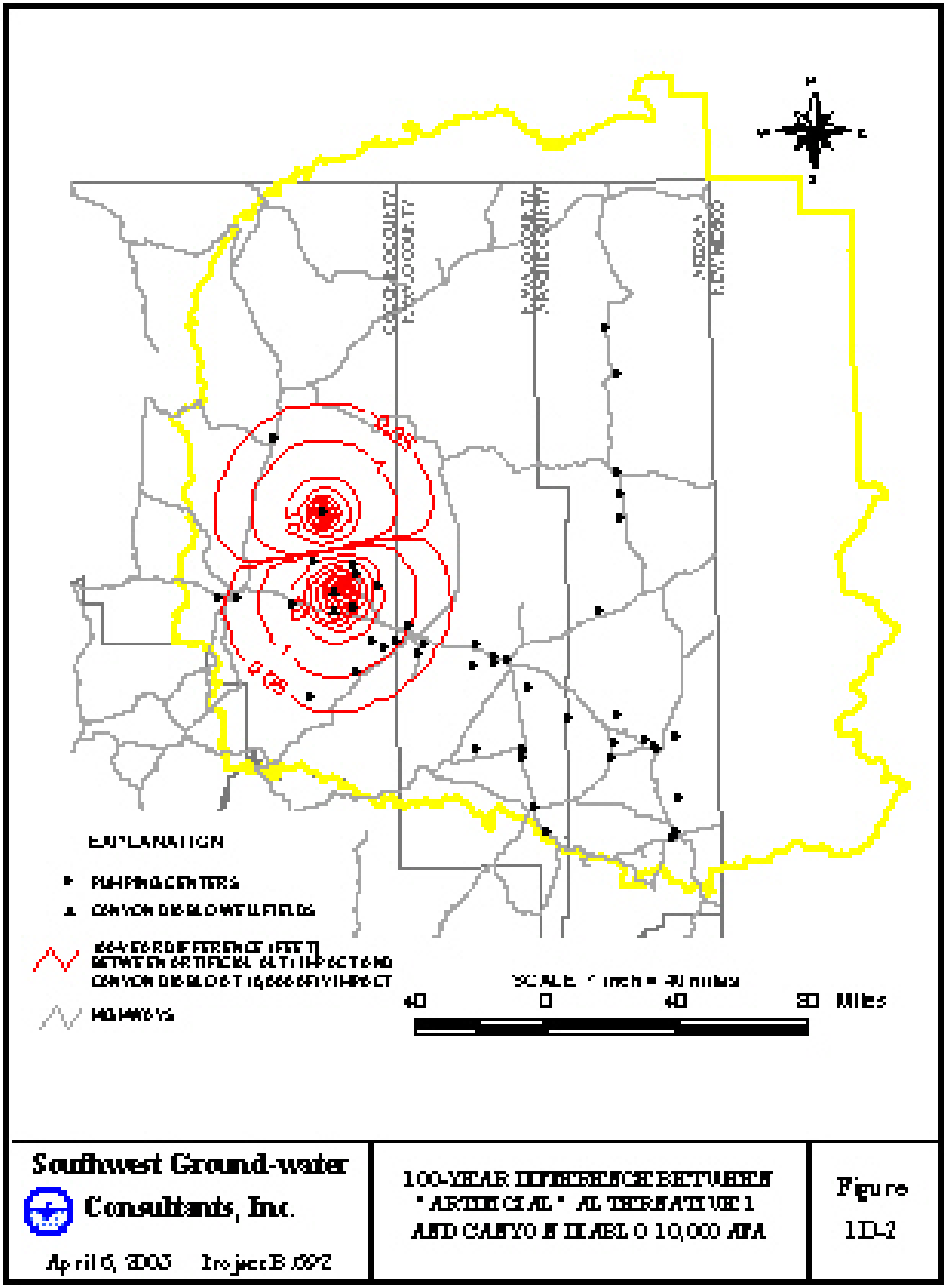


Figure A-9.—Canyon Diablo Alternative difference contour map – 10,000 af/yr.

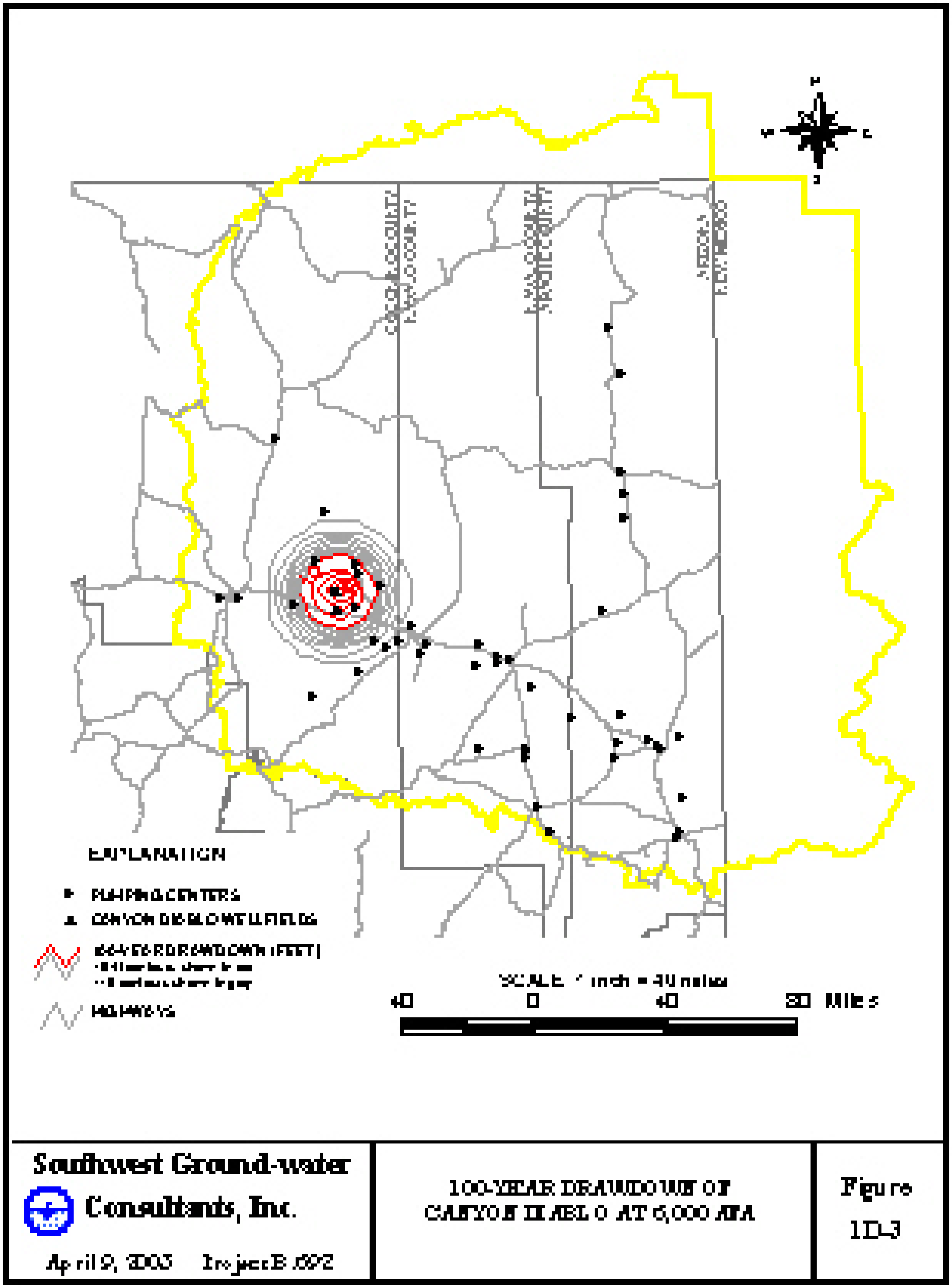


Figure A-10.–Canyon Diablo Alternative drawdown contour map – 6,000 af/yr.

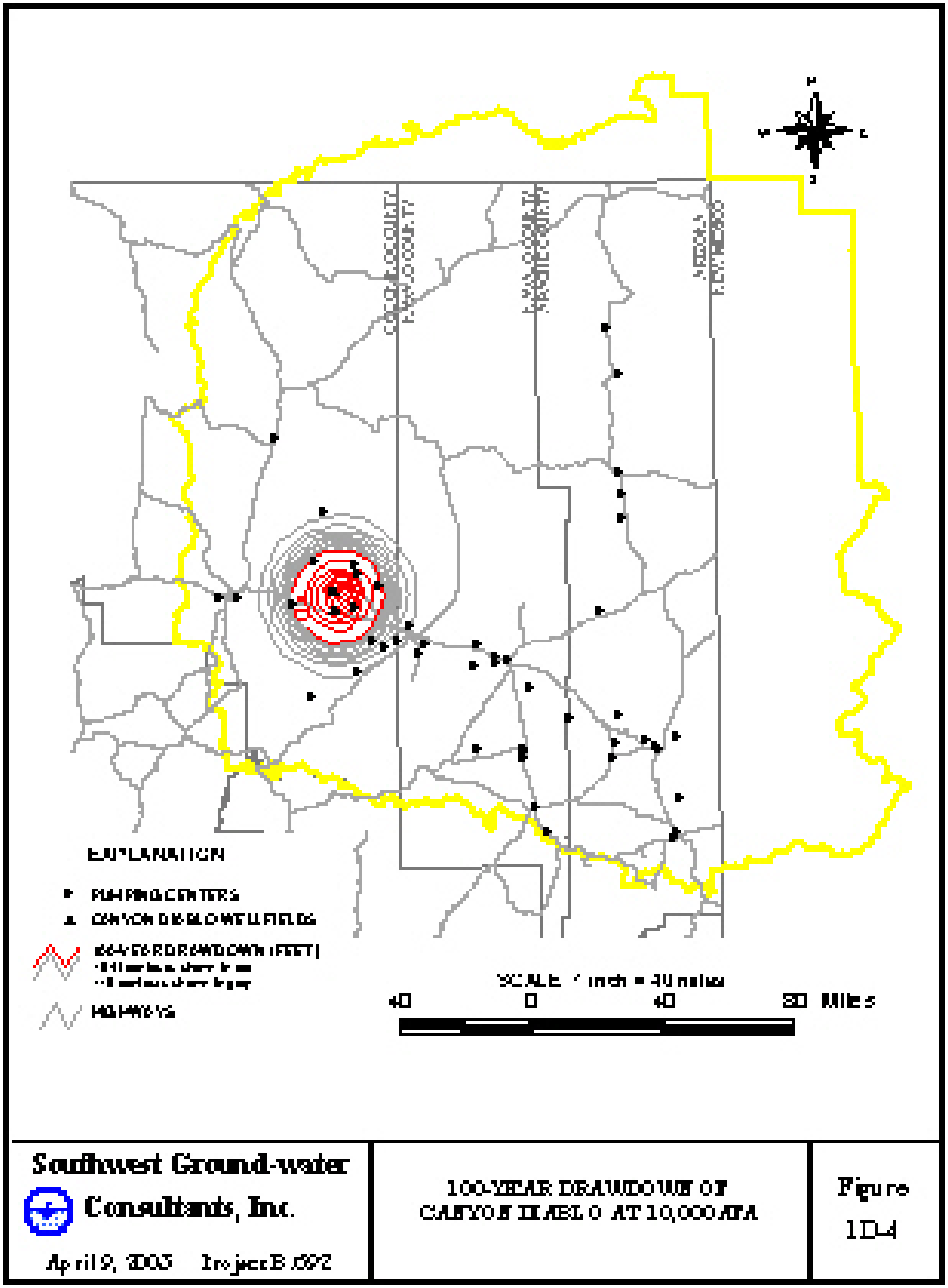


Figure A-11.–Canyon Diablo Alternative Drawdown Contour Map – 10,000 af/yr.

Canyon Diablo Alternative Wellfield – Best Guess Demand Pumping Scenario

This alternative wellfield location (see figureA-1) was selected cooperatively between Reclamation and SGC based on results from the Canyon Diablo Alternative using the total demand scenario (projected demands from all entities including those demand centers who probably will never pump the volumes of water as projected in table A-1. Wellfield location and wellfield layout remain unchanged from the Task 1D Canyon Diablo wellfield with the exception of several pumping center demand areas which have been removed from consideration. These centers and a total pumpage of 999,080 af/yr to be removed from this scenario are:

- ✓ Navajo Powerplant #2 demand (0.0 af/yr under the mid-range demand)
- ✓ Leupp Irrigation east and west agricultural demand (151,380 af total 2040 – 2100)
- ✓ Hopi Ranches – Clear Creek and Aja agricultural demand (not M&I which is retained) (187,700 af total between 2020 and 2100)
- ✓ Future Mining – Ward Terrace (660,000 af total 2000 – 2100)

As pointed out before, Reclamation determined that this wellfield should be situated completely off the Red Gap Ranch but with a portion (three wells) within the Canyon Diablo parcel, below the railroad tracks, and the remaining 10 wells on the Navajo Nation. (see figure A-1).

This section documents the demand assumptions and modeling results from this latest Phase 2 Canyon Diablo wellfield iteration reflecting the so-called Best Guess demand picture.

Another pumping center demand table is not included here. The table A-1 mid-range figures apply except that the demands for the four entities above (999,080 af/yr) should be backed out for the complete 100-year period in the mid-range demand rows.

Canyon Diablo Alternative (Best Guess) Modeling Results

The following statements and conclusions are based on the mid-range pumping demand data results for this Phase 2 Canyon Diablo alternative e-mailed to Reclamation by SGC on April 11, 2003.

Streamflow.─Table A-11 shows that the Canyon Diablo wellfield, under either 6,000 af/yr or 10,000 af/yr, plus the other "Best Guess" demand pumping, has negligible impact to the Upper Clear Creek measurement point. It is identical in magnitude to the I-40 wellfield scenario.

Beginning in 2030, this Canyon Diablo scenario shows that complete dewatering doesn't happen until year 2100 for the Canyon Diablo where complete dewatering began for the 2090 decade in the I-40 wellfield (for both 6,000 and 10,000 af/yr pumping regimes.

Nontheless, the Lower Chevelon Creek (MP1/2) flow depletion exceeds 10 percent of the base 4.04 cfs flow by 2020 under either 6,000/10,000 af/yr pumping from the Canyon Diablo wellfield. For the Lower Chevelon Creek flow (at MP3), either pumping rate produces nearly identical results, and nearly identical reductions as the I-40 wellfield – that the 10 percent flow reduction criteria is exceeded shortly after year 2010. There is no impacts to Blue Springs.

Pumping Lifts/Drawdown.─Table a-9 shows the mid-range lifts computed for the Canyon Diablo wellfield pumping at 6,000 af/yr and 10,000 af/yr plus all "best guess" demand center pumping. As expected the 10,000 af/yr pumping rates result in roughly several percent to 10 percent, and about 15 to 30 percent additional drawdown (increased lift) for the Canyon Diablo Navajo and Hopi wellfield portions, respectively. The lift exceeds 300 feet by 2050 in the 10,000 af/yr pumping at the canyon Diablo wellfield. The lift differences in the Leupp and Hopi Ranches between the two pump regimes was nearly identical. There is no difference in the Cameron pumping lifts. Pumping power costs will increase incrementally with each 10-year period.

Drawdown. ─Table a-10 shows the mid-range drawdowns computed for the Canyon Diablo wellfield pumping at 6,000 af/yr and 10,000 af/yr plus all "best guess" demand center pumping. As expected the 10,000 af/yr pumping rates result in roughly several percent to 10 percent, and about 15 to 30 percent additional drawdown (increased drawdown) for the Canyon Diablo-Navajo and Canyon Diablo-Hopi wellfield portions, respectively. The drawdown exceeds 100 feet by 2050 in the 10,000 af/yr pumping at the Canyon Diablo-Navajo wellfield, but not until 2070 for a pump rate of 6,000 af/yr.

Cameron drawdowns remain unchanged, Leupp drawdowns increase a little from the larger pump rate, and the Hopi Ranches drawdowns at both pumping regimes change little between the Canyon Diablo and I-40 wellfield locations. The Canyon Diablo-Navajo wellfield drawdowns are very similar in magnitude to those for the I-40 wellfield although in the later years, the Canyon Diablo-Navajo drawdowns are a little greater at 6,000 af/yr. At 10,000 af/yr, the Canyon Diablo-Navajo drawdown changes increase incrementally each 10-years, compared to the I-40 wellfield.

At 2100, the Hopi portion (which has 3 wells pumping at 500 gpm) shows 67 feet less drawdown (98 feet drawdown) than the Navajo wellfield (at 165 feet drawdown) which has 10 wells. The I-40 wellfield at 10,000 af/yr, by comparison, had 178 feet of drawdown.

Figures A-12 through A-13 are drawdown contour maps for the Canyon Diablo "Best Guess" simulations showing the 100-year drawdown contour distributions under 6,000 af/yr and 10,000 af/yr. The drawdown cone of depression distribution is similar to that of figure A- 4 – the I-40 run of 6,000 af/yr for the C-aquifer east of Winslow. The 50-foot contour from figure A-12 for the Leupp and Canyon Diablo wellfields does not coalesce with the Winslow M&I area 50-foot cone of depression, and the spatial extent is not as pronounced as for the I-40 simulation (figure A-4). Approximately 50 feet of drawdown (the Alternative 1 baseline as shown in figure A-9 by 2100 had about 30 to 40 feet of C-aquifer drawdown) is estimated below Lower Chevelon Canyon points MP1/2 and MP3 for this Canyon Diablo alternative). Only several feet of drawdown change occurs below the Upper East Clear Creek measurement point.

Canyon Diablo Alternative (Phase 2) - Foreseeable Demand Scenario Wellfield Conclusions

Creek flow impacts were estimated from the Canyon Diablo wellfield scenario plus the "best guess" demands (Table A-10). About 999,080 af/yr total cumulative pumping demand was removed from the Canyon Diablo Phase 2 scenario. The Leupp irrigation pumping removal was 151,380 af/yr from the modeling. The Hopi Ranch Clear Creek mid-range demand was 187,700 af/yr.

The Canyon Diablo wellfield, either the 6,000 af/yr or 10,000 af/yr pumping scenario, plus the other "Best Guess" demand pumping, has negligible impact to the Upper Clear Creek measurement point, similar to the I-40 wellfield scenario. There is no Blue Springs impact under the Canyon Diablo wellfield.

Beginning in 2030, this Canyon Diablo scenario shows that complete dewatering does not happen until year 2100 for the Canyon Diablo wellfield (complete dewatering began for the 2090 decade in the I-40 wellfield for both 6,000 and 10,000 af/yr pumping regimes).

The Lower Chevelon Creek (MP1/2) flow depletion exceeds 10 percent of the base 4.04 cfs flow by 2020 under either 6,000/10,000 af/yr pumping from the Canyon Diablo wellfield. For the Lower Chevelon Creek flow (at MP3), either pumping rate produces nearly identical results, and nearly identical reductions as the I-40 wellfield – that the 10 percent flow reduction criteria is exceeded shortly after year 2010.

Drawdown effects, distribution, and magnitudes are similar to the I-40 Wellfield (especially east of Winslow) although in general the Canyon Diablo pumping results in slightly more C-aquifer drawdown than for the I-40 alternative in the Leupp M&I and Navajo Powerplant #1 demand centers (total drawdown of 200 feet). However, in the Hopi Ranches areas the I-40 simulations paint a slightly more dismal picture with higher drawdown over most 10-year timesteps.

Drawdowns below Lower Chevelon Creek and Upper East Clear Creek are similar to those of the I-40 wellfield (which were 30 to 40 feet) at about 50 feet (figures A-12 and A-13). The Canyon Diablo alternative shows virtually identical drawdown distribution whether 6,000 or 10,000 af/yr is pumped through to 2100.

Table A-9.—Aquifer Mid-Range Demand Pumping Lifts for the Canyon Diablo Alternative Wellfield, Best Guess Demands

CANYON DIABLO 6,000 AFA AND 10,000 AFA AND CANYON DIABLO 10,000 AFA PLUS MAXIMUM DEMANDS

Canyon Diablo Wellfield Demand = 6,000 af/yr plus "Best Guess" Wellfields											
YEAR		LIFT (ft)									
		2010	2020	2030	2040	2050	2060	2070	2080	2090	2100
M&I Demand Center	Depth to SWL (ft)										
Cameron	500	503	505	507	509	512	516	520	525	531	539
Leupp	120	147	193	222	246	268	289	309	330	353	380
Hopi Ranches-Aja	150	150	151	157	164	170	174	178	182	185	189
Hopi Ranches-Clear Creek	150	153	156	170	180	187	192	197	201	206	211
Canyon Diablo Navajo Wellfield	200	230	261	266	277	287	297	307	316	326	335
Canyon Diablo Hopi Wellfield	200	201	231	211	216	221	227	233	239	245	252

Canyon Diablo Wellfield Demand = 10,000 af/yr plus "Best Guess"											
YEAR		LIFT (ft)									
		2010	2020	2030	2040	2050	2060	2070	2080	2090	2100
M&I Demand Center	Depth to SWL (ft)										
Cameron	500	500	505	507	509	512	516	520	525	531	539
Leupp	120	148	194	224	249	273	296	318	340	365	393
Hopi Ranches-Aja	150	150	151	157	164	170	174	178	182	185	189
Hopi Ranches-Clear Creek	150	153	156	170	180	188	193	198	202	207	213
Canyon Diablo Navajo Wellfield	200	237	261	279	293	306	319	331	342	354	365
Canyon Diablo Hopi Wellfield	200	214	231	241	249	258	266	274	282	290	298

Table A-10.—C-Aquifer Mid-Range Demand Drawdowns for the Canyon Diablo Alternative Wellfield, Foreseeable Demands

CANYON DIABLO 6,000 AFA AND 10,000 AFA AND CANYON DIABLO 10,000 AFA PLUS "BEST GUESS" DEMANDS

Canyon Diablo Wellfield Demand = 6,000 af/yr plus "Best Guess" Wellfields											
		Drawdown (s) (ft)									
YEAR		2010	2020	2030	2040	2050	2060	2070	2080	2090	2100
M&I Demand Center	Depth to SWL (ft)										
Cameron	500	3	5	7	9	12	16	20	25	31	39
Leupp	120	27	73	102	126	148	169	189	210	233	260
Hopi Ranches-Aja	150	0	1	7	14	20	24	28	32	35	39
Hopi Ranches-Clear Creek	150	3	6	20	30	37	42	47	51	56	61
Canyon Diablo Navajo Wellfield	200	30	53	66	77	87	97	107	116	126	135
Canyon Diablo Hopi Wellfield	200	1	5	11	16	21	27	33	39	45	52

Canyon Diablo Wellfield Demand = 10,000 af/yr plus "Best Guess"											
		Drawdown (s) (ft)									
YEAR		2010	2020	2030	2040	2050	2060	2070	2080	2090	2100
M&I Demand Center	Depth to SWL (ft)										
Cameron	500	3	5	7	9	12	16	20	25	31	39
Leupp	120	28	74	104	129	153	176	198	220	245	273
Hopi Ranches-Aja	150	0	1	7	14	20	24	28	32	35	39
Hopi Ranches-Clear Creek	150	3	6	20	30	38	43	48	52	57	63
Canyon Diablo Navajo Wellfield	200	37	61	79	93	106	119	131	142	154	165
Canyon Diablo Hopi Wellfield	200	14	31	41	49	58	66	74	82	90	98

Table A-11.— (Phase 2) Impacts to Creek Flows from Canyon Diablo Alternative Wellfield Under "Foreseeable" Demand Scenarios

Upper East Clear Creek Flow (cubic feet per second)

Best Guess Alternative	Demand Scenario	2000	2010	2020	2030	2040	2050	2060	2070	2080	2090	2100
CD 6000	Mid Range	4.62	4.62	4.61	4.60	4.59	4.57	4.56	4.55	4.53	4.52	4.51
CD 10000	Mid Range	4.62	4.62	4.61	4.60	4.59	4.57	4.56	4.55	4.53	4.52	4.51

Lower Chevelon Canyon Flow - MP1/2 (cubic feet per second)

Best Guess Alternative	Demand Scenario	2000	2010	2020	2030	2040	2050	2060	2070	2080	2090	2100
CD 6000	Mid Range	4.04	3.60	2.90	2.22	1.58	1.07	0.77	0.52	0.28	0.07	0.00
CD 10000	Mid Range	4.04	3.60	2.90	2.22	1.58	1.06	0.77	0.52	0.28	0.06	0.00

Lower Chevelon Canyon Flow - MP3 (cubic feet per second)

Best Guess Alternative	Demand Scenario	2000	2010	2020	2030	2040	2050	2060	2070	2080	2090	2100
CD 6000	Mid Range	1.01	0.91	0.69	0.47	0.25	0.07	0.00	0.00	0.00	0.00	0.00
CD 10000	Mid Range	1.01	0.91	0.69	0.47	0.25	0.07	0.00	0.00	0.00	0.00	0.00

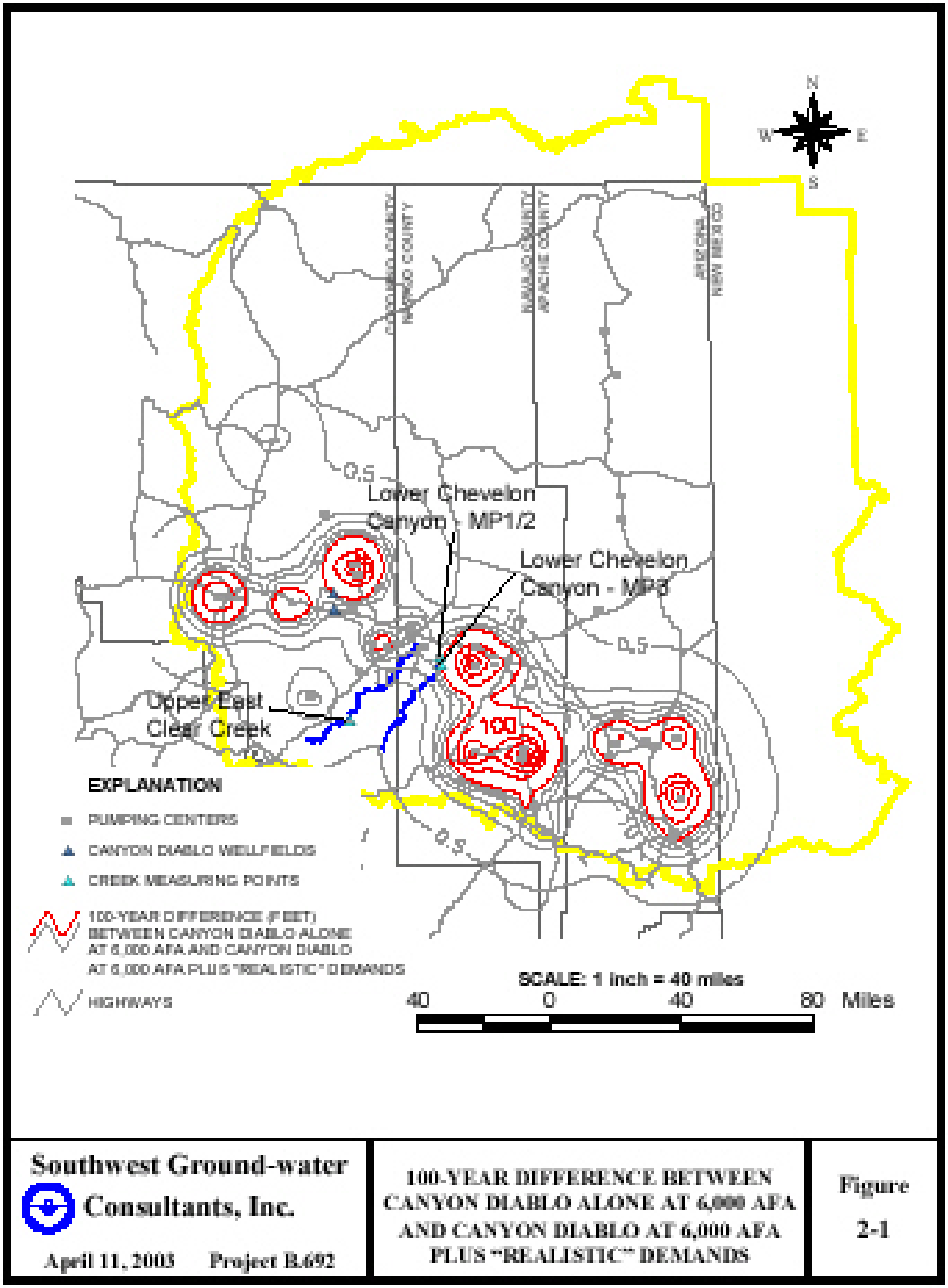


Figure A-12.–Canyon Diablo Alternative drawdown contour map – 6,000 af/yr.

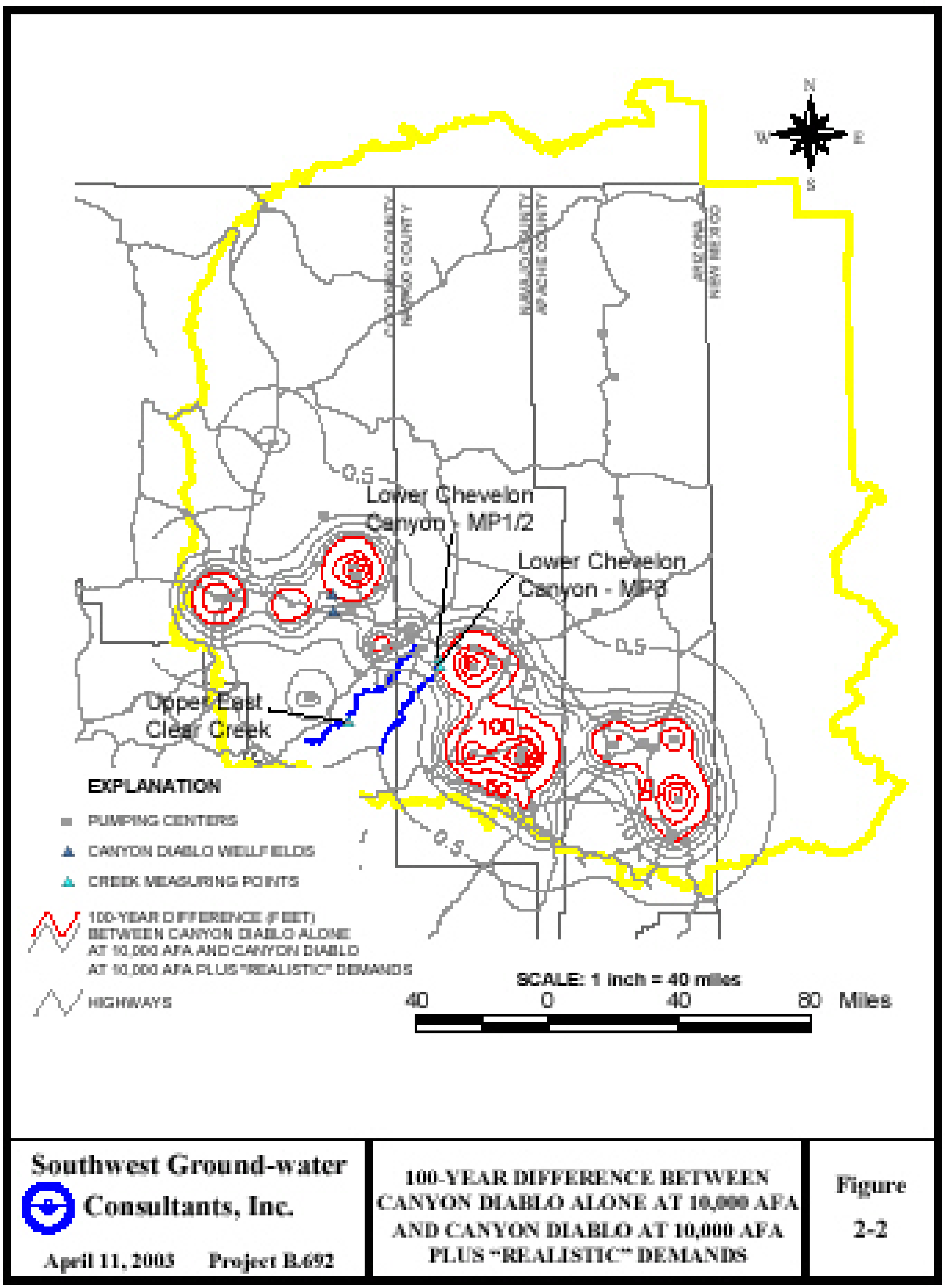


Figure A-13.–Canyon Diablo Alternative drawdown contour map – 6,000 af/yr.

Wellfield Characteristics and Cost Summary

The current Canyon Diablo wellfield is located as shown on figure A-3. Based on an identified Peabody Western Coal Company demand of 6,000 af/yr, and 2,000 af/yr each of Navajo and Hopi M&I demand, the conceptual wellfield layout is illustrated on figure A-1. The Canyon Diablo wellfield consists of 13 wells, three on the Canyon Diablo parcel to supply their 2,000 af/yr demands and 10 wells on the Navajo Nation to supply the 2,000 af/yr Navajo M&I demand, and for the Peabody Coal demand of 6,000 af/yr. All wells would target the regional C-Aquifer, specifically the Coconino Sandstone.

From existing well database and other information, and as used in the Hopi-Western Navajo Water Supply Study modeling work (analytical and numerical models) and for the purposes of this study, each well is assumed to pump continuously yielding 500 gpm (807 af/yr) from year 2000 through 2100. This yields an annual total of 6,500 gpm or 10, 485 af/yr. Thus three Hopi wells would provide theoretical yields of 1,500 gpm or 2,420 af/yr to satisfy their anticipated needs, three wells would pump 2,420 af/yr to satisfy the Navajo demand, and the remaining seven wells would pump 3,500 gpm or 5,646 af/yr to essentially meet Peabody Coal's needs.

In reality, the wells would be drilled and completed in a phased approach as demands ramped up through time. The Peabody Coal life-of-mine ends about year 2030 at which time that demand would be absorbed by one or both tribes or other tribal or non-tribal interests. The water supply system is being developed for an average annual peaking demand factor of 2. Water pumped from the Hopi wells, and wells further northeastwards will flow by gravity in a pipeline to the storage facilities near Leupp.

Hydrogeologic Characteristics

The C-aquifer (primarily the eolian Coconino Sandstone) has quartz sand grains generally well lithified (bound together or indurated) and is considered a fractured rock aquifer. Much less groundwater moves through the matrix (sand grains) as it does via fracture flow. So, wells with their drawdown zones of influence in proximity to water bearing fractures will be much better producers, other factors being equal. The Coconino Sandstone (C-aquifer) in the wellfield area has a gentle regional dip towards the Black Mesa basin. For appraisal purposes, the top and bottom stratigraphic formational contact for the C-aquifer are 4950 and 4150 feet above mean sea level (MSL) for an average thickness of 800 feet. These numbers are taken from the I-40 wellfield modeling work.

The three Hopi wells would be drilled from about ground surface elevation 5400. For the remaining 10 wells, the ground surface elevation is fairly flat at about 5400 at the Canyon Diablo and Navajo Nation boundary, then it drops to about 5200 feet as one goes northeast.

The I-40 and Canyon Diablo Hopi wellfield portions are located (spatially) roughly along the strike of the Coconino Sandstone; therefore, the Canyon Diablo Hopi wellfield is assumed to have a similar depth to water and depth to base of aquifer. Although the top and bottom contact elevations of the C-aquifer (along the Navajo/Peabody well alignment) will probably get increasingly deeper, the ground surface elevations also decrease in that direction so depth of wells are assumed to remain fairly constant.

Assuming confined to semi-confined C-aquifer conditions and fully penetrating wells, the Hopi wells should be about 1250 feet deep, and the Navajo and Peabody wells will range from about 1150 to 1050 feet deep towards the northeast. To keep things simple, the well depths are normalized to 800-foot depth, the depth used for the analytical and numerical modeling simulations, and the depth to static water level assumed to be 200 feet (or about elevation 4800).

Twelve-inch diameter wells would be the minimum size necessary to yield 500 gpm. The well casing string will consist of about 300-feet of well screen and 500-feet of blank well casing. A 50 to 75-hp submersible pump is expected using a TDH of 350 feet. Power requirements and O&M costs are not considered here. The field cost estimate for 13 wells is about $3.1 million or $235,000 per well.

Table A-12.— Cost Estimate for 13 Water Production Wells in the C-Aquifer

Item No.	Description of work	Estimated quantity	Unit	Unit cost/ lump sum ($)	Total cost ($)
1.	Mobilization/demobilization	13 wells	each	$8,000	$104,000
2.	Drill, furnish, install, and cement 20-inch surface casing	40 ft x 13 wells = 520 ft	ft	$200/ft	$104,000
3.	Drill 8-inch pilot hole, ream to 17-1/4-inch hole air or mud rotary	13 wells x 800 ft = 10,400 ft	ft	$85/ft	$884,000
4.	Standby	16	hr	$250	$4,000
5.	Furnish, install 300-foot, 12-inch well screen	13 wells x 300 ft = 3,900 ft	ft	$160/ft	$624,000
6.	Furnish, install 500-foot, 12-inch blank well casing	13 wells x 500 ft = 6,500 ft	ft	$65/ft	$422,500
7.	Furnish, install 350-foot, (5 cy[4]) gravel pack	13 wells x 5 cy = 65 cy (227,500 lbs)	ton	$500/ton	$56,875
8.	Furnish and install 450-feet of cement to ground surface	13 wells x 450 ft = 5,850 ft	ft	$25 /ft	$146,250
9.	Swab/air lift well to develop	13 wells x 8 hrs = 104 hrs	hr	$250/hr	$26,000
10.	Furnish,and install pump and 4-inch drop pipe, misc. meter, pump test	13 wells x 8 hrs = 104 hrs	hr	400/hr	$41,600
11.	Geophysical well scan	13	ea	$2,500	$32,500
12.	Disinfection	13	ea	$3,000	$39,000
13.	Furnish and install 50-100 hp submersible pump (avg 65 hp)	13	ea	$15,000	$195,000
					$2,700,000

Criteria for Wellfield Site Selection

Criteria include several important factors which taken collectively will dictate the best or optimum wellfield site. These factors are:

1.) Depth to C-aquifer from ground surface and depth to water. This greatly affects the drilling method used and costs to drill the hole and complete the well. It also has a bearing on pump selection and pumping costs, and the long-term OM&R.

2.) The existing network (density) of municipal and domestic wells tapping the C-aquifer adjacent to the proposed wellfield sites. A given wellfield may unacceptably overdraft the aquifer or change flow directions due to the many existing wells already pumping, leading to legalities.

3.) Average specific yield and current yields of existing C-aquifer wells.

4.) Excavation characteristics for the delivery pipeline(s) required from each proposed wellfield towards the existing Peabody slurry pipeline. One particular wellfield site may require much more rock excavation than another to link to the existing slurry line.

5.) Water Quality Considerations. One wellfield site may have better groundwater quality than another. Quality at one site might suffice for the slurry line but not for potable use.

6.) Proximity to available electrical power/powerline corridors.

7.) Degree of Bedrock faulting. Faulting fractures the bedrock and depending on its strength, usually increases the secondary permeability and thus improves yields to wells and springs. Fractures normally control the volume and flow direction of groundwater in bedrock aquifers, including the Coconino Sandstone.

8.) Hydrologic impacts (e.g., baseflow/subflow impacts) due to pumping the C-aquifer on hydraulically connected surface water bodies. Additional C-aquifer pumping could cause additional depletion from the LCR by leakage, or direct streamflow depletion from tributaries such as Chevelon creek.

Appendix B

Hydraulic Calculations

Table B-1.—

PEABODY COAL MINE - 6000 AF (V1) **6 Pumps**

OPERATING COSTS		**TOTAL Q =**		9.95	CFS	**COVER =**	3.00		
Site		Gravity 1	LEUPP PP	RED LAKE PP	SAND SPRINGS PP	HOTEL VILLA PP	BLACK MESA PP	SHEEP VALLEY PP	Gravity 2
MP		0	18.50	28.63	54.38	64.60	95.98	106.08	114.48
Pipe dia. (in)		20	24	30	24	30	24	24	20
PVC PIPE		STEEL	STEEL	STEEL	STEEL	STEEL	STEEL	STEEL	STEEL
Q(CFS)		9.95	9.95	9.95	9.95	9.95	9.95	9.95	9.95
Velocity		4.6	3.2	2.0	3.2	2.0	3.2	3.2	4.6
Total Length (ft)		97680	53486	135960	53961	165686	53328	44352	44035
Friction Loss	140	286.57	64.57	55.37	65.15	67.48	64.38	53.55	129.19
Begin El		5080	4695	5052	5440	5823	6151	6445	6739
End El.		4695	5052	5440	5823	6151	6445	6753	6617
Static Head (ft)		385	357	388	383	328	294	308	-122
Begin HGL		4982	4705	5495	5888	6218	6509	6807	6753
End HGL		4705	5052	5440	5823	6151	6445	6753	6624
Pump Lift		0	422	443	448	395	358	362	0
HP		0	595	626	632	558	506	510	0
KWH		0	444	467	472	416	377	381	0
KW-hr/yr		0	3,887,511	4,088,504	4,132,556	3,646,854	3,304,802	3,333,972	
Friction/Static		0%	18%	14%	17%	21%	22%	17%	0%
Maximum Head	feet	385	548	576	583	514	466	470	122
(Includes 30% Upsurge)	psi	167	237	250	252	223	202	203	53
Maximum Thickness	in	0.07	0.16	0.20	0.17	0.18	0.13	0.13	0.08
Average Thickness	in	0.07	0.10	0.13	0.10	0.12	0.10	0.10	0.08
Pipe Excavation	cy	94843	58917	90420	27483	110190	27161	22589	18309
Pipe Backfill	cy	91237	56228	80338	24770	97903	24480	20359	16683
Pipe CBF	cy	16796	10906	34475	11003	42013	10874	9044	7572
Excavation type		Common	Common	Common	Rock	Rock	Common	Common	Rock
		$7.50	$7.50	$7.50	$20.00	$20.00	$7.50	$7.50	$20.00

PEABODY COAL MINE - 6000 AF (V1)		6 Pumps								
CONSTRUCTION COSTS										
Pumping Plant Cost			$0	$980,000	$980,000	$980,000	$980,000	$800,000	$800,000	$0
Air Chamber Cost			$0	$100,000	$100,000	$100,000	$100,000	$100,000	$100,000	$0
Power Line Costs			$0	$400,000	$1,480,000	$1,500,000	$2,100,000	$1,800,000	$1,000,000	$0
Pipe Cost	$1.50		$2,463,486	$2,068,500	$8,765,466	$2,254,644	$10,223,751	$2,049,911	$1,710,100	$1,189,655
Pipe Excavation	$20.00		$711,323	$441,875	$678,153	$549,659	$2,203,796	$203,704	$169,417	$366,170
Pipe Backfill	$3.25		$296,521	$182,741	$261,099	$80,504	$318,185	$79,560	$66,168	$54,220
Pipe CBF	$15.00		$251,944	$163,589	$517,132	$371,557	$630,196	$163,106	$135,653	$113,578
Storage Tank Costs			$300,000	$55,000	$55,000	$55,000	$55,000	$55,000	$55,000	$300,000
Total Construction Costs			$4,023,275	$4,391,705	$12,836,850	$5,891,364	$16,610,928	$5,251,280	$4,036,338	$2,023,624
ANNUAL COSTS										
Energy Charge	0.0650			$252,688	$265,753	$268,616	$237,045	$214,812	$216,708	
Energy Charge	0.0550			$213,813	$224,868	$227,291	$200,577	$181,764	$183,368	
Cost of Power ($/yr)				$252,688	$252,688	$252,688	$252,688	$252,688	$252,688	
Annual Cost of Pump Sta. over 20 yrs. @ 6%(.0871)($)				$85,358	$85,358	$85,358	$85,358	$69,680	$69,680	
Total annual cost of pumping ($/yr)				$338,046	$338,046	$338,046	$338,046	$322,368	$322,368	
Annual cost of pipeline over 40 yrs @ 6%(.0664)($)			$163,575	$137,348	$582,027	$149,708	$678,857	$136,114	$113,551	$78,993
Total annual costs ($)				$475,395	$920,073	$487,755	$1,016,903	$458,482	$435,919	

PEABODY COAL MINE - 10000 AF (V2)		6 Pumps								
OPERATING COSTS		TOTAL Q =		21.00	CFS	COVER =	3.00			
Site		Gravity 1	LEUPP PP	RED LAKE PP	SAND SPRINGS PP	HOTEL VILLA PP	BLACK MESA PP	SHEEP VALLEY PP	Gravity 2	Mine
MP		0	18.50	28.63	54.38	64.60	95.98	106.08	114.48	122.82
Pipe dia. (in)		26	27	33	27	30	24	24	20	
PVC PIPE		DR41		STEEL	STEEL	STEEL	STEEL	STEEL	DR51	
Q(CFS)		21.00	15.48	15.48	15.48	9.95	9.95	9.95	9.95	
Velocity		5.7	3.9	2.6	3.9	2.0	3.2	3.2	4.6	
Total Length (ft)		97680	53486	135960	53961	165686	53328	44352	44035	
Friction Loss	140	318.50	82.50	78.92	83.23	67.48	64.38	53.55	129.19	
Begin El		5080	4695	5052	5440	5823	6151	6445	6739	
End El.		4695	5052	5440	5823	6151	6445	6753	6617	
Static Head (ft)		385	357	388	383	328	294	308	-122	
Begin HGL		5014	4705	5519	5906	6218	6509	6807	6753	
End HGL		4705	5056	5440	5823	6151	6445	6753	6624	
Pump Lift		0	439	467	466	395	358	362	0	
HP		0	965	1025	1024	558	506	510	0	
KWH		0	720	765	764	416	377	381	0	
KW-hr/yr		0	6,305,224	6,698,650	6,688,743	3,646,854	3,304,802	3,333,972		
Friction/Static		0%	23%	20%	22%	21%	22%	17%	0%	
Maximum Head	feet	385	571	607	606	514	466	470	122	
(Includes 30% Upsurge)	psi	167	247	263	262	223	202	203	53	
Maximum Thickness	in	0.09	0.18	0.24	0.19	0.18	0.13	0.13	0.08	
Average Thickness	in	0.09	0.12	0.14	0.12	0.12	0.10	0.10	0.08	Hand Calculation
Pipe Excavation	cy	114277	64443	193800	65016	217517	58743	48855	42756	
Pipe Backfill	cy	108639	61147	181858	61690	205231	56062	46626	41131	
Pipe CBF	cy	21512	12220	37958	12329	42013	10874	9044	7572	
Excavation type		Common	Common	Common	Rock	Rock	Common	Common	Rock	
		$7.50	$7.50	$7.50	$20.00	$20.00	$7.50	$7.50	$20.00	

PEABODY COAL MINE - 10000 AF (V2) – 6 PUMPS

CONSTRUCTION COSTS										
Pumping Plant Cost		$0	$980,000	$980,000	$1,000,000	$1,000,000	$800,000	$800,000	$0	
Air Chamber Cost		$0	$100,000	$100,000	$100,000	$100,000	$100,000	$100,000		
Power Line Costs		$0	$400,000	$1,480,000	$1,500,000	$2,100,000	$200,000	$1,000,000	$0	
Pipe Cost	$1.50	$3,815,221	$2,793,721	$10,214,782	$2,886,252	$9,576,981	$2,049,911	$1,710,100	$1,189,655	$34,236,622
Pipe Excavation	$20.00	$857,074	$483,326	$1,453,503	$1,300,316	$4,350,350	$440,569	$366,414	$855,122	
Pipe Backfill	$3.25	$353,076	$198,728	$591,039	$200,493	$667,000	$182,201	$151,534	$133,674	
Pipe CBF	$15.00	$322,676	$183,304	$569,375	$925,350	$630,196	$163,106	$135,653	$113,578	
Storage Tank Costs		$300,000	$55,000	$55,000	$55,000	$55,000	$55,000	$55,000	$300,000	
Total Construction Costs		$5,648,048	$5,194,078	$15,443,699	$7,967,411	$18,479,527	$3,990,787	$4,318,700	$2,592,030	

ANNUAL COSTS								
Energy Charge	0.0650	$0	$409,840	$435,412	$434,768	$237,045	$214,812	$216,708
Cost of Power ($/yr)	0.0550	$0	$346,787	$368,426	$367,881	$200,577	$181,764	$183,368
Annual Cost of Pump Sta. over 20 yrs. @ 6%(.0871)($)		$0	$85,358	$85,358	$87,100	$87,100	$69,680	$69,680
Total annual cost of pumping ($/yr)		$0	$85,358	$85,358	$87,100	$87,100	$69,680	$69,680
Annual cost of pipeline over 40 yrs @ 6%(.0664)($)		$253,331	$185,503	$678,262	$191,647	$635,912	$136,114	$113,551
Total annual costs ($)		$253,331	$270,861	$763,620	$278,747	$723,012	$205,794	$183,231

PEABODY COAL MINE - 10000 AF (V2) – 6 PUMPS

SUBLATERALS

	LEUPP / DILKON LATERAL				3 - MESAS					
	Gravity A								Shungpovi	
Site	Leupp (MP 0)	Relift 1 (MP 0)	Relift 2 (MP 17.2)	Relift 3 (MP29.5)	Gravity	Bacovi TO	Gravity (MP 8.2)	Relift 1 (MP 11.50)	Gravity (MP 16.6)	Sh
MP	END MP 1.08	END MP 17.2	END MP 29.5	END MP 38.8	MP 8.2		MP 11.50	MP 16.6	MP 17	
Pipe dia. (in)	20	18	18	18	20	16	18	18	18	
PVC PIPE										
Q(CFS)	5.53	3.871	3.871	3.871	5.53	2.34	3.19	3.19	3.19	
Velocity	2.5	2.2	2.2	2.2	2.53	1.68	1.81	1.81	1.81	
Total Length (ft)	5703	90816	64944	49104	43296	32736	17424	26928	10560	
Friction Loss	5.64	77.47	55.40	41.89	42.8	19.5	10.4	16.1	6.3	
Begin El	4695	4701	5062	5490	5823	5647	5647	5750	6340	
End El.	4701	5062	5490	5885	5647	6366	5750	6340	6003	
Static Head (ft)	6	361	428	395	-176	719	-103	590	-337	
Begin HGL	4705	5062	5490	5885	5823	6386	5780	6356	6340	
End HGL	4699.36	5062	5490	5885	5780	6366	5770	6340	6334	
Pump Lift		438.47	483.40	436.89		739		606		
HP		241	265	240		245		274		
KWH		180	198	179		183		205		
KW-hr/yr		1,573,019	1,734,212	1,567,349		1,601,571		1,791,741		
Friction/Static		21%	13%	11%		3%		3%		
Maximum Head	2	570	628	568	133	960	133	788	337	
(Includes 30% Upsurge)	1	247	272	246	58	416	58	341	146	
Maximum Thickness	0.00	0.12	0.13	0.12	0.03	0.18	0.03	0.17	0.07	
Average Thickness	0.06	0.09	0.10	0.09	0.07	0.11	0.07	0.10	0.08	
Pipe Excavation	5537	82530	59018	44624	42039	27780	15834	24471	9596	
Pipe Backfill	5327	79713	57004	43101	37103	26588	14152	23636	9527	
Pipe CBF	920	14197	10152	7676	6983	4750	2528	4210	1878	
Excavation type										

PEABODY COAL MINE - 10000 AF (V2) – 6 PUMPS

SUBLATERALS

CONSTRUCTION COSTS									
Pumping Plant Cost	$980,000	$980,000	$980,000	$980,000	$0	$980,000	$0	$980,000	$0
Air Chamber Cost	$100,000	$100,000	$100,000	$100,000	$0	$100,000	$0	$100,000	$0
Power Line Costs	$400,000	$400,000	$400,000	$400,000	$0	$400,000	$0	$400,000	$0
Pipe Cost	$120,553	$2,580,239	$1,907,238	$1,393,479	$1,029,261	$968,719	$370,689	$861,101	$259,801
Pipe Excavation	$0	$0	$0	$0	$0	$0	$0	$0	$0
Pipe Backfill	$17,312	$259,069	$185,264	$140,078	$120,585	$86,412	$45,994	$76,817	$30,962
Pipe CBF	$13,798	$212,951	$152,285	$115,142	$104,751	$71,243	$37,920	$63,143	$28,166
Storage Tank Costs	$55,000	$55,000	$55,000	$55,000	$55,000	$55,000	$55,000	$55,000	$55,000
Total Construction Costs	$1,686,663	$4,587,259	$3,779,788	$3,183,699	$1,309,597	$2,661,374	$509,602	$2,536,061	$373,929
ANNUAL COSTS									
Energy Charge	$0	$102,246	$112,724	$101,878		$104,102	$0	$116,463	$0
Cost of Power ($/yr)	$0	$86,516	$95,382	$86,204		$88,086		$98,546	
Annual Cost of Pump Sta. over 20 yrs. @ 6%(.0871)($)	$85,358	$85,358	$85,358	$85,358		$85,358		$85,358	
Total annual cost of pumping ($/yr)	$85,358	$85,358	$85,358	$85,358		$85,358		$85,358	
Annual cost of pipeline over 40 yrs @ 6%(.0664)($)	$8,005	$171,328	$126,641	$92,527		$64,323	$24,614	$57,177	$17,251
Total annual costs ($)	$93,363	$256,686	$211,999	$177,885		$149,681	$24,614	$142,535	$17,251

Table B-2.—

PEABODY COAL MINE - 10336 AF (V2A)			**6 Pumps**	**Includes Jeddito**						
I-40 WELLFIELD										
OPERATING COSTS			**TOTAL Q =**	21.00	CFS	**COVER =**	3.00			
Site		Gravity 1	LEUPP PP	RED LAKE PP	SAND SPRINGS PP	HOTEL VILLA PP	BLACK MESA PP	SHEEP VALLEY PP	Gravity 2	Mine
MP		0	18.50	28.63	54.38	64.60	95.98	106.08	114.48	122.82
Pipe dia. (in)		26	27	33	27	30	24	24	20	
PIPE		STEEL	STEEL	STEEL	STEEL	STEEL	STEEL	STEEL	HDPE DR26	
Q(CFS)		21.93	16.40	16.40	16.40	9.95	9.95	9.95	9.95	
Velocity		6.0	4.1	2.8	4.1	2.0	3.2	3.2	4.6	
Total Length (ft)		97680	53486	135960	53961	165686	53328	44352	44035	
Friction Loss	140	345.12	91.81	87.82	92.62	67.48	64.38	53.55	129.19	
Begin El		5080	4695	5052	5440	5823	6151	6445	6739	
End El.		4695	5052	5440	5823	6151	6445	6753	6617	
Static Head (ft)		385	357	388	383	328	294	308	-122	
Begin HGL		5040	5144	5528	5916	6218	6509	6807	6753	
End HGL		4705	5052	5440	5823	6151	6445	6753	6624	
Pump Lift		0	449	476	476	395	358	362	0	
HP		0	1044	1107	1106	558	506	510	0	
KW		0	779	826	825	416	377	381	0	
KW-hr/yr		0	6,821,446	7,232,120	7,229,015	3,646,854	3,304,802	3,333,972		
Friction/Static		0%	26%	23%	24%	21%	22%	17%	0%	
Maximum Head	feet	385	583	619	618	514	466	470	122	
(Includes 30% Upsurge)	psi	167	253	268	268	223	202	203	53	
Maximum Thickness	in	0.09	0.19	0.24	0.20	0.18	0.13	0.13	0.08	
Average Thickness	in	0.09	0.12	0.14	0.12	0.12	0.10	0.10	0.08	Hand Calculation
Pipe Excavation	cy	109305	61680	186146	62228	208574	56111	46666	40719	
Pipe Backfill	cy	94925	53212	154405	53684	176418	49380	41069	36797	

Pipe CBF	cy	19950	11337	35277	11437	39010	10078	8382	7009
Pipe Bedding	cy	6331	3522	9791	3553	11421	3347	2783	2628
Excavation type		Common	Common	Common	Rock	Rock	Common	Common	Rock
		$7.50	$7.50	$7.50	$20.00	$20.00	$7.50	$7.50	$20.00

PEABODY COAL MINE - 10336 AF (V2A)			**6 Pumps**	**Includes Jeddito**						
CONSTRUCTION COSTS										
Pumping Plant Cost		$0	$980,000	$980,000	$1,000,000	$1,000,000	$800,000	$800,000	$0	
Air Chamber Cost		$0	$100,000	$100,000	$100,000	$100,000	$100,000	$100,000		
Power Line Costs		$0	$400,000	$1,480,000	$1,500,000	$2,100,000	$1,800,000	$1,000,000	$0	
Pipe Cost	$1.50	$3,815,221	$2,817,094	$10,299,122	$2,910,047	$9,576,981	$2,049,911	$1,710,100	$1,189,655	
Pipe Excavation	$20.00	$819,789	$462,600	$1,396,098	$1,244,557	$4,171,470	$420,831	$349,998	$814,376	
Pipe Backfill	$3.25	$308,506	$172,938	$501,815	$174,474	$573,357	$160,485	$133,473	$119,592	
Pipe CBF	$15.00	$299,251	$170,049	$529,151	$805,265	$585,157	$151,171	$125,726	$105,133	
Tank Required		Storage	Forebay	Forebay	Forebay	Forebay	Forebay	Forebay	Storage	
Storage Tank Costs		$300,000	$55,000	$55,000	$55,000	$55,000	$55,000	$55,000	$300,000	
Total Construction Costs		$5,542,766	$5,157,682	$15,341,186	$7,789,343	$18,161,965	$5,537,397	$4,274,296	$2,528,756	$64,333,392
ANNUAL COSTS										
Cost of Power ($/yr)	0.0550	$0	$375,180	$397,767	$397,596	$200,577	$181,764	$183,368	$0	$1,736,252
Annual Cost of Pump Sta. over 20 yrs. @ %(.0871)($)		$0	$85,358	$85,358	$87,100	$87,100	$69,680	$69,680	$0	
Total annual cost of pumping ($/yr)		$0	$460,538	$483,125	$484,696	$287,677	$251,444	$253,048	$0	
Annual cost of pipeline over 40 yrs @ 6%(.0664)($)		$253,331	$187,055	$683,862	$193,227	$635,912	$136,114	$113,551	$78,993	
Total annual costs ($)		$253,331	$1,108,130	$1,650,111	$1,162,619	$1,211,265	$639,002	$619,648	$78,993	
Energy Charge	0.0650	$0	$443,394	$470,088	$469,886	$237,045	$214,812	$216,708	$0	

Table B-3.—

PEABODY COAL MINE - 10336 AF (V2A) 6 PUMPS W/ JEDITTO													
SUBLATERALS		Gravity = 5.53			3 - MESAS								
OPERATING COSTS		Leupp TO = 1.66										Jeddito	
	Canyon Diablo Wellfield	Leupp (MP 0)	Relift 2	Relift 3		HPt = 6366	Gravity B	Relift 1	Shung-	Keams Canyon	Keams	Relift P.P.	Jeddito
Site	Gravity (MP 0.0)	A Relift 1 (MP 0.00)	MP 17.2	MP29.5	Gravity A	Relift PP	MP 8.2	MP 11.50	povi	Gravity C (MP 16.6)	Canyon	(MP38.8)	Gravity D
MP	END MP 10.38	END MP 17.2	MP 29.5	MP 38.8	MP 8.2	to Bacovi TO	MP 11.50	MP 16.6	TO	MP 38.8	TO	MP 41.1	MP43.6
Pipe dia. (in)	12.5	18	18	18	20	16	18	18		16		8	6
PIPE													
Q(CFS)	5.53	3.871	3.871	3.871	6.46	2.34	4.12	4.12	1.16	2.96	2.03	0.93	0.93
Velocity	6.5	2.2	2.2	2.2	2.96	1.68	2.33	2.33		2.12		2.66	4.74
Total Length (ft)	53750	90816	64944	49104	43296	32736	17424	26928		117216		12114	13200
Friction Loss	524.12	77.47	55.40	41.89	57.1	19.5	16.7	25.8		108.0		38.2	169.1
Begin El	5272	4701	5062	5490	5823	5647	5647	5750		6340		6198	6522
End El.	4701	5062	5490	5885	5647	6366	5750	6340		6198		6522	6327
Static Head (ft)	-571	361	428	395	-176	719	-103	590		-142		324	-195
Begin HGL	5272	5139	5545	5927	5823	6386	5766	6366		6340		6560	6522
End HGL	4748	5062	5490	5885	5766	6366	5749	6340		6232		6522	6353
Pump Lift	0	438	483	437		739		616				362	0
HP	0	241	265	240		245		360				48	0
KW	0	180	198	179		183		268				36	0
KW-hr/yr	0	1,573,019	1,734,212	1,567,349		1,601,571		2,351,246		LPt = 5585		312,202	0
Friction/Static	-92%	21%	13%	11%		3%		4%				12%	0%
Maximum Head	571	570	628	568	176	960	119	801		701		471	26
(Includes	247	247	272	246	76	416	51	347		303		204	11

30% Upsurge)											
Maximum Thickness	0.08	0.12	0.13	0.12	0.04	0.18	0.03	0.17	0.1327	0.04	0.00
Average Thickness	0.08	0.09	0.10	0.09	0.07	0.11	0.07	0.11	0.10	0.07	0.06
Pipe Excavation	38046	78468	56114	42427	41336	26367	15560	23267	94410	7167	7171
Pipe Backfill	36068	71848	51380	38848	37103	24456	14152	21304	87570	6969	7041
Pipe CBF	5685	13132	9391	7101	6983	4265	2528	3894	15271	912	820
Pipe Bedding	2793	5232	3742	2829	2584	1819	1004	1551	6512	573	598
Excavation type	Common	Common	Common	Common	Common	Rock	Rock	Rock	Common	Rock	Rock
	$7.50	$7.50	$7.50	$7.50	$7.50	$20.00	$20.00	$20.00	$7.50	$20.00	$20.00

PEABODY COAL MINE - 10336 AF (V2A) 6 PUMPS W/ JEDITTO

SUBLATERALS

CONSTRUCTION COSTS

Pumping Plant Cost	100000	100000	100000		100000		100000				100000	
Air Chamber Cost	50000	50000	50000		50000		50000				50000	
Power Line Costs	$400,000	$2,000,000	$2,000,000		$200,000		$800,000				$600,000	
Pipe Cost	$2,580,239	$1,907,238	$1,393,479	$1,066,380	$968,719	$366,629	$866,680		$3,072,724		$129,759	$94,110
Pipe Excavation	$588,510	$420,853	$318,206	$310,020	$527,333	$311,200	$465,334		$708,072		$143,334	$143,429
Pipe Backfill	$233,507	$166,984	$126,256	$120,585	$79,483	$45,994	$69,237		$284,602		$22,648	$22,883
Pipe CBF	$196,987	$140,869	$106,511	$104,745	$63,971	$37,920	$58,409		$229,059		$13,680	$12,299
Tank Required	Storage +Forebay	Forebay	Forebay	None	Storage +Forebay	None	Forebay	Storage	Storage	Storage	Forebay	Storage
Storage Tank Costs	$355,000	$55,000	$55,000	$0	$55,000	$0	$55,000	$300,000	$300,000	$300,000	$300,000	$300,000
Total Construction Costs	$4,504,244	$4,840,945	$4,149,452	$1,601,730	$2,044,506	$761,743	$2,464,660	$300,000	$4,594,457	$300,000	$1,359,422	$572,722

ANNUAL COSTS										
Cost of Power ($/yr)	$86,516	$95,382	$86,204	$0	$88,086	$0	$129,319	$0	$17,171	$0
Annual Cost of Pump Sta. over 20 yrs. @ 6%(.0871)($)	$8,710	$8,710	$8,710	$0	$8,710	$0	$8,710	$0	$8,710	
Total annual cost of pumping ($/yr)	$95,226	$104,092	$94,914	$0	$96,796	$0	$138,029	$0	$25,881	
Annual cost of pipeline over 40 yrs @ 6%(.0664)($)	$171,328	$126,641	$92,527	$70,808	$64,323	$24,344	$57,548	$204,029	$8,616	$6,249
Total annual costs ($)	$257,844	$334,824	$282,355	$70,808	$257,916	$24,344	$333,605	$204,029	$34,497	

Pumping Plant O&M Calculations

LEUPP PP - V1 - PEABODY LATERAL

UNATTENDED PLANT

CAPACITY 10. CFS DESIGN HEAD 449. FT
H0RSEPOWER 710. PUMP EFFICIENCY .72
PERIOD OF OPERATION 52 WKS OPERATORS WAGE $ 75.00 /HR
COST INDEX(1962=1.0) 5.65 MECHANICS WAGE $ 75.00 /HR
ANNUAL DIVERSION 6000. AF

COST OF OPERATION		COST OF MAINTENANCE	
LABOR COST	$ 8716.	LABOR COST	$ 47792.
OTHER COST	$ 563.	OTHER COST	$ 7503.
TOTAL	$ 9279.	TOTAL	$ 55295.

ANNUAL O. & M. COST $ 64574.

TOTAL ANNUAL COST $ 64574.

RED LAKE PP - V1 - PEABODY LATERAL

UNATTENDED PLANT

CAPACITY 10. CFS DESIGN HEAD 476. FT
H0RSEPOWER 752. PUMP EFFICIENCY .72
PERIOD OF OPERATION 52 WKS OPERATORS WAGE $ 75.00 /HR
COST INDEX(1962=1.0) 5.65 MECHANICS WAGE $ 75.00 /HR
ANNUAL DIVERSION 6000. AF

COST OF OPERATION		COST OF MAINTENANCE	
LABOR COST	$ 8849.	LABOR COST	$ 48950.
OTHER COST	$ 572.	OTHER COST	$ 7685.
TOTAL	$ 9421.	TOTAL	$ 56635.

ANNUAL O. & M. COST $ 66056.

TOTAL ANNUAL COST $ 66056.

SAND SPRINGS PP - V1 - PEABODY LATERAL

UNATTENDED PLANT

CAPACITY 10. CFS DESIGN HEAD 476. FT
H0RSEPOWER 752. PUMP EFFICIENCY .72
PERIOD OF OPERATION 52 WKS OPERATORS WAGE $ 75.00 /HR
COST INDEX(1962=1.0) 5.65 MECHANICS WAGE $ 75.00 /HR
ANNUAL DIVERSION 6000. AF

COST OF OPERATION		COST OF MAINTENANCE	
LABOR COST	$ 8849.	LABOR COST	$ 48950.
OTHER COST	$ 572.	OTHER COST	$ 7685.
TOTAL	$ 9421.	TOTAL	$ 56635.

ANNUAL O. & M. COST $ 66056.

TOTAL ANNUAL COST $ 66056.

HOTEVILLA PP - V1 - PEABODY LATERAL

UNATTENDED PLANT

CAPACITY 10. CFS DESIGN HEAD 395. FT
H0RSEPOWER 626. PUMP EFFICIENCY .72
PERIOD OF OPERATION 52 WKS OPERATORS WAGE $ 75.00 /HR
COST INDEX(1962=1.0) 5.65 MECHANICS WAGE $ 75.00 /HR
ANNUAL DIVERSION 6000. AF

COST OF OPERATION		COST OF MAINTENANCE	
LABOR COST	$ 8430.	LABOR COST	$ 45346.
OTHER COST	$ 545.	OTHER COST	$ 7119.
TOTAL	$ 8975.	TOTAL	$ 52465.

ANNUAL O. & M. COST $ 61440.

TOTAL ANNUAL COST $ 61440.

BLACK MESA PP - V1 - PEABODY LATERAL

UNATTENDED PLANT

CAPACITY 10. CFS DESIGN HEAD 358. FT
H0RSEPOWER 569. PUMP EFFICIENCY .71
PERIOD OF OPERATION 52 WKS OPERATORS WAGE $ 75.00 /HR
COST INDEX(1962=1.0) 5.65 MECHANICS WAGE $ 75.00 /HR
ANNUAL DIVERSION 6000. AF

COST OF OPERATION		COST OF MAINTENANCE	
LABOR COST	$ 8217.	LABOR COST	$ 43554.
OTHER COST	$ 531.	OTHER COST	$ 6838.
TOTAL	$ 8748.	TOTAL	$ 50392.

ANNUAL O. & M. COST $ 59140.

TOTAL ANNUAL COST $ 59140.

SHEEP VALLEY PP - V1 - PEABODY LATERAL

UNATTENDED PLANT

CAPACITY 10. CFS DESIGN HEAD 362. FT
H0RSEPOWER 575. PUMP EFFICIENCY .71
PERIOD OF OPERATION 52 WKS OPERATORS WAGE $ 75.00 /HR
COST INDEX(1962=1.0) 5.65 MECHANICS WAGE $ 75.00 /HR
ANNUAL DIVERSION 6000. AF

COST OF OPERATION		COST OF MAINTENANCE	
LABOR COST	$ 8241.	LABOR COST	$ 43753.
OTHER COST	$ 532.	OTHER COST	$ 6869.
TOTAL	$ 8773.	TOTAL	$ 50622.

ANNUAL O. & M. COST $ 59395.

TOTAL ANNUAL COST $ 59395.

LEUPP PP - V2 - PEABODY LATERAL

SEMI-ATTENDED PLANT

CAPACITY 21. CFS DESIGN HEAD 439. FT
H0RSEPOWER 1435. PUMP EFFICIENCY .73
PERIOD OF OPERATION 52 WKS OPERATORS WAGE $ 75.00 /HR
COST INDEX(1962=1.0) 5.65 MECHANICS WAGE $ 75.00 /HR
ANNUAL DIVERSION 8000. AF

COST PER KWH .0550 KWH REQUIRED 4932170.

COST OF OPERATION		COST OF MAINTENANCE	
LABOR COST	$ 311805.	LABOR COST	$ 58145.
OTHER COST	$ 8146.	OTHER COST	$ 9128.
TOTAL	$ 319950.	TOTAL	$ 67274.

ANNUAL O. & M. COST $ 387224.

TOTAL ANNUAL COST $ 387224.

RED LAKE PP - V2 - PEABODY LATERAL

SEMI-ATTENDED PLANT

CAPACITY 21. CFS DESIGN HEAD 467. FT
H0RSEPOWER 1525. PUMP EFFICIENCY .73
PERIOD OF OPERATION 52 WKS OPERATORS WAGE $ 75.00 /HR
COST INDEX(1962=1.0) 5.65 MECHANICS WAGE $ 75.00 /HR
ANNUAL DIVERSION 8000. AF

COST PER KWH .0550 KWH REQUIRED 5239774.

COST OF OPERATION		COST OF MAINTENANCE	
LABOR COST	$ 316662.	LABOR COST	$ 59638.
OTHER COST	$ 8272.	OTHER COST	$ 9363.
TOTAL	$ 324934.	TOTAL	$ 69001.

ANNUAL O. & M. COST $ 393936.

TOTAL ANNUAL COST $ 393936.

SAND SPRINGS PP - V2 - PEABODY LATERAL

SEMI-ATTENDED PLANT

CAPACITY 21. CFS DESIGN HEAD 466. FT
H0RSEPOWER 1521. PUMP EFFICIENCY .73
PERIOD OF OPERATION 52 WKS OPERATORS WAGE $ 75.00 /HR
COST INDEX(1962=1.0) 5.65 MECHANICS WAGE $ 75.00 /HR
ANNUAL DIVERSION 8000. AF

COST PER KWH .0550 KWH REQUIRED 5228795.

COST OF OPERATION		COST OF MAINTENANCE	
LABOR COST	$ 316492.	LABOR COST	$ 59586.
OTHER COST	$ 8268.	OTHER COST	$ 9355.
TOTAL	$ 324760.	TOTAL	$ 68941.

ANNUAL O. & M. COST $ 393701.

TOTAL ANNUAL COST $ 393701.

RELIFT 1 PP - V2 - DILKON LATERAL

SEMI-ATTENDED PLANT

CAPACITY 4. CFS DESIGN HEAD 438. FT
H0RSEPOWER 280. PUMP EFFICIENCY .69
PERIOD OF OPERATION 52 WKS OPERATORS WAGE $ 75.00 /HR
COST INDEX(1962=1.0) 5.65 MECHANICS WAGE $ 75.00 /HR
ANNUAL DIVERSION 1400. AF

COST PER KWH .0550 KWH REQUIRED 913504.

COST OF OPERATION		COST OF MAINTENANCE	
LABOR COST	$ 286362.	LABOR COST	$ 22795.
OTHER COST	$ 7481.	OTHER COST	$ 3579.
TOTAL	$ 293843.	TOTAL	$ 26373.

ANNUAL O. & M. COST $ 320216.

TOTAL ANNUAL COST $ 26373.

RELIFT 2 PP - V2 - DILKON LATERAL

SEMI-ATTENDED PLANT

CAPACITY 4. CFS DESIGN HEAD 483. FT
H0RSEPOWER 307. PUMP EFFICIENCY .69
PERIOD OF OPERATION 52 WKS OPERATORS WAGE $ 75.00 /HR
COST INDEX(1962=1.0) 5.65 MECHANICS WAGE $ 75.00 /HR
ANNUAL DIVERSION 1400. AF

COST PER KWH .0550 KWH REQUIRED 1002195.

COST OF OPERATION		COST OF MAINTENANCE	
LABOR COST	$ 293450.	LABOR COST	$ 23727.
OTHER COST	$ 7666.	OTHER COST	$ 3725.
TOTAL	$ 301116.	TOTAL	$ 27452.

ANNUAL O. & M. COST $ 328568.

TOTAL ANNUAL COST $ 328568.

RELIFT 3 PP - V2 - DILKON LATERAL

SEMI-ATTENDED PLANT

CAPACITY 4. CFS DESIGN HEAD 437. FT
H0RSEPOWER 279. PUMP EFFICIENCY .69
PERIOD OF OPERATION 52 WKS OPERATORS WAGE $ 75.00 /HR
COST INDEX(1962=1.0) 5.65 MECHANICS WAGE $ 75.00 /HR
ANNUAL DIVERSION 1400. AF

COST PER KWH .0550 KWH REQUIRED 911528.

COST OF OPERATION		COST OF MAINTENANCE	
LABOR COST	$ 286199.	LABOR COST	$ 22773.
OTHER COST	$ 7477.	OTHER COST	$ 3575.
TOTAL	$ 293675.	TOTAL	$ 26349.

ANNUAL O. & M. COST $ 320024.

TOTAL ANNUAL COST $ 320024.

BACOVI PP - V2 - 3 MESA LATERALS

SEMI-ATTENDED PLANT

CAPACITY 6. CFS DESIGN HEAD 738. FT
H0RSEPOWER 647. PUMP EFFICIENCY .72
PERIOD OF OPERATION 52 WKS OPERATORS WAGE $ 75.00 /HR
COST INDEX(1962=1.0) 5.65 MECHANICS WAGE $ 75.00 /HR
ANNUAL DIVERSION 850. AF

COST PER KWH .0550 KWH REQUIRED 896699.

COST OF OPERATION		COST OF MAINTENANCE	
LABOR COST	$ 332129.	LABOR COST	$ 23691.
OTHER COST	$ 8676.	OTHER COST	$ 3719.
TOTAL	$ 340805.	TOTAL	$ 27410.

ANNUAL O. & M. COST $ 368216.

TOTAL ANNUAL COST $ 417533.

RELIFT 1 PP - V2 - 3 MESA LATERALS

SEMI-ATTENDED PLANT

CAPACITY 6. CFS DESIGN HEAD 616. FT
H0RSEPOWER 542. PUMP EFFICIENCY .71
PERIOD OF OPERATION 52 WKS OPERATORS WAGE $ 75.00 /HR
COST INDEX(1962=1.0) 5.65 MECHANICS WAGE $ 75.00 /HR
ANNUAL DIVERSION 1150. AF

COST PER KWH .0550 KWH REQUIRED 1016654.

COST OF OPERATION		COST OF MAINTENANCE	
LABOR COST	$ 317459.	LABOR COST	$ 25053.
OTHER COST	$ 8293.	OTHER COST	$ 3933.
TOTAL	$ 325752.	TOTAL	$ 28986.

ANNUAL O. & M. COST $ 354738.

TOTAL ANNUAL COST $ 354738.

LEUPP PP - V2A - PEABODY LATERAL

SEMI-ATTENDED PLANT

CAPACITY 22. CFS DESIGN HEAD 449. FT
H0RSEPOWER 1531. PUMP EFFICIENCY .73
PERIOD OF OPERATION 52 WKS OPERATORS WAGE $ 75.00 /HR
COST INDEX(1962=1.0) 5.65 MECHANICS WAGE $ 75.00 /HR
ANNUAL DIVERSION 8000. AF

COST PER KWH .0550 KWH REQUIRED 5037377.

COST OF OPERATION		COST OF MAINTENANCE	
LABOR COST	$ 314246.	LABOR COST	$ 58965.
OTHER COST	$ 8209.	OTHER COST	$ 9257.
TOTAL	$ 322455.	TOTAL	$ 68222.

ANNUAL O. & M. COST $ 390678.

TOTAL ANNUAL COST $ 390678.

RED LAKE PP - V2A - PEABODY LATERAL

SEMI-ATTENDED PLANT

CAPACITY 22. CFS DESIGN HEAD 476. FT
H0RSEPOWER 1621. PUMP EFFICIENCY .73
PERIOD OF OPERATION 52 WKS OPERATORS WAGE $ 75.00 /HR
COST INDEX(1962=1.0) 5.65 MECHANICS WAGE $ 75.00 /HR
ANNUAL DIVERSION 8000. AF

COST PER KWH .0550 KWH REQUIRED 5333596.

COST OF OPERATION		COST OF MAINTENANCE	
LABOR COST	$ 318867.	LABOR COST	$ 60394.
OTHER COST	$ 8330.	OTHER COST	$ 9482.
TOTAL	$ 327197.	TOTAL	$ 69876.

ANNUAL O. & M. COST $ 397073.

TOTAL ANNUAL COST $ 397603.

SAND SPRINGS PP - V2A - PEABODY LATERAL

SEMI-ATTENDED PLANT

CAPACITY 22. CFS DESIGN HEAD 476. FT
H0RSEPOWER 1621. PUMP EFFICIENCY .73
PERIOD OF OPERATION 52 WKS OPERATORS WAGE $ 75.00 /HR
COST INDEX(1962=1.0) 5.65 MECHANICS WAGE $ 75.00 /HR
ANNUAL DIVERSION 8000. AF

COST PER KWH .0550 KWH REQUIRED 5333596.

COST OF OPERATION		COST OF MAINTENANCE	
LABOR COST	$ 318867.	LABOR COST	$ 60394.
OTHER COST	$ 8330.	OTHER COST	$ 9482.
TOTAL	$ 327197.	TOTAL	$ 69876.

ANNUAL O. & M. COST $ 397073.

TOTAL ANNUAL COST $ 397073.

RELIFT 1 PP - V2A - 3 MESA LATERALS

SEMI-ATTENDED PLANT

CAPACITY 6. CFS DESIGN HEAD 616. FT
H0RSEPOWER 631. PUMP EFFICIENCY .72
PERIOD OF OPERATION 52 WKS OPERATORS WAGE $ 75.00 /HR
COST INDEX(1962=1.0) 5.65 MECHANICS WAGE $ 75.00 /HR
ANNUAL DIVERSION 1986. AF

COST PER KWH .0550 KWH REQUIRED 1749733.

COST OF OPERATION		COST OF MAINTENANCE	
LABOR COST	$ 319936.	LABOR COST	$ 32234.
OTHER COST	$ 8358.	OTHER COST	$ 5061.
TOTAL	$ 328294.	TOTAL	$ 37295.

ANNUAL O. & M. COST $ 365588.

TOTAL ANNUAL COST $ 365588.

JEDDITO PP - V2A - 3 MESA LATERALS

SEMI-ATTENDED PLANT

CAPACITY 6. CFS DESIGN HEAD 362. FT
H0RSEPOWER 380. PUMP EFFICIENCY .70
PERIOD OF OPERATION 52 WKS OPERATORS WAGE $ 75.00 /HR
COST INDEX(1962=1.0) 5.65 MECHANICS WAGE $ 75.00 /HR
ANNUAL DIVERSION 336. AF

COST PER KWH .0550 KWH REQUIRED 178182.

COST OF OPERATION		COST OF MAINTENANCE	
LABOR COST	$ 280120.	LABOR COST	$ 12074.
OTHER COST	$ 7318.	OTHER COST	$ 1896.
TOTAL	$ 287438.	TOTAL	$ 13970.

ANNUAL O. & M. COST $ 301408.

TOTAL ANNUAL COST $ 13970.

Appendix C

Special Status Species of Concern

Special Status Species of Concern

The following is a list of 28 species to be considered in the scoping of potential fish and wildlife issues associated with the proposed Peabody Coal Lower Basin Pipeline**.** This list was developed through a review of species listed for Coconino County under the Federal Endangered Species Act (ESA), of 1973 as amended, and the Navajo Nation Endangered Species List Species (NESL) which was created and distributed by the Navajo Natural Heritage Program, Department of Fish and Wildlife Service (Service).

The Federal Action Agency is obligated to abide by the process outlined in Section 7 of the ESA. A biological assessment would be developed to determine the effects of the project on these species of concern. This assessment would be provided to the Service to prepare a biological opinion on whether the proposed project will jeopardize the continued existence of the listed species. It is likely that surveys will be needed to determine whether some of these species occur along the pipeline alignment. Relatively expensive reasonable and prudent alternatives and measures may need to be implemented in order for the project to proceed.

Consultation would also be required with the Navajo Nation to address project impacts to species on the NESL. The NESL categorizes the species into the following groups:

- **G2**: A species or subspecies whose prospects of survival or recruitment are in jeopardy.

- **G3**: A species or subspecies whose prospects of survival or recruitment are likely to be in jeopardy in the foreseeable future.

- **G4**: Any species or subspecies for which the Navajo Nation Department of Fish and Wildlife does not currently have sufficient information to support their being listed in G2 or G3 but has reason to consider them.

The Fish and Wildlife Coordination Act requires that fish and wildlife resources be considered in the development of all Federal water projects. Usually, this is done in consultation with the Service, the state game and fish agency, and the Federal land management agency on whose lands the project will occur on. Since this project is within the Navajo Nation, it is anticipated that this consultation would be between the action agency, the Navajo Nation Department of Fish and Wildlife, and the Service. The consultation would consider effects to non-listed Federal species (e.g. mule deer, bighorn sheep) such as habitat loss and disruption of movement or dispersal corridors. The Service would then issue a *Fish and Wildlife Coordination Act Report* that would list measures to mitigate these impacts and losses.

This "first cut" list was developed without the benefit of visiting the proposed project area and alignment. In addition, discussions with the Navajo Nation or the Service staff biologists were not conducted on terrestrial species within the time constraints for this report. Therefore, it is a very conservative list and could be reduced. At this time, a "fatal flaw" or "project stopper" was not identified. However, there will need to be close consultation with both the Service and the Navajo Nation to determine more specific effects from the project. Where there are data gaps, extensive surveys may be required and there could be a number of seasonal and disturbance related restrictions during construction.

1. **California Condor (***Gymnogyps californianus***)**:

NESL Status: None Federal Status: Endangered

The condor forages for carrion and can travel 48 to 96 miles per day in search of food. Roosting is usually on rock cliffs, snags, or in live conifer stands. A release site is due west of the proposed pipeline along Vermillion Cliffs. The potential exists for condors to roost within the project area along the Colorado River. It is likely that the Service would recommend seasonal restrictions on blasting and drilling as well as training for all personnel on disturbance avoidance to condors, if in the area.

2. **Bald Eagle (***Haliaeetus leucocephalus***)**:

NESL Status: None Federal Status: Threatened

The potential exists for small numbers of wintering Bald Eagles to perch and forage in the area along the Colorado River. In the presence of a localized food source, wintering eagles could congregate along the river and the Service could recommend blasting or drilling restrictions.

3. **Northern Leopard Frog** (*Rana pipiens*):

NESL Status: G2 Federal Status: None

This frog breeds in wetlands, usually with permanent water and aquatic vegetation (especially cattails), ranging from irrigation ditches, small streams, rivers, small ponds, marshes, lakes and reservoirs. The recommended survey period is May 1 to July 31. The Navajo Nation recommends no disturbance within 60-15 meters of occupied habitat if a stream, or 60 meters of wetlands, and avoidance of upstream activities that might impact water quantity and chemistry

4. **Southwestern Willow Flycatcher** (*Empidonax traillii extimus*):

NESL Status: G2 Federal Status: Endangered

The southwestern willow flycatcher breeds in dense riparian vegetation near surface water or saturated soils; either in monotypic or mixed stands of native (e.g. willow) and exotic (e.g. salt cedar) species. The species is known to breed in locations along the Colorado River, downstream of the proposed project area. If a suitable habitat exists within, or is adjacent to, the project area (e.g. infiltration gallery), surveys will be required from mid-May to mid-July. According to the Navajo Nation, there will be no activity within ¼ mile of an active nest from April 15 to September 15. This buffer may be less depending on the activity type and noise level. There will be no alteration of suitable habitat year-round within ¼ mile of habitat patches used for breeding, or potential habitat until surveyed. No activity will take place within migratory habitat, from May 1 through June 15.

5. **Black-footed Ferret (***Mustella nigripes***)**:

NESL Status: G2 Federal Status: Endangered

There are no known wild ferrets on the Navajo Nation or within the other lands that may be traversed by the proposed pipeline. However, the alignment is close to the northern range limit of Gunnison's prairie dog. Ferret distribution is closely tied to that of prairie dogs. The proposed alignment may need to be surveyed for the presence of prairie dog towns. If prairie dog towns are found, it will be necessary to implement Navajo Nation survey guidelines on all Nation lands and the Service guidelines for segments of the pipeline off the Nation. According to the Navajo Nation guidelines, there can be no alteration of prairie dog towns where ferrets occur, or where no recent surveys have been conducted.

6. **Brady Pincushion Cactus** (*Pediocactus bradyi* L. Benson)**:**

NESL Status: G2 Federal Status: Endangered

This cactus is found on Kaibab Limestone chips overlaying soils derived from Moenkopi shale and sandstone. It is typically found on gently sloping benches and terraces with sparse vegetation. Populations are known from El. 3340 to 5200. On the Navajo Nation, the plant is found south of Lee's Ferry along the east side of the Colorado River, south to an unnamed canyon across from North Canyon Point. The potential distribution is described as from Lee's Ferry south and west of Echo Cliffs, along the canyons of the Colorado River south to Shinumo Wash. The recommended survey period is from mid-March to late-April. The Navajo Nation recommends a 200-foot buffer zone to avoid disturbance and it may be more or less depending on slope, size and nature of the project.

7. **Golden Eagle (***Aquila chrysaetos)*:

NESL Status: G3 Federal Status: None

Nesting occurs at nearly all elevations across the Navajo Nation, and on nearly all cliff substrates including sandstone, limestone, and those of volcanic origin. Golden eagles nest on steep cliffs, typically 30 meter in height, although shorter cliffs (greater than 10 meters in height) are infrequently used. The recommended survey period is from March 1 through June 15. The Navajo Nation recommends no activity within a half mile to a mile of an active nest during February 1 through July 15, depending on the orientation of the nest cliff and topographic shielding.

8. **Ferruginous Hawk** (*Buteo regalis*):

NESL Status: G3 Federal Status: None

This hawk nests in badlands, flat or rolling desert grasslands, and desert-scrub. The Navajo Nation is used by Ferruginous Hawks year-round. Although most breed and winter in northwestern New Mexico, they also occur in the Chinle Valley and Dillon area. The proposed alignment should be surveyed to determine the presence or absence of the species. Navajo Nation recommends surveys are conducted between March 1 and June 15. The guidelines also recommend no disturbance within a half mile of an active nest site during March 15 through July 15 for brief activity; 5/8 of a mile for light activity, ¾ of a mile for heavy activity, and 1 mile for long-term and loud activity. Activity can commence 30 days post fledging.

9. **Yellow-billed cuckoo** (*Coccyzus americanus*):

NESL Status: G3 Federal Status: Candidate

The Yellow-billed Cuckoo nests within close proximity to water in mature riparian woodlands with a dense understory. Potential breeding may occur along the Colorado River with appropriate habitat. Surveys are recommended between June 15 and July 30. The Navajo Nation recommends no activity within 1/8 mile of active nests from June 1 to September 15; extreme disturbances (e.g. blasting) may require larger buffers. There should be no alteration of suitable habitat year-round within ¼ mile of habitat patches used for breeding, or potential habitat until surveyed.

10. **Pronghorn** (*Antilocapra americana*):

NESL Status: G3 Federal Status: None

Pronghorn are to be found in grasslands or desert-scrub areas with rolling or dissected hills or small mesas. The proposed alignment may need to be surveyed to determine whether there would be impacts to movement corridors or fawning grounds. The Navajo

Nation recommends that there be no disturbance within 1 mile of known fawning areas during May 1 to June 15 and that "wildlife friendly" fences be used within occupied habitat.

11. **Bighorn Sheep** (*Ovis Canadensis*):

NESL Status: G3 Federal Status: None

Bighorns can be found year-round in arid, precipitous terrain with rocky slopes, ridges, cliffs, and rugged canyons. Vegetation is typically low shrubs, grasses and forbs. Rare sightings of bighorns have been documented along Marble Canyon along the Colorado River. Surveys may be required to determine the presence or absence of the species and the location of any lambing areas. The Navajo Nation recommends that there be no disturbance within 1 mile of lambing areas during April 1 to September 1 and that disturbance be minimized to habitat and to individuals year-round.

12. **Hevron or Marble Canyon Milk-vetch** (*Astragalus cremnophylax* Barneby var. *hevronii* Barneby):

NESL Status: G3 Federal Status: None

This plant is found in crevices and depressions with shallow soils on Kaibab Limestone on rim-rock benches at canyon edges in Great Basin Desert-scrub communities, El.5000. The known distribution of the plant on the Navajo Nation is from Marble Canyon, south of Shinumo Canyon. Potential distribution is in Marble Canyon, from the Little Colorado River Gorge to Navajo Bridge where suitable habitat is to be found. The recommended survey period is from April to May. A 200-foot buffer zone is recommended to avoid disturbance and it may be more or less depending on the size and nature of the project.

13. **Navajo Sedge** (*Carex specuicola* J.T. Howell):

NESL Status: G3 Federal Status: Threatened with Critical Habitat

This perennial grass-like plant is typically found in seeps and hanging gardens, on vertical sandstone cliffs and alcoves. Known populations occur from El. 4600 to 7200. On the Navajo Nation, the species can be found from the Navajo Creek drainage in Coconino County, east to the Tsegi Canyon watershed in Navajo County, and to the Rock Point and Mexican Water area in Apache County, Arizona. Positive identification of the species is only possible from late June through September. The Navajo Nation recommends a 200-foot buffer zone to avoid disturbance and it may be more or less depending on the size and nature of the project. Any activity affecting groundwater would need special consideration.

14. **Fickeisen Plains Cactus** (*Pediocactus peeblesianus* (Croizat) L. Benson var. *fickeiseniae* L. Benson):

NESL Status: G3 Federal Status: Candidate

This plant is found on soils overlain by Kaibab Limestone in Navajoan Desert or Great Plains grassland, along canyon rims and flat terraces along washes, typically with limestone chips scattered across the surface. Populations are known to occur between El. 4000- 5600. Potential distribution on the Navajo Nation is from Marble Canyon to Gray Mountain. The recommended survey season is from late-March to late-April. A 200-foot buffer zone is recommended to avoid disturbance and it may be more or less depending on slope, size, and nature of the project.

15. **Alcove Bog-orchid** (*Platanthera zothecina* (Higgins & Welsh) Kartesz and Ghandi):

NESL Status: G3 Federal Status: None

The alcove bog-orchid is found in seeps, hanging gardens, and moist streams areas from the desert shrub to pinyon-juniper and ponderosa pine mixed conifer communities. The plant is known from the Oljeto Wash, Tsegi Canyon watershed, Carrizo Mountains, and Chinle Wash areas of the Navajo Nation. However, the plant has the potential to be found throughout the Nation where suitable habitat occurs. The recommended survey period is from July to August. A 200 foot buffer zone is recommended to avoid disturbance and it may be more or less depending on the size and nature of the project. Any activity impacting groundwater will need special consideration.

16. **Belted Kingfisher** (*Ceryle alcyon*):

NESL Status: G4 Federal Status: None

Kingfishers nest in burrows in earthen banks usually near major water sources such as streams and rivers. Potential breeding habitat occurs throughout the Navajo Nation where appropriate habitat exists. Surveys should be conducted from May 1 to July 1. There should be no disturbance to nesting habitat year-round and no activity within 1/8 of a mile of an active nest during the April 15 to August 15 period. A buffer may be less or more depending on the activity type and duration but not less than 0.1 km.

17. **Yellow Warbler** (*Dendroica petechia*):

NESL Status: G4 Federal Status: None

Yellow warblers nest in wet, deciduous thickets, especially those dominated by willows, and in disturbed and early successional habitats. There are no current breeding records for the Navajo Nation. The recommended survey period is from May 1 to June 30. Avoidance restrictions include no activity within an eighth of a mile of an active nest from April 15 to July 31. Extreme disturbance (e.g. blasting) may require a larger buffer and there should be no alteration of suitable habitat year-round within 1/8 of a mile of habitat patches used for breeding, or potential habitat until surveyed.

18. **Chisel-toothed kangaroo rat** (*Dipodomys microps*):

NESL Status: G4 Federal Status: None

This kangaroo rat is found in Great Basin desert-scrub habitat with open, sandy areas and vegetation dominated by sparse grasses, shadscale, four-wing saltbush, or blackbrush. Preferred areas have surface soils with rock or gravel component, and are relatively undisturbed by cattle grazing. The only known population on the Navajo Nation is near Navajo Bridge in Marble Canyon; potential range is likely restricted to the upper Marble Canyon area. It is recommended that there be no year-round activity within 60 meters of occupied habitat that could result in destruction of burrows or mounds and individuals.

19. **Townsend's Big-eared Bat** (*Plecotus townsendii*):

NESL Status: G4 Federal Status: None

This bat raises young and hibernates primarily in sandstone or limestone caves, lava tubes, mine tunnels, and other man-made structures. It uses a variety of habitats for foraging including coniferous forests and pinion-juniper woodlands, riparian woodlands, and desert lands. Only two roost caves are known on the Navajo Nation (Shiprock and Page). The suggested survey period is May 1 to August 31. Suggested avoidance measures are not to close occupied mines or caves until consultation is conducted with the Navajo Nation Department of Fish and Wildlife. In addition, there will be no activity within 60 meters of occupied roost-site during April 15 through August 31.

20. **Milk Snake** (*Lampropeltis triangulum*):

NESL Status: G4 Federal Status: None

This secretive species uses rocks, logs, stumps, boards, and other objects as cover within a variety of habitats including river valleys, desert-scrub and grasslands, pinyon-juniper, and coniferous forests. Currently there are no known records from the Navajo Nation but it has potential to be found throughout all elevations and habitats. The recommended survey period is from April 1 to September 1. Suggested avoidance is no surface disturbance within occupied habitat that could result in take of individuals or habitat alteration.

21. **Chuckwalla** *(Sauromalus ater)*:

NESL Status: G4 Federal Status: None

Typical habitats for the Chuckwalla are low desert-lands (especially with volcanic debris and lava flows or desert hardpan), and rocky canyons (especially with large boulders). Known range on the Navajo Nation is not well known but it likely includes deep canyons and adjacent desert-lands of the Little Colorado River, Marble Canyon area, including Echo Cliffs, of the Colorado River. Suggested survey period is from April 15 to August 15. Suggested avoidance is no surface disturbance within occupied habitat that could result in take of individuals or habitat alteration.

22. **Kanab Ambersnail** (*Oxyloma kanabense*):

NESL Status: G4 Federal Status: Endangered

This species is restricted to perennially wet soil surfaces or shallow standing water and decaying plant matter associated with springs and seep-fed marshes near sandstone or limestone cliffs. Although not currently known from the Navajo Nation, the snail has the potential to occur in the tributaries of the Colorado and Little Colorado Rivers, springs on Echo Cliffs, and creeks north and west of Navajo Mountain. Suggested avoidance on the Navajo Nation includes no surface disturbance year-round within 60 meters of occupied habitat and no alteration of water quantity and chemistry.

23. **Welsh's Milkweed** (*Asclepias welshii* N. & P. Holmgren):

NESL Status: G4 Federal Status: Threatened

Welsh's Milkweed is found on active sand dunes derived from Navajo sandstone in sagebrush, juniper, and ponderosa pine communities between El. 1700 and 1900 meters. It is not known from the Navajo Nation but potential habitat exists on all active sand dunes between Page and Tuba City. The recommended survey period is from late May through September. A 200-foot buffer zone is recommended to avoid disturbance and it may be more or less depending on the size and nature of the project.

24. **Painted Desert Milk-Vetch** (*Astragalus sophoroides* Jones):

NESL Status: G4 Federal Status: None

This species occurs in the cold desert shrub community, on sandy soils, usually associated with dry washes between El. 4200 and 4900. The known distribution on the Navajo Nation is between Cameron and The Gap, east to Tuba City. Potential distribution is the Little Colorado River drainage from the Leupp area to the Cameron area, then north to The Gap. The recommended survey period is from May through June. A 200-foot buffer zone is recommended to avoid disturbance and it may be more or less depending on slope, size, and nature of the project.

25. **Atwood's Catseye** (*Cryptantha atwoodii* Higgins):

NESL Status: G4 Federal Status: None

This plant is found on dry hillsides in shaley soils. On the Navajo Nation it is known to occur on the Moenkopi Formation, often overlain by Kaibab Limestone chips. The species is known from Marble Canyon from west of Bitter Springs to the north side of the Little Colorado River Gorge. The optimum survey period is from early April through mid May. A 200-foot buffer zone is recommended to avoid disturbance and it may be more or less depending on slope, size, and nature of the project.

26. **Round Dune-broom** (*Errazurizia rotundata* (Wooton Barn.) :

NESL Status: G4 Federal Status: None

This plant is known from several types of outcrops ranging from sandy soils in sandstone, gravelly soils in calcareous outcrops, to deep, debris cinders in sandstone breaks. Populations are known from El. 4800 to 5200. On the Navajo Nation potential habitat may be found between The Gap and the Petrified Forest National Park. The suggested survey period is from mid-April through September. A 200-foot buffer zone is recommended to avoid disturbance and it may be more or less depending on slope, size, and nature of the project.

27. **Welsh's Phacelia** (*Phacelia welshii* Atwood):

NESL Status: G4 Federal Status: None

Welsh's Phacelia is found in cold desert communities, often located along roadsides and gravelly washes typically in the red shale outcrops of the Moenkopi Formation, but also on black, sandy, volcanic ash. Elevations for known populations are from El. 4250 to 5100. The species has the potential to occur from Marble Canyon to Gray Mountain, east and west of U.S. Highway 89. The recommended survey period is in May and June. A 200-foot buffer is recommended to avoid disturbance and it may be more or less depending on slope, size and nature of the project.

28. **Parish's Alkali Grass** (*Puccinellia parishii* Hitchc.):

NESL Status: G4 Federal Status: None

Habitat for this grass is alkaline seeps, springs, and seasonally wet areas such as washes. The grass is known from a series of widely disjunct populations in southern California to northern and eastern Arizona, western New Mexico and southwestern Colorado. Potential distribution on the Navajo Nation would be along any alkaline seep, spring or seasonally wet area. The optimum survey period is from mid April to early June. A 200-foot buffer zone is recommended to avoid disturbance and it may be more or less depending on slope, size and nature of the project.

29. **Peebles Navajo Cactus** (*Pediocactus peeblesianus* var. *peeblesianus*):

NESL Status: None Federal Status: Endangered

This hard to detect cactus occurs on gravelly soils of the Shinarump conglomerate of the Chinle Formation at elevations ranging from 5,400-5,600 feet in elevation. Associated species are sparsely scattered, low shrubs and grasses of the Navajo Desert. The current known range of the cactus is in central Navajo County, near Holbrook.

30. **Little Colorado River Spinedace** (*Lepidomeda vittata*):

NESL Status: None Federal Status: Threatened with critical habitat

The spinedace is a small (less than 4 inches long) silvery minnow which is darker on the back than the belly. The spinedace inhabits medium to small streams in north-flowing tributaries in the Little Colorado River drainage. The species is characteristically found in pools with water flowing over fine gravel and silt-mud substrates. The species is found in East Clear Creek and its tributaries (Coconino County), Chevelon and Silver Creeks (Navajo County), and Nutrioso Creek and the Little Colorado River (Apache County). Critical habitat includes 31 miles of East Clear Creek in Coconino County; eight miles of Chevelon Creek from the confluence with the Little Colorado River upstream to the confluence of Bell Cow Canyon in Navajo County; and five miles of Nutrioso Creek downstream from Nelson Reservoir in Apache County.

Although generally undocumented, spinedace populations are believed to be impacted by: 1) reduction in stream discharge due to dam construction on the Little Colorado River; 2) alteration in patterns of flows; 3) changes in sedimentation, movement and deposition; and 4) introductions of non-native fishes.

31. **Humpback Chub** (*Gila cypha*):

NESL Status: None Federal Status: Endangered with critical habitat

The chub is a fairly large (20 inches long) minnow characterized by a narrow, flattened head and a long fleshy snout, large fins, and a very large hump between the head and the dorsal fin. Some adults from the mainstem Colorado River annually ascend the Little Colorado River to spawn between March and May, but there is also a large resident population in the Little Colorado River. The chub is a broadcast spawner with a relatively low fecundity rate compared to cyprinids of similar size.

The primary threats to the chub are streamflow regulation, habitat modification (especially thermal), predation by non-native fish species, and parasites and disease transmitted by non-native organisms.