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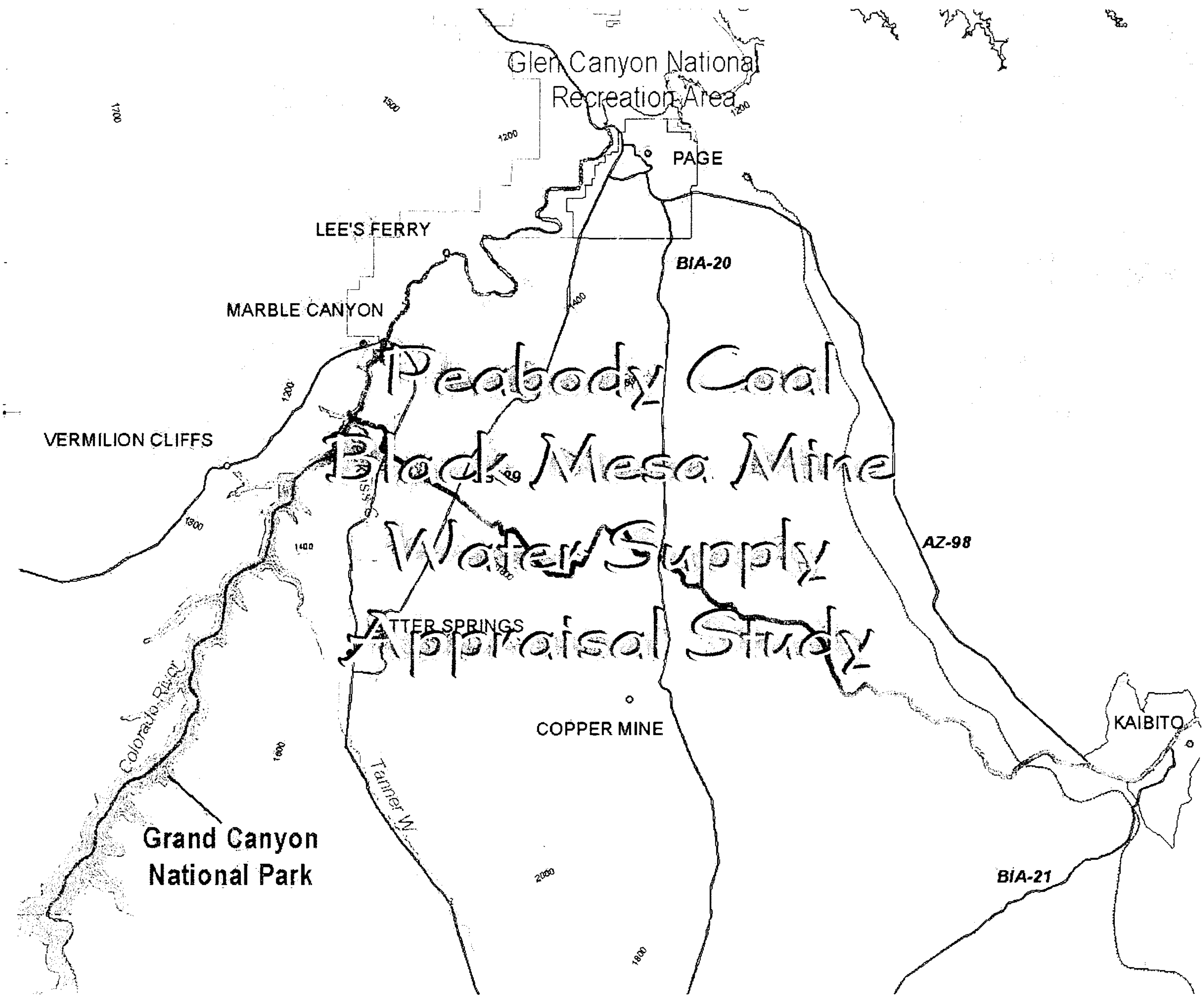
Peabody Coal Black Mesa Mine Water Supply Appraisal Study



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

October 2002

Peabody Coal
Black Mesa Mine
Water Supply
Appraisal Study

Prepared by

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

October 2002

Executive Summary

This appraisal engineering study describes the Bureau of Reclamation's analysis of a Colorado River mainstem diversion and conveyance of the water to Kaibito, Arizona. The water would serve the Peabody Western Coal Company's Black Mesa Mine. This study concentrates on a mainstem Colorado River diversion within the lower Colorado River Basin below Lees Ferry and evaluates two alternatives: diversion of 5,700 acre-feet (AF) and diversion of 11,400 AF annually. This report describes and evaluates the diversion works, storage facilities, pipeline requirements, power requirements, appraisal cost estimates, hydraulic parameters, and potential environmental impacts.

The conceptual pipeline alignment would extend east from the confluence of Badger Creek (Jackass Canyon) and the mainstem Colorado River to Kaibito, Arizona. The Bureau of Indian Affairs contractor, HKM Inc., will evaluate the continuing portion of the pipeline, from Kaibito to the Black Mesa mine.

Study Need

The Peabody Western Coal Company's Black Mesa Mine, located in the lower basin of the Colorado River, currently relies on groundwater pumping from the N-Aquifer for its operation. Alternative supplies are being sought to replace the groundwater pumping. This study was undertaken in response to a request from the U.S. Little Colorado River Settlement Negotiation Team to investigate and evaluate possible diversion options below Lee Ferry, which constitutes the boundary between the upper and lower basin.

Alternative Scenarios and Estimated Costs

Reclamation analyzed two different water demands: 5,700 AF per year and 11,400 AF per year. Using a peaking factor of 1.2-based on information provided by the Little Colorado River Settlement Negotiation Team and assuming pumping occurs 20 out of 24 hours on the maximum demand days, the required design flow would be 11.34 cubic feet per second (ft^3/s) for the 5,700-AF alternative and 22.68 ft^3/s for the 11,400-AF alternative.

Reclamation considered three possible methods for diverting water from the Colorado River including: (1) an infiltration gallery, (2) a river intake structure, and (3) a canal diversion structure. After evaluating these three options and due to the short time frame for this study, Reclamation concluded that the infiltration gallery was the best and least intrusive method for diverting the water.

Diversion would be made at Jackass Canyon, a site in a fairly large area with an undetermined depth of permeable debris. The minimum flow in the Colorado River at this location is approximately 5,000 ft^3/s. Preliminarily, the analysis indicates that the site would be suitable as an infiltration gallery. However, before a final determination is made, Reclamation recommends that extensive testing be done to determine the actual permeability and depth of debris.

Conceptually, the infiltration gallery would collect water from within the alluvium adjacent to the river and convey it laterally to a below-ground sump and pumping plant. The pumping plant would consist of 2 vertical turbine pumps that would lift the water to the canyon rim through a directionally drilled hole to another pumping plant on the rim. No noise abatement was considered in this analysis due to the location of the rapids nearby and the fact that the pumps would be below ground level.

Current technology for directional drilling suggests that it is feasible to drill the holes required for this project to convey water through the geologic formations to the top of the canyon rim and Echo Cliffs. For this analysis, Reclamation considered a fiberglass or steel pipeline, but it is probable that other pipe types could be viable as well.

The pipeline alignment would start at the infiltration gallery constructed at Jackass Canyon in the debris fan, on the east bank of the Colorado River. After the directional drill hole to the top of the canyon rim, the Rim Pumping Plant would then lift water to the Echo Cliffs Pumping Plant. Another directional drill hole would be required to the top of the Echo Cliffs. The water would then flow by gravity to the Kaibito Pumping Plant. The water would then be lifted to a storage tank at the high point of the system and water flows by gravity from the tank to the community of Kaibito.

Estimated construction costs would be approximately $50 million for the 5,700-AF scenario and approximately $79 million for the 11,400-AF scenario. Typical costs for nonconstruction activities are estimated at approximately 25 percent of the construction costs for either alternative.

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 resources, recreation and aesthetics, wilderness, cultural resources, social analysis and environmental justice, and Indian Trust Assets.

Due to the proposed pipeline's sensitive location within the Park, issues of concern were identified for each resource. Impacts cannot be analyzed without more specific information. However, no "fatal flaws" could be established at this level of analysis. Further evaluation will occur if the project proceeds to feasibility study level.

Conclusions

The infiltration gallery option provides one method for diverting water from Marble Canyon and would have the least amount of environmental impacts, based on the alternatives this study considered. The site appears to have suitable soils and topographic conditions necessary to construct an infiltration gallery. To confirm this assumption, use of ground mapping, pump tests and/or geophysical seismic techniques to determine the permeability of the debris fan are the next steps for determining the feasibility of the debris fan for use as an infiltration gallery. In addition, the Lee's Ferry site should be considered as a possible diversion site as well. The reliability of the infiltration gallery and the actual permeability of the debris fan still must also be addressed in more depth; however, infiltration galleries have been successfully used in locations where large amounts of sands and gravels are available in sufficient depths to provide a natural filtration system without plugging, and their use appears to be a viable alternative in this case.

ACRONYMS and ABREVIATIONS

ACHP	Advisory Council on Historical Preservation
AF	acre-feet
BIA	Bureau of Indian Affairs
El.	elevation
ESA	Endangered Species Act
ITAs	Indian Trust Assets
MOA	memorandum of agreement
National Register	National Register of Historic Places
NEPA	National Environmental Policy Act
NESL	Navajo Endangered Species List
NHPA	National Historic Preservation Act
NNTHPO	Navajo Nation Tribal Historical Preservation Office
NPS	National Parks Service
OD	outer diameter
O&M	operation and maintenance
Park	Grand Canyon National Park
ppd	per person per day
RM	river mile
Reclamation	Bureau of Reclamation
Service	U.S. Fish and Wildlife Service
TCPs	traditional cultural properties

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Chapter 1

INTRODUCTION

1.1 Background, Purpose, and Scope of the Study

Various alternatives have been evaluated to divert Colorado River surface water from Lake Powell to meet the current and future demands of the Peabody Western Coal Company's Black Mesa Mine. Lake Powell is located in the upper Colorado River Basin. The Black Mesa Mine, located in the lower basin of the Colorado River, currently relies on groundwater. Alternative supplies are being sought to replace the groundwater. This study concentrates on a mainstem Colorado River diversion within the lower Colorado River Basin below Lees Ferry (river mile [RM] 0.0) in response to a request from the U.S. Little Colorado River Settlement Negotiation Team.

The Bureau of Reclamation (Reclamation) conducted this conceptual appraisal engineering study to identify "fatal flaws" associated with two alternative scenarios (5,700 and 11,400 acre-feet (AF) annually) to divert mainstem Colorado River water to Kaibito, Arizona. The alignment from Kaibito to Black Mesa will be evaluated and reported by the Bureau of Indian Affairs (BIA) contractor, HKM Inc. This report includes text, figures, and photographs necessary to describe the diversion point, storage facilities, power requirements, pipeline alignment, appraisal cost estimates, hydraulic parameters, and potential environmental impacts.

1.2 Assumptions

This report represents a cursory review conducted over a 3-week period. All data evaluated for this study are from interviews, available reports, databases, and afield trip. The field trip report has been incorporated into the body of this report. Navajo Nation right-of-way costs are not included but could be obtained at a unit price, as determined by the Navajo Nation's Division of Natural Resources. Assumptions associated with the engineering analysis are listed in Chapter 2, "Alternatives." Environmental issues related to the diversion of mainstem Colorado River are beyond the scope of this study and are not addressed in this report. Implementation of one of the alternatives considered (the entire project from the Colorado River to Black Mesa) 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 1-1) is predominantly within the boundaries of the Navajo Nation, following a conceptual pipeline alignment from the confluence of Badger Creek (Jackass Canyon

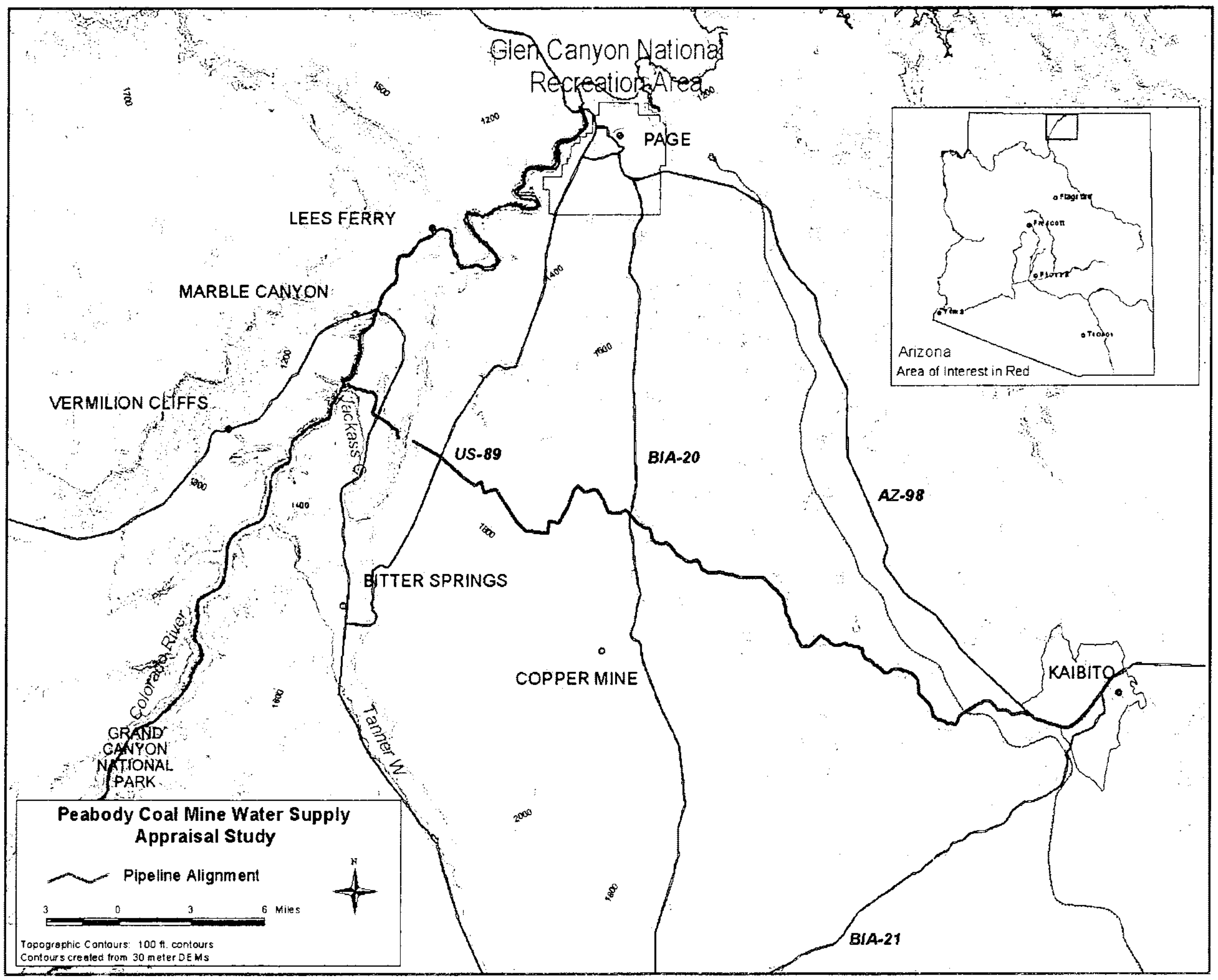

Figure 1-1.—Location map.

RM 8.0) and the mainstem Colorado River east to Kaibito, Arizona. The diversion structure will be located within the boundary of the Grand Canyon National Park (Park). The Navajo Nation disagrees[1] with the boundary established by the Federal Government on the east side of Marble Canyon; the delineation of the boundary is beyond the scope of this study.

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.

[1] The Navajo Nation does not recognize the boundary established by the Federal government. There is a Department of Interior solicitor's opinion (1969) that the boundary is ¼ mile east of the river. The Grand Canyon Enlargement Act (1975) authorizes this boundary.

Chapter 2

ALTERNATIVES

This chapter presents two alternatives for conveying Colorado River water from a diversion point in the Lower Basin to Kaibito, Arizona, to meet water demands for the Peabody Coal Company.

2.1 Alternative Formulation and Engineering Methods of Analysis

On September 6, 2002, Reclamation conducted a site visit to the Page, Arizona, vicinity to review possible diversion sites and pipeline alignments. During this effort, a possible diversion site was located at the confluence of the Colorado River and Jackass Canyon (RM -8 left) within Grand Canyon National Park. A pipeline alignment, extending east through the Echo Cliffs and into Kaibito, was also proposed. The location map (figure 1-1) outlines the proposed route and pumping plants from the Jackass Canyon diversion point, east approximately 40 miles, to the community of Kaibito. This RM 8 point is located 8 miles downstream of Lee's Ferry, 3 miles downstream of Navajo Bridge, and 15 RM below Glen Canyon Dam. Due to time constraints, only one route and diversion site were analyzed; however, two flow rates were analyzed.

2.1.1 Flow Demand

Reclamation analyzed two different water demands: 5,700 AF per year and 11,400 AF per year. Reclamation used a peaking factor of 1.2, based on information provided by the Little Colorado River Settlement Negotiation Team. Assuming pumping occurs 20 out of 24 hours on the maximum day demand, the required design flow is 5,700 AF (11.34 cubic feet per second [ft^3/s]) and 11,400 AF (22.68 ft^3/s), respectively.

Table 2.1.—The average flow and peaking factors

Annual flow (AF)	Peaking factor	Pump factor[1]	Maximum flow (ft^3/s)
5,700	1.2	1.2	11.34
11,400	1.2	1.2	22.68

[1] Pump 20 hours out of 24

2.2 Alternatives Considered

2.2.1 Options for Diverting Colorado River Water

Three possible methods exist for diverting water out of the Colorado River to a pumping plant site: (1) infiltration gallery; (2) river intake; and (3) canal diversion. These methods are described and briefly analyzed below.

Infiltration Gallery

An infiltration gallery is essentially a horizontal well or subsurface drain that intercepts underflow of permeable materials adjacent to or under the river. Infiltration galleries require permeable soils and are usually constructed to collect and discharge water into a sump, from which it is then pumped into a conveyance system. A typical schematic is shown in figure 2.1. The advantages and disadvantages of an infiltration gallery are discussed below.

Advantages

- The intake facility would be buried.
- Because of the filtration characteristics of the infiltration gallery no sediments are not expected to be a problem in the pumped water and no disposal will be required.
- It could be installed outside the riverbed.
- It works with large river elevation fluctuations.

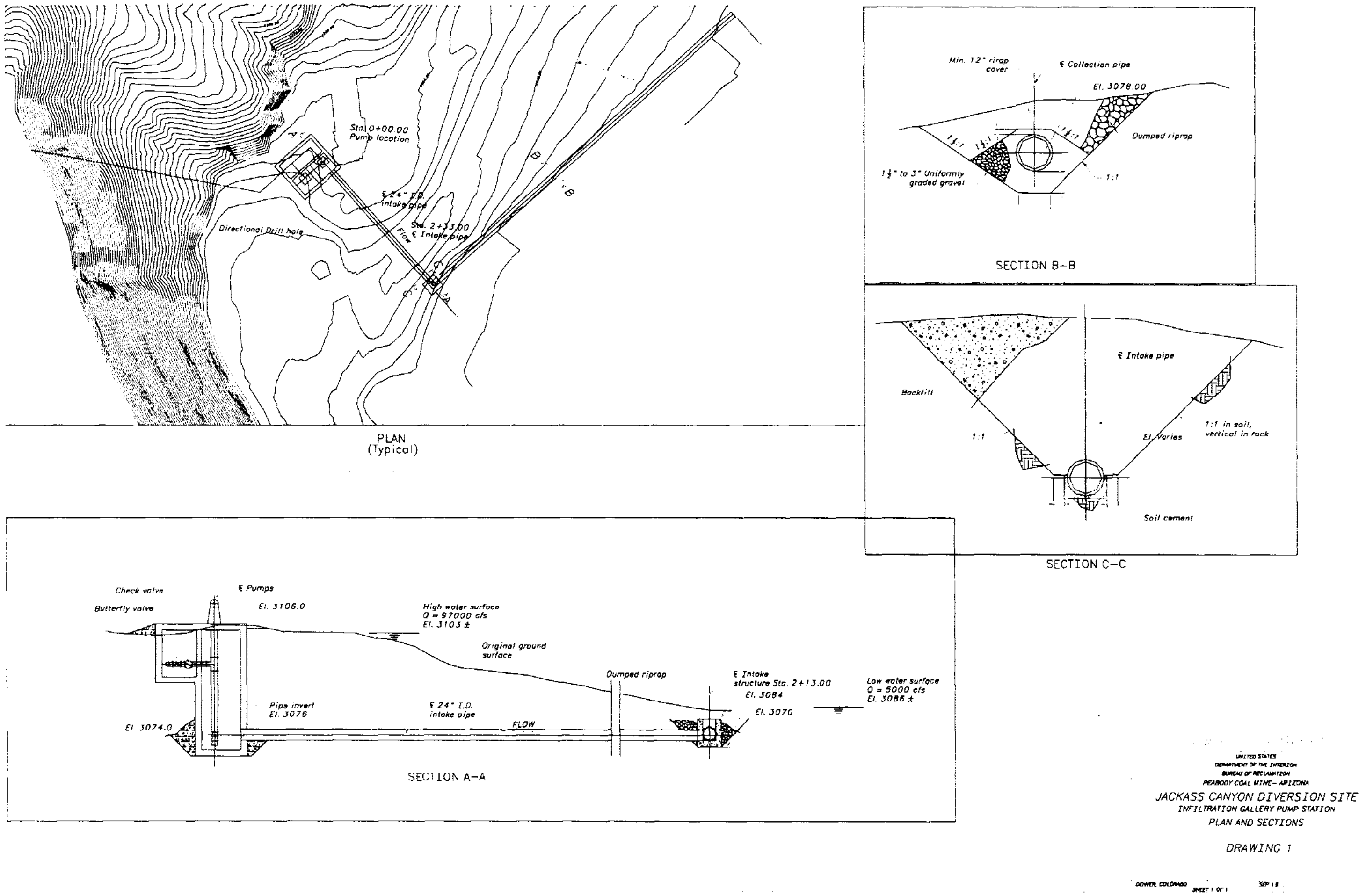

Figure 2-1.—A typical infiltration gallery and pumping plant configuration.

Disadvantages

- Sands and gravels of sufficient stability may be difficult to locate in the canyon.
- A gallery with three times the capacity to provide required reliability may be required.

River Intake

A river intake is a pipe that extends into the river and has a screening system at the end of the pipeline. Water is pumped through a pipe into a settling basin or clarifier. The screens would be exposed to the elements in the river. The advantages and disadvantages of a river intake are discussed below.

Advantages

- It can be installed in rocky areas.
- It works with large fluctuations in river elevation.
- Intake facility would be buried or below the water line in the river.
- There is less sediment to dispose of than with a canal diversion.

Disadvantages

- The pump station may have to be exposed.
- It requires a sediment trap.
- The settling basin or clarifier is exposed.
- It requires sediment disposal.

Canal Diversion

To divert water out of the Colorado River, a canal could be constructed that would divert water from the river into a settling basin, where the sediment would drop out. Typically, this method requires a diversion dam to provide a constant head into the canal diversion. The advantages and disadvantages of a canal diversion are discussed below.

Advantages

- It is a simple system that provides reliable water delivery.

Disadvantages

- It requires sediment disposal or sluicing back into the river.
- The facilities are exposed.
- It requires a diversion dam.
- Costs for removing sediment may be high.

After evaluating these three options, and due to the short time frame for this study, Reclamation concluded that the infiltration gallery was the least intrusive method for diverting the water and the best option for use at the Jackass Canyon site.

2.2.2 Directional Drilling Technology

Current technology for 10- to 20-inch drill holes suggests that it is feasible to drill the holes required for this project to convey water through the canyon rim and Echo Cliffs. Based on previous directional drilling at the Park, it is likely that the hole will have to be drilled with air, instead of fluid, due to drill fluid leakage into the rock. Based on telephone conversations with Jerry Cerkovnik, of Baker-Hughes (a horizontal directional drilling contractor), the practical length of air drilling is limited to around 6,000 feet. This practical length is more than adequate for this project.

A directional drilled hole at the Park in the 1980s missed the final exit point by 200 feet (horizontally). Based on conversations with Baker-Hughes, subsequent technological advances should significantly improve drilling accuracy to within 20 feet. In the *Grand Canyon National Park Water Supply Appraisal Study* (January 2002), Baker-Hughes gave guidelines for cost but stated that, without more information, uncertainties still exist. The construction cost estimates for a 12-3/4-inch borehole for the Grand Canyon Project, assuming 200 feet per day could be drilled, would be $100,000 for mobilization and demobilization and $30,000 per day for drilling costs. Baker-Hughes did not have time to prepare an estimate so to scale up for the 18-3/4 inch borehole used in this study, all these cost were doubled. Doubling the cost was considered reasonable and within the margins of this estimate, given the lack of more reliable estimates. Larger boreholes may be available by using more common directional drilling techniques, but the geologic conditions must be assessed before the viability of these methods can be determined.

2.2.3 Pipelines

Fiberglass and steel pipe are able to withstand the high pressures (up to 1,100 pounds per square inch) required for the pipe sizes under consideration. The disadvantage of steel pipe is the need for cathodic protection. The disadvantage of fiberglass pipe is that it is less durable than steel pipe, but it is lighter and requires no welding because of its threaded joints.

The required pressure class of the pipe equals the elevation of the design gradient (static plus 10 percent) minus the centerline elevation of the pipe. Pressure classes for pipe were divided into five zones: 500 feet; 1,000 feet; 1,500 feet; 2,000 feet; and 2,500 feet. In-line sectionalizing valves would be spaced every 3 miles. Sectionalizing valves would be housed in a corrugated-metal pipe vault-type structure.

Blowoff valves would be located at several low points along the alignment to allow a 3-mile section to be drained and filled 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.

Time constraints did not allow for an indepth analysis of these construction components. These costs categorized as unlisted items and estimated at 15 percent of total cost.

Hydraulics for the pipeline were based on the assumption of steel pipe and using a "C" value of 143 in the Hazen-Williams formula.

2.2.4 Excavation and Backfill

The cost estimate for excavation was based on 100-percent rock trenching. The trench excavation for a pipeline was based on a depth equal to the pipe diameter plus 2 feet, vertical sidewalls, and a trench width of 2 feet (figure 2-1). This limits the type of equipment available for this work. A track-mounted excavator, such as the Vermeer T455, likely would be used. It is assumed that this material would be obtained from borrow pits within 2 miles of point of use.

Backfilling of the pipe trenches requires a select material to be placed around the pipe to a depth of 3 inches over the top of the pipe. It is assumed that this material would be obtained at nearby borrow pits. The remainder of the fill over the top of the pipe can be trench excavation material. The costs for the excavation and backfill for this report are shown in table 2-1.

Table 2-2.—Pipe trenching costs

Pipe installation item	Unit cost ($/cubic yard)
Excavation (rock trenching)	$20.00
Pipe bedding (select material)	$15.00
Backfill	$ 3.25

2.2.5 Storage Tanks

Forebay tanks will be required in front of the Rim, Echo, and Kaibito Pumping Plants. The estimated size for these tanks is 20 feet tall (188,000 gallons) and 40 feet in diameter (200,000 gallons). Tank costs were estimated using numbers from the *Navajo Gallup Water Supply Report* (April 2002).

One large storage tank was assumed to be located at the high point in the system at elevation (El.) 6085, near the Circular White Cliffs. The storage tank was arbitrarily sized to take into account the repair and maintenance downtime and give 1-1/2 days of storage at the maximum flow rate. For the 11.22-ft^3/s option, the tank was sized at 20 feet tall and 160 feet in diameter (3,000,000). For the 22.68-ft^3/s option the tank was sized at 20 feet tall and 250 feet in diameter (7.34 million gallons). Tank cost was estimated using numbers from the *Navajo Gallup Water Supply Report* (April 2002).

2.3 Construct an Infiltration Gallery and Pumping Plant in Jackass Canyon

Under this alternative an infiltration gallery would be constructed at Jackass Canyon in the Colorado River with the water conveyed to the community of Kaibito, Arizona, through a series of pump lifts (figure 2-1).

2.3.1 Diversion Site

The diversion site would be located at Jackass Canyon in the Park (figure 2-2). The site is located in a fairly large area with an undetermined depth of debris. The minimum flow in the Colorado River at this location is approximately 5,000 ft^3/s. The required diversion rate of between 11.22 and 22.68 ft^3/s is very small when compared to the flow in the river. Preliminary analysis indicates the site is suitable for constructing an infiltration gallery without substantial excavation in the river and with all excavation done during periods of low flow and confined to a small 200-foot by 200-foot corner of Jackass Canyon. However, the diversion site would require extensive testing to determine the actual permeability and depth of debris before a final determination can be made as to its suitability as an infiltration gallery.

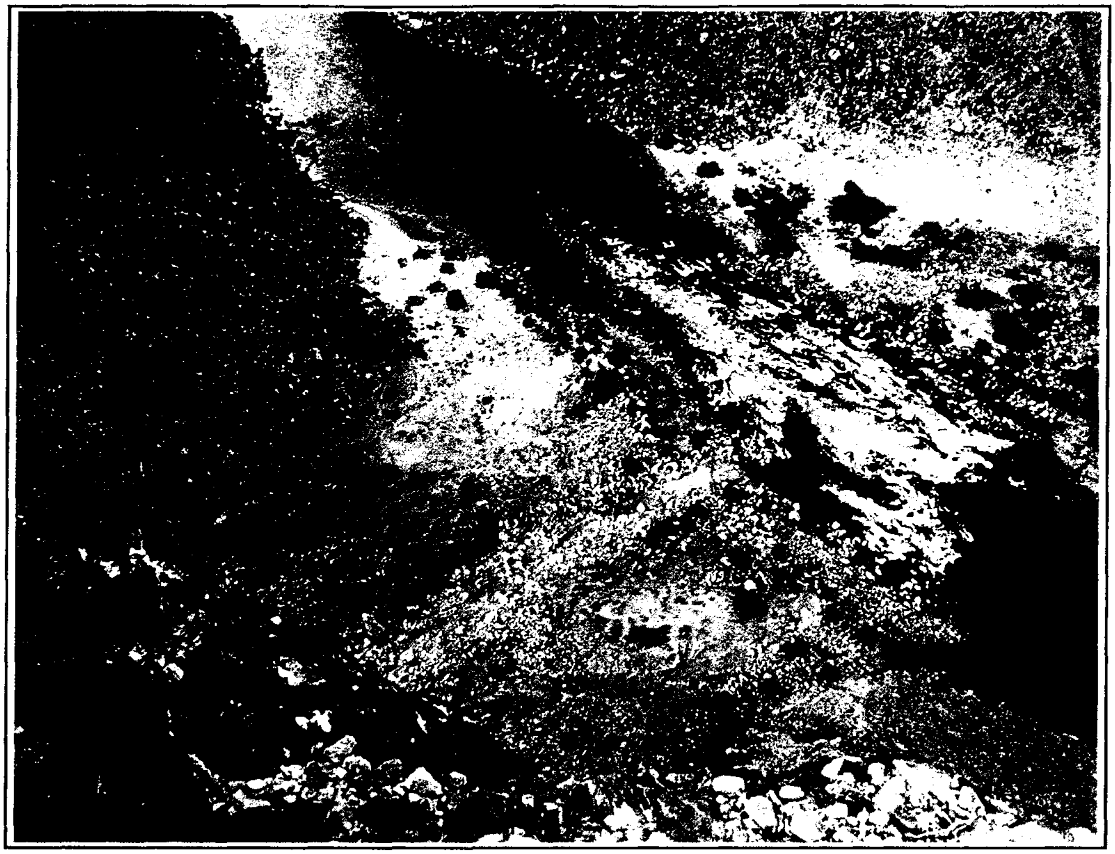

Figure 2-2.—Looking down at the Colorado River, some 700 feet, into Marble Canyon from its north rim. This is on the north side of Jackass Canyon at RM 8 left, at the rapids of Badger Creek. Riverflow is from right to left. The debris fan exiting Jackass Canyon (the reddish-brown gravel, cobbles, boulders, and lighter-colored delta bar of sand below the river in this picture) links with the debris fan from the mouth of Badger Canyon on the west side (above the river in this picture). Here, the bedrock channel is filled with debris and creates the shallow rapids. An infiltration gallery might be constructed on this debris fan, possibly parallel to the rapids. The debris here is estimated to be 30 feet thick and, possibly, much more.

2.3.2 Directional Drilling

A 1,200-foot-long directionally drilled hole is feasible at the Jackass Canyon site. The profile for the directional drill borehole is shown in figure 2-3. Rock conditions are currently unknown, but the cliffs indicate a high level of jointing which would require air drilling in lieu of using a fluid. Baker-Hughes possesses drill equipment that can drill holes up to the required 18.25 inches in diameter.

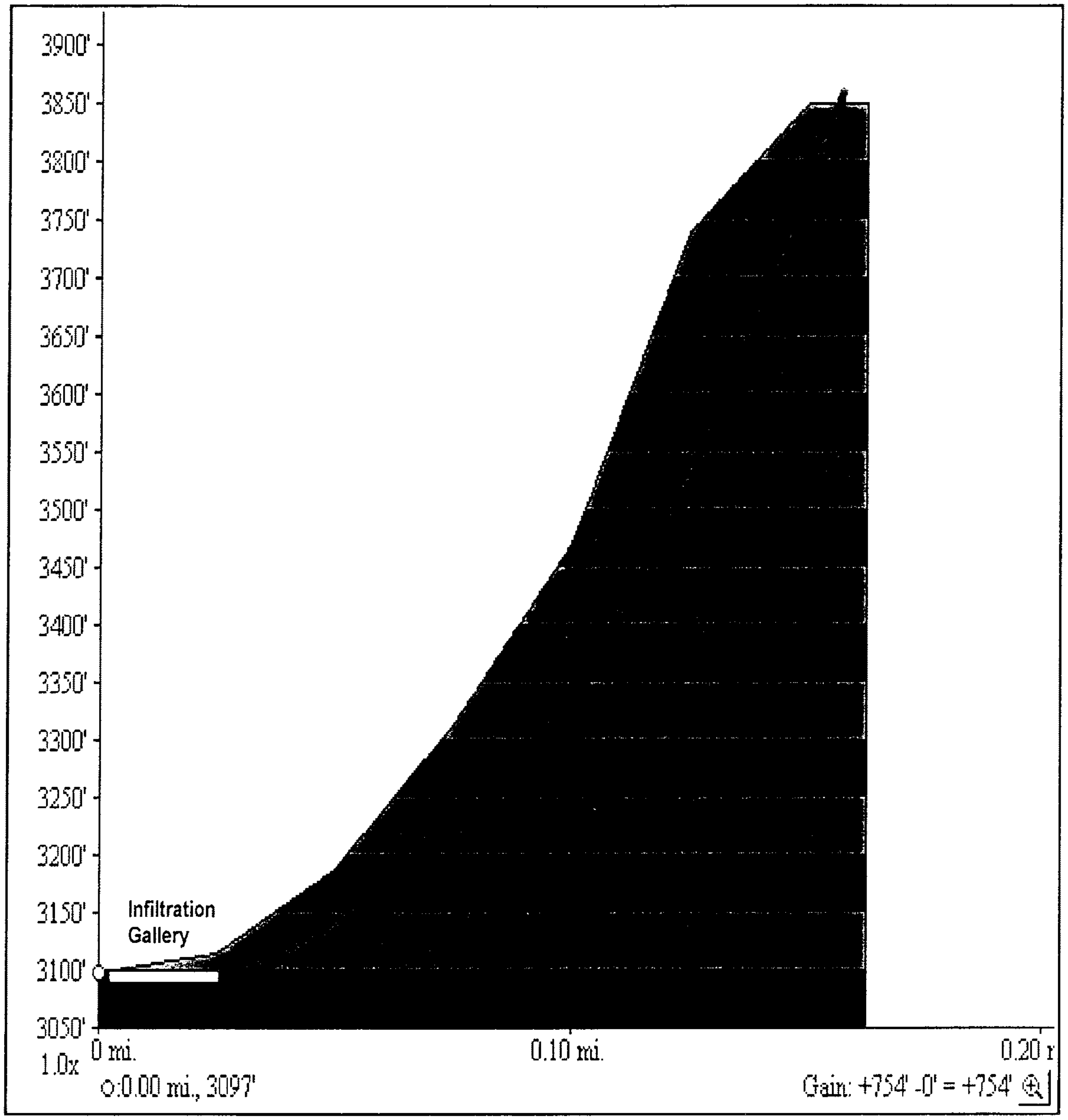

Figure 2-3.—Jackass Canyon directional drill hole profile.

A typical drill hole is required to be 1.5 times the outer diameter (OD) of the casing pipe to allow placement inside the borehole. Therefore, a pipeline with an OD of 12 inches would require a borehole of approximately 18.25 inches. If two holes were to be drilled, then a borehole size of 12.75 inches would be required for an 8.25-inch-diameter casing pipe. The 12-inch sections are limited to the directional drill boreholes. Reclamation believes that, for these relatively short sections, a velocity of 14 feet per second is high but not unreasonable from a friction loss, transient, or fitting perspective.

The borehole diameter required for a single hole and a maximum flow rate of 22.38 ft^3/s is 25.5 inches. The technology may not be available to construct such a large hole. Therefore, two 18.25-inch-diameter holes may be required rather than one hole. The high velocities associated with the system do not create excessive losses due to the short length of the borehole and do not pose transient risks.

An additional directional drill site will be required at Echo Cliffs (figure 2-4). This site will require the directional drilling of a 3,600-foot hole (3,000-foot horizontal and 2000-foot vertical). The hole size required for the two different flow rates would be the same as required at the Jackass Canyon site.

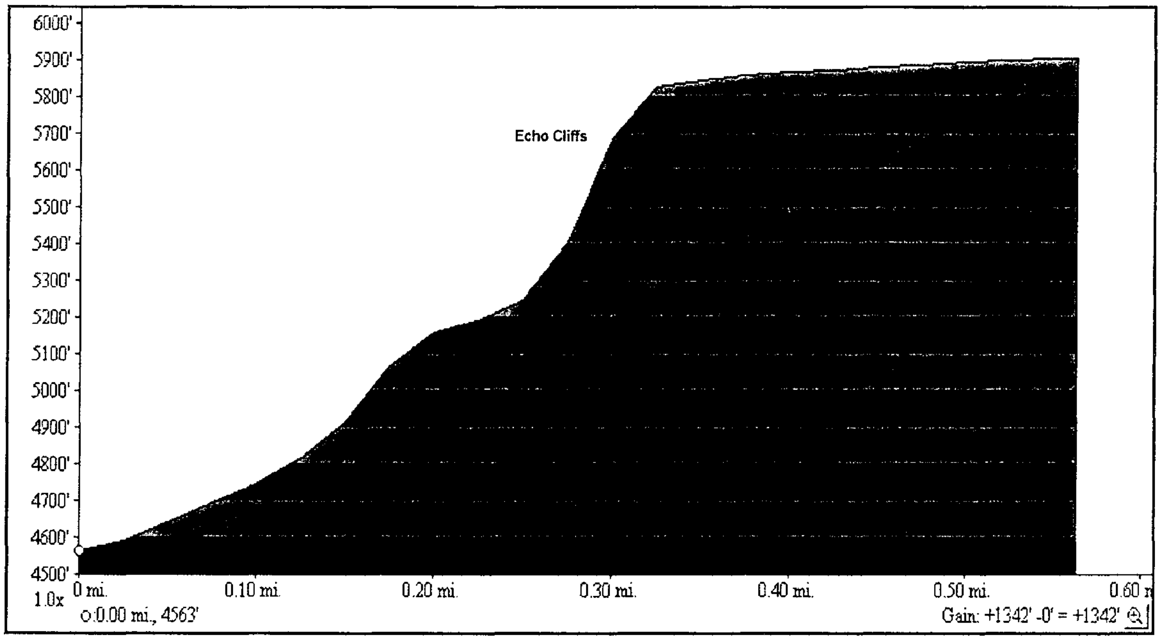

Figure 2-4.—Directional drill hole shaft from the foothills up to Echo Cliffs summit.

The directional drill sites would require a 300-foot by 300-foot area for setup of the drill rig and associated equipment. This may be a problem at the Jackass Canyon site because an endangered species of cactus exists on the South Rim. Exact location of the drill site and pipe length would have to be finalized, based on further environmental analysis.

2.3.3. Pipeline alignment

The complete pipeline alignment is shown on figures 2-5 and 2-6. The alignment would start at the infiltration gallery constructed in Jackass Canyon, on the east bank of the Colorado River. After the directional drill hole to the top of the canyon rim, the Rim Pumping Plant would then lift water to the Echo Cliffs Pumping Plant. The pipeline would run in a trench excavated into bedrock along topographic contours around the northern tributary side of Jackass Canyon, cross below Arizona State Highway 89, and run to the foothills of Echo Cliffs at about El. 4560 (figure 2-7).

Figure 2-5.—Proposed pipeline alignment from RM 8, Jackass Canyon towards Kaibito.

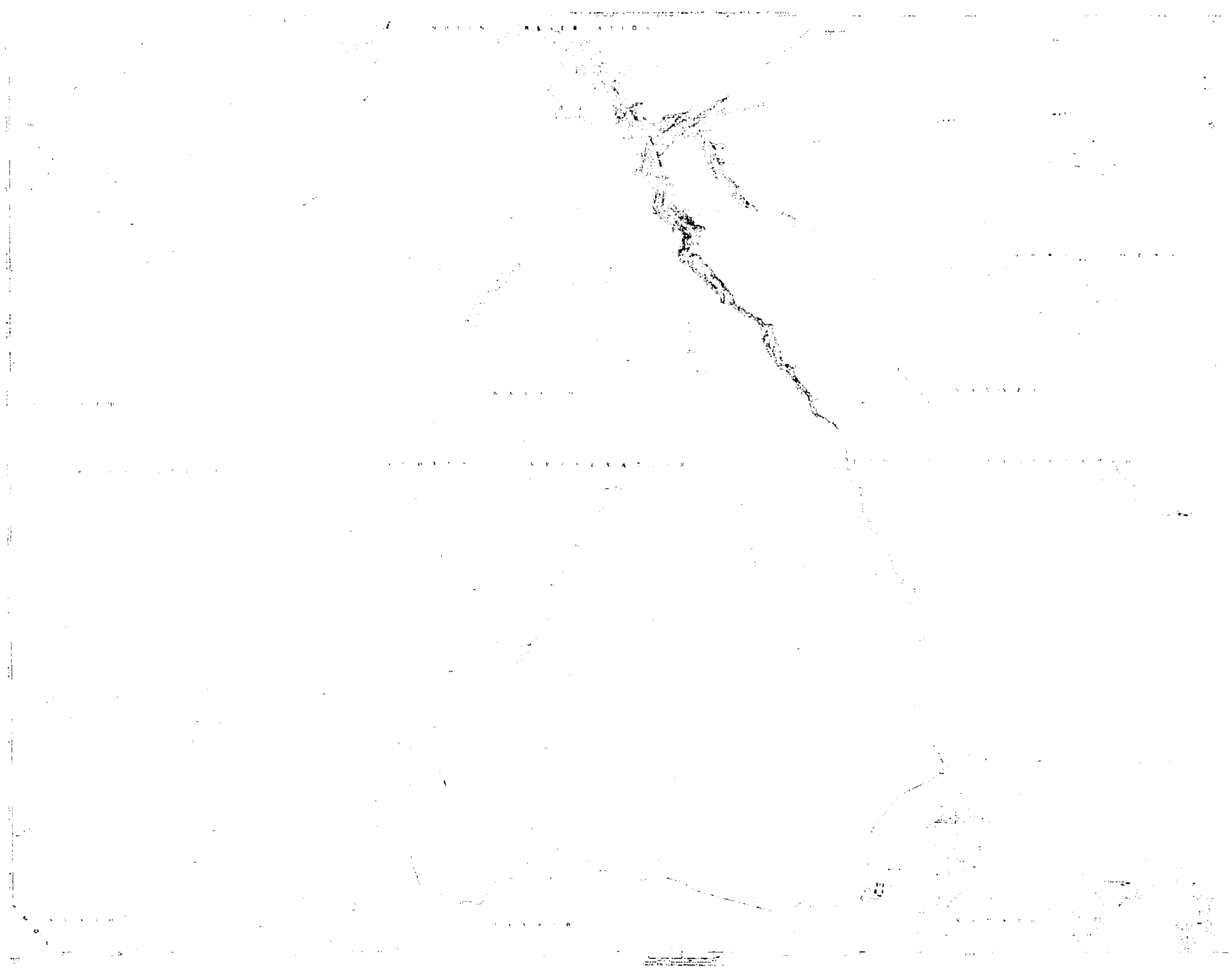

Figure 2-6.—Continuation of proposed pipeline alignment to Kaibito.

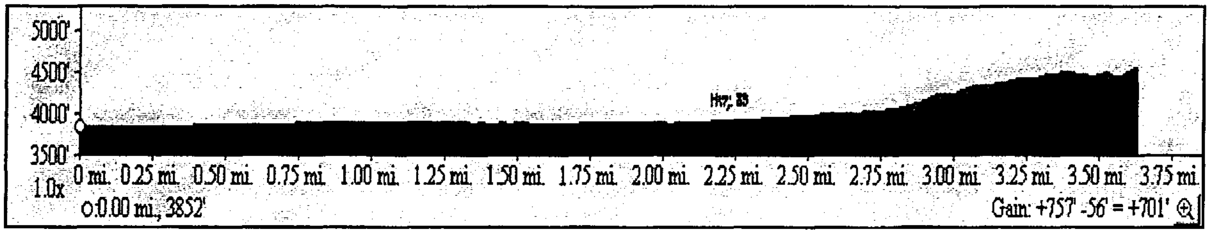

Figure 2-7.—Typographic profile for pipeline.

Echo Cliffs would be transversed with a directional drill hole. This drill hole would reduce the pipeline length by approximately 20 miles by avoiding the traditional route along existing roads. The water would flow by gravity from the top of Echo Cliffs into the Kaibito Pumping Plant. At the Kaibito Pumping Plant, water would be pumped into a storage tank at the high point of the system (figure 2-8).

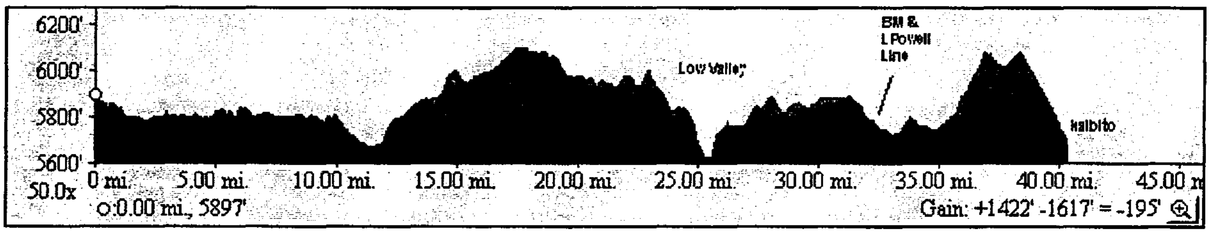

Figure 2-8.—Topographic profile from outlet of Echo Cliff directional drill hole to Kaibito, Arizona.

2.3.4 Pumping Plants

The Jackass Pumping Plant, located on the debris fan at the bottom of the Grand Canyon, would be the first of four pump lifts from the Colorado River out of the bottom of the Canyon. This plant would be designed as a two-pump system with each pump supplying half the total flow. A concrete structure would be constructed to house the pumps. The pumping plant structure would be buried and made to blend in with the surrounding debris fan. The infiltration gallery would also be completely buried. A check valve would be installed in the pipeline after the pumps. Figure 2-1 illustrates a typical infiltration gallery and pumping plant configuration. O&M activities could be minimal, with pump maintenance undertaken monthly by one person from a boat and yearly from a barge. But actual maintenance requirements depend on pump and motor warranties and service requirements. A SCADA system would have to be installed to monitor pump and motor operations to lessen the need for a person to visit the plant.

The remainder of the pumping plants along the system — Rim, Echo and Kaibito — would be designed as flat slab plants with a forebay tank. A storage tank would be built at the high point of the system beyond the Kaibito Pumping Plant to provide an emergency backup supply of water.

The types of pumps were assumed to be vertical turbine units installed below ground level. No noise abatement was considered, due to the location of the rapids nearby and the fact that the pumping plant is underground. Sound insulation could be applied to the interior of the structure walls if required. The assumption was made that construction and O&M activities could be provided by barge or helicopter and no access road would be required, similar to the National Park Service access to pumping plants in the Grand Canyon. This assumption would be explored further in a subsequent phase. Pumping plant data are summarized in table 2-2. A discussion of energy costs is included in appendix A.

Table 2-3.—Pipeline hydraulic parameters for 5,700 AF and 11,400 AF

Q = 11.34 ft^3/s (5,700-AF scenario)

Pumping plant	Static lift (ft)	Total lift (ft)	Horsepower	Annual pumping cost (81 millions)	Annual pumping cost (65 millions)
Jackass	730	791	1,271	$666,684	$539,909
Rim	550	578	929	$487,529	$394,821
Echo	1,505	1,635	2,628	$1,378,610	$1,116,456
Kaibito	275	312	502	$263,348	$213,414
Totals				**$2,796,348**	**$2,264,800**

Q = 22.68 ft^3/s (11,400-AF scenario)

Pumping plant	Static lift (ft)	Total lift (ft)	Horsepower	Annual pumping cost (81 millions)	Annual pumping cost (65 millions)
Jackass	730	770	1,585	$1,306,852	$1,051,872
Rim	550	607	1,250	$1,030,433	$829,322
Echo	1,505	1,591	3,274	$2,699,992	$2,173,030
Kaibito	275	321	660	$544,182	$437,973
Totals				**$5,581,559**	**$4,492,197**

2.3.5 Surge Control

The Jackass and Echo Cliff Pumping Plants would probably not require any surge control. Because of the high heads and relatively vertical alignments that result when check valves are used in line. Air chambers may be required in proximity to the Rim and Kaibito Pumping Plants, based on the alignment profiles.

2.3.6 Power

Reclamation assumed that a power cable would be extended through the borehole to the Jackass Pumping Plant. The remainder of the pumping plants would be served by above-ground power connected into existing systems. The cost of power was based on bringing power from an existing power line located 15 miles east of Jackass Canyon near 8IA Road 20. The cost of constructing the new power lines was assumed to be $200,000 per mile. The power was assumed to be 69 kilovolts.

2.3.7 Water Treatment

Due to the filtering action of the infiltration gallery, it was assumed that no water treatment would be necessary for industrial use.

2.3.8 Geology

Jackass Canyon is one of the 736 ungaged tributaries into the Colorado River between Lees Ferry and Diamond Creek, Arizona (R.H. Webb et al., 2000). It contributes sediment to the mouth of the Colorado River by flash flooding and mass wasting processes. Recently (post-closure of Glen Canyon Dam), this sediment formed a constructional landform, referred to in this report and in the literature as a "debris fan".

The Jackass Creek Canyon is about 3 miles long, with its headwaters beginning near Arizona State Highway 89, El. 4010. The creek bottom drops about 915 feet through the Permian Kaibab Limestone to its present base level, El. 3095, at the Colorado River. The topographic gradient is about 12 percent in the first 2 miles, and then drops steeper, about a 19-percent gradient, in the final mile (Topography, 2001). This may be due to softer beds within the Kaibab Limestone. The tributary's drainage area is 52.24 km^2 (20.2 mi^2) (Webb, et al, 2000).

In appendix C, photographs 3 through 6 and photoragphs 8 and 9 show the debris fans for both Jackass and Badger Canyons. Over time, debris fans have coalesced to partially fill the Colorado River channel, thus restricting flow and creating the Badger Creek rapids. Due to the low flow conditions, little reworking and sediment shifting of these deposits occurs now. Approximately 25 percent of the debris fan volume is reworked and reduced in 10-year cycles as a result of diminished floodflows after the construction of Glen Canyon Dam (Webb, et al., 2000). This means less finer-grained sediment (sand and silt) is winnowed out into the river and redistributed. These debris fans are a composite deposit and are likely interstratified, both with sediment from the tributaries and with sediment transported by the Colorado River upstream.

Based on particle-size gradation, sieve analyses from 41 debris fans that were sampled in the canyon and considered typical[2], a typical debris fan consists, by weight, of 4 percent fines, 18 percent sand, 41 percent pebbles (gravels), 24 percent cobbles, and 13 percent boulders. These percentages appear to be a reasonable assumption for the Jackass Canyon debris fan, and they roughly match the well-graded (poorly sorted) character of the sediments as seen from a distance. The estimated reach B (RM 0.9 to 61.5) mean sand particle sizes are 0.13 mm, 0.20 mm, and 0.29 mm for the D_{20}, D_{50}, and D_{80} sizes, respectively (Webb et al., 2000).

Little is known about the vertical morphology and lithology of this debris fan. Visually, at a distance, the deposit consists of unconsolidated, probably well-graded gravel with sand and silt, cobbles and boulders, and rock blocks. In simple terms, this is sandy gravel with cobbles and boulders. A visual estimate, from 700 feet above the river, estimatesthe debris fan to be roughly 30 feet thick, although it could be much more. Fine, sand-sized particles are probably derived primarily from the Glen Canyon Group sandstones and siltstones, and the larger fragments are probably composed chiefly of Kaibab Limestone cobbles and boulders.

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[2] The 41 fans were aggrading between 1965 and 1999 and are not necessarily located near Jackass Canyon (Webb et al., 2000)

Colorado River to Rim of Marble Canyon

From the Colorado River to the rim of Marble Canyon, the first directional drill hole (figure 2-3) would begin at the location of the Rim Pumping Plant through the Permian Kaibab Limestone. Approximately 1,100 feet of Kaibab Limestone and, possibly, some Toroweap Formation and Coconino Sandstone would be encountered in the drill hole. The geologic formations (units) in this area are approximately horizontally bedded. The limestone is moderately hard to hard with interbedded chert lenses. The unit shows some desert varnish on some surfaces.

The Kaibab Limestone observed at the surface is jointed with the primary joint sets oriented (striking) northwest-southeast and the other set striking about normal (northeast-southwest). Both sets are vertical to steeply dipping. These joints reflect the tensional stresses and associated faulting and fracturing associated with the monoclinal folding of the East Kaibab and Echo Cliffs structures. Some large, stress-relief joints marginal to the rim of Jackass Canyon (southeast strikes) were open from 0.1 foot several feet. Most likely, the large crevasses were opened by solutioning and to a lesser extent, by movement. Openness of joints and bedding planes is expected to decrease as elevation decreases towards the river. Lost circulation zones in joints or along solutioned bedding planes in the limestone should be anticipated while drilling. A thick, air-foam drilling fluid may be required for drill fluid returns.

Rim of Marble Canyon (Rim Pumping Plant) to Echo Cliffs Foothills (Echo Pumping Plant)

From the Jackass Pumping Plant to the Echo Pumping Plant, the pipeline would traverse the Kaibab Limestone flats as shown in photographs 1 and 2 in appendix C. The limestone will require rock trenching. Very little soil development is apparent until approaching the base of Echo Cliffs east of alternative Arizona State Highway 89. The pipeline could be either pipejacked below the road or the road could be cut and recovered.

From about Arizona State Highway 89, east 1 mile, the pipeline excavation would rise towards the Echo Pumping Plant in the foothills, through moderately soft to very soft, slope-forming, reddish-brown sandstone, siltstone, shale, and mudstones (Triassic

Moenkopi Formation and, above that, the Chinle Formation [Chronic,1983]). The Moenkopi overlies the Kaibab Limestone and crops out, dipping gently eastward at the base of Echo Cliffs. The excavation should be accomplished here and through the overlying Chinle Formation by common methods. Gypsum seams in the Moenkopi may require some treatment, as they tend to be soluble, especially if present in the pumping plant foundation.

If present in this area, the basal portion of the Chinle Formation may include a layer of coarser pebbles and cobbles, which make up the Shinarump Conglomerate. This unit is more resistant and could present tougher digging. As shown on the 1960 geologic map of Coconino County, Arizona (R.T. Moore, E.D. Wilson, and R.T. O'Haire), the Chinle Formation overlies the Moenkopi and is capped by the Glen Canyon Group sedimentary rocks. This map shows an outcrop of the Shinarump in the pipeline alignment and pumping plant area. The unit contacts cannot be precisely pinpointed for this appraisal report. Also, as shown in Chronic (1983), there may be some outcrop blocks of the Moenkopi or Chinle Formation at the base of Echo Cliffs, which have rotated along curved failure planes. Whether or not these landslide slumps are present here and still active; whether they have a bearing on the pipeline, pumping plant design, and construction; or whether they have an advancement and integrity of the directional borehole and pipeline remains to be identified. Beside the Moenkopi, the Chinle is also fossiliferous and famous for its fossilized trees (petrified wood).

Echo Cliffs Foothills (Echo Pumping Plant) to Summit of Echo Cliffs

The directional drill hole bore from the summit of Echo Cliffs (figure 2-4) to the Echo Pumping Plant may require excavation to create a sufficient vertical face to allow the drill bit to exit and daylight above ground level.

The drill hole site is on the Kaibito Plateau. This flat area, and the Glen Canyon Group as a whole, dips about 4 degrees eastward (R.T. Moore, E.D. Wilson, and R.T. O'Haire, 1960 geologic map). It is characterized at the surface by the salmon-colored, eolian, cross-bedded Navajo Sandstone of the Glen Canyon Group. An existing dirt road would allow fairly good access from alternate Arizona State Route 89 to the drill site and minimize ground-disturbing activity.

Roughly 4,000 feet of the Mesozoic Glen Canyon Group, and probably the Chinle Formation towards the bottom, would be encountered in the drill hole bore. The Glen Canyon Group consists of red sandstones and mudstones of four mapable formations. In descending order, from younger to older, they are: Navajo Sandstone, Kayenta Formation, Moenave Formation, and the Wingate Sandstone (Nations and Stump, 1981).

These units vary in hardness but in general are a little softer (predominantly moderately hard) and would drill a little easier than the Kaibab Limestone. Some bit deflection should also be anticipated in this directional hole due to alternating harder and softer beds. Lost drill fluid circulation zones would be of less a concern than in the Kaibab Limestone, where solutioning is more prevalent. The Navajo and Wingate Sandstone units tend to be the cliff formers, whereas the softer, slope-forming units are probably represented by the Moenave and Kayenta Formations, which have more mudstone. According to Nations and Stump (1981), Wingate and Moenave are predominantly red, orange, and brown shale and sandstone. The Wingate is also cross-bedded and may not be clearly visible from Highway 89. The Kayenta is composed of red-brown to purple sandstone and mudstone (claystone and siltstone) with some limestone interbeds. These units are known to contain vertebrate skeleton fossils and tracks of dinosaurs.

Summit of Echo Cliffs to Kaibito

From the top of Echo Cliffs, the pipeline would extend southeast to Kaibito in a trench excavated into the Navajo Sandstone, or perhaps into remnants of the San Rafael Group sandstones. Excavation and constructability in the San Rafael should be comparable to that of the Navajo Sandstone. Common excavation methods should suffice for much of the trench alignment, although areas of rock excavation should be expected.

Numerous isolated, low-lying outcrops of the Navajo Sandstone were evident from the helicopter. Much of the pipeline alignment would start in barren rock. It was estimated from the air that a thin soil cover (approximately 1 foot to 10 feet thick) of surficial soils and colluvium might fill local swales and depressions. These areas may show a mixed soil and rock profile in the trench. In some places the Jurassic sediments from the San Rafael Group may be the geologic unit excavated.

To reduce ground disturbance, for this preliminary appraisal, the pipeline route was placed generally along ground surface contours to try to keep the route as level as possible and follow along the existing network of vehicle trails as much as practical. Alignment trends along contours from the top of Echo Cliffs, along the base of Circular White Ridge, are shown in figure 2-5. The Kaibito Pumping Plant would be constructed immediately east of the point where the pipeline crosses Copper Mine Road, Indian Route 20.

About 7 miles down the pipeline from Kaibito Pumping Plant, a water storage tank would be constructed, benchmark 6085, as shown on figure 2-5.

2.3.9 Estimated Costs

Nonconstruction contract activities are usually based on a percentage of construction costs. Typical costs for this alternative are shown in table 2-3.

Table 2-4.—Typical costs of nonconstruction activities

Activity	Percent of construction costs
Planning	5.0
Investigations	3.5
Design and specifications	3.0
Contract administration	7.0
Cultural resources	1.0
Environmental permits	5.0
Total	24.5

The estimated costs for this alternative are summarized in table 2-4. These costs are based on previous studies performed in the area. The estimate does not include all noncontract costs.

Table 2-5.—Summary of construction costs

Q = 11.34 ft³/s (5,700-AF scenario)

	Jackass	Rim	Echo	Gravity 1	Kaibito	Gravity 2	Subtotal	Mobilization 5%	Construction cost (unlisted items)[1] 15%	Field cost (contingencies[2]) 25%	Project cost (non-contract) 24.5%
Pumping plant	$1,000,000	$1,035,000	$1,950,000	$0	$1,225,000	$0					
Power line	$800,000	$400,000	$2,400,000	$0	$200,000	$0					
Pipe	$32,997	$256,925	$147,548	$1,478,318	$803,758	$2,781,240					
Pipe excavation	$0	$399,380	$0	$1,957,613	$532,857	$1,590,075					
Pipe backfill	$0	$254,505	$0	$251,188	$73,572	$224,296					
Pipe CBF[3]	$0		$0	$300,580	$77,395	$224,284					
Directional drill	$1,360,000	$0		$0	$0	$0					
Storage tank	$0	$130,000	$1,300,000	$1,290,000	$130,000	$600,000	**$26,657,380**	**$27,990,249**	**$32,188,786**	**$40,235,982**	**$50,093,795**

Q = 22.68 ft³/s (11,400-AF scenario)

	Jackass	Rim	Echo	Gravity 1	Kaibito	Gravity 2	Subtotal	Mobilization 5%	Construction cost (unlisted items)[1] 15%	Field cost (contingencies)[2] 25%	Project cost (non-contract) 24.5%
Pumping plant	$1,400,000	$1,873,000	$3,090,000	$0	$1,225,000	$0					
Power line	$800,000	$400,000	$2,400,000	$0	$200,000	$0					
Pipe	$63,047	$1,663,903	$375,517	$2,441,489	$1,437,581	$4,551,319					
Pipe excavation	$0	$444,980	$0	$1,957,613	$656,565	$1,949,715					
Pipe backfill	$0	$59,898	$0	$251,188	$86,342	$262,446					
Pipe CBF	$0	$66,280	$0	$300,580	$99,587	$290,412					
Directional drill	$2,720,000	$0	$4,640,000	$0	$0	$0					
Storage tank	$0	$130,000	$130,000	$3,010,000	$130,000	$600,000	**$39,612,582**	**$41,593,212**	**$47,832,193**	**$59,790,242**	**$79,438,851**

[1] Unlisted items include small cost items, such as air valves, fittings, etc.

[2] Contingencies are for construction modifications, quality overruns, or changed site conditions.

[3] Compacted backfill

2.4 Other Alternatives for Obtaining Water from the Marble Canyon Area

Two other possible avenues for diverting Colorado River water were discussed but not pursued, due to limited time to complete the report. These are: (1) construct an infiltration gallery on the west side of the Colorado River at Lees Ferry, route a pipeline across the Navajo Bridge, and then tie into the future alignment to Kaibito through the Echo Cliffs area; or (2) instead of constructing a pumping plant at the Jackass Canyon site, use a submersible pump in the directional drill hole and connect directly to the infiltration gallery. Maintenance of the submersible pump would be similar to a vertical well.

2.5 Conclusions

The infiltration gallery option provides one method for diverting water from Marble Canyon with relatively minimal environmental impacts. The reliability of the infiltration gallery and the actual permeability of the debris still must be addressed. Infiltration galleries have been successfully used in locations where large amounts of sands and gravels are available in sufficient depths to provide a natural filtration system without plugging.

The Ranney Corporation has constructed numerous "Ranney Collectors" (infiltration galleries) throughout the country that have performed satisfactorily for many years. The site also appears to have the soils and topographic conditions necessary to construct an infiltration gallery. On-the-ground mapping or reference to more detailed geologic maps would be necessary for feasibility designs. An obvious first task to help delineate the top of rock and debris thickness would be one, or several, noninvasive geophysical seismic refraction or ground penetrating radar survey transects. The possibility also exists for a vertical well to be used to obtain water from this area. Based on the site visit and literature studies, no insurmountable geologic conditions were identified that should preclude consideration of the Jackass Canyon infiltration gallery alternative or similar variations.

Chapter 3

RESOURCES EVALUATION

Construction of one of the alternative pipeline projects would be subject to Federal environmental laws and regulations. This chapter presents a reconnaissance level evaluation of resources in the study area. Impacts cannot be analyzed without more specific information. However, this chapter discusses issues of concern for each resource.

3.1 Biological Resources

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 (NESL) which was created and distributed by the Navajo Natural Heritage Program's Department of Fish and Wildlife.

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 would 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 U.S. Fish and Wildlife Service (Service), the State game and fish agency, and the Federal land management agency on whose lands the project will occur. Since this project is within the Navajo Nation and Grand Canyon National Park, it is anticipated that this consultation would be among the action agency, the Navajo Nation Department of Fish and Wildlife, Grand Canyon National Park Science Center, and the Service. The consultation would consider effects to nonlisted 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[3]. In addition, discussions with the Navajo Nation, the Park, 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 must be close consultation with the Service, the Navajo Nation, and the Park 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.

[3] The Humpback Chub and Flannelmouth Sucker may also be species of concern.

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. Condors 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. Condors frequent Marble Canyon throughout the year, especially during the winter after they have left the higher elevations in the park. They are attracted to human activity and trash and are commonly seen on fishing and camping beaches with access from the rim in Marble Canyon.

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

NESL Status: None   Federal Status: Threatened

Wintering Bald Eagles commonly occur in Marble Canyon and may perch and forage in the project 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 15-60 meters of occupied habitat (if a stream), or 60 meters (if 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 1/4 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 Navajo Nation lands and the Service guidelines for segments of the pipeline off the Navajo Nation. According to 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 Lees 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 Lees 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; however, it may vary, 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 usually nest on steep cliffs (typically 30 meters high), although shorter cliffs (at least 10 meters high) are infrequently used. The recommended survey period is from March 1 through June 15. The Navajo Nation recommends no activity within 1/2 mile to 1 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 that surveys be conducted between March 1 and June 15. The guidelines also recommend no disturbance within a 1/2 mile of an active nest site during March 15 through July 15 for brief activity; 5/8 of a mile for light activity, 3/4 of a mile for heavy activity; and 1 mile for long-term and loud activity. Activity can commence 30 days after fledging.

9. **Yellow-Billed Cuckoo** (*Coccyzus americanus*)

NESL Status: G3 Federal Status: Candidate

The Yellow-Billed Cuckoo nests in 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 1/4 mile of habitat patches used for breeding, or potential habitat, until surveyed.

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

NESL Status: G3 Federal Status: None

Pronghorn can 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

Bighorn 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 bighorn have been documented in 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 rimrock 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; however, it may vary, 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 El. 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; however, it may vary, 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 and El. 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; however, it may vary, 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 stream 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 Navajo Nation where suitable habitat occurs. The recommended survey period is from July to August. A 200-foot buffer zone is recommended to avoid disturbance; however, it may vary, 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 between April 15 and August 15. A buffer may vary, depending on the activity type and duration, but not be less than 0.1 kilometer.

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 1/8 of a mile of an active nest from April 15 to July 31. Extreme disturbance (e.g., blasting) may require a larger buffer. In addition, 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 that 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 manmade 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 from 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 an occupied roost site from 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; however, the milk snake could potentially 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 sketchy, 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. and 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 El. 1900 meters. Its presence has not been confirmed by 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; however, it may vary, 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 El. 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; however, it may vary, 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, 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; however, it may vary, 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 El. 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; however, it may vary, 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. Known populations are from El. 4250 to El. 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; however, it may vary, depending on slope, size and nature of the project.

27. **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; however, it may vary, depending on slope, size and nature of the project.

3.2 Recreation and Aesthetics

3.2.1 Existing Conditions

The Grand Canyon is recognized as a place of universal value, containing superlative natural and cultural features. It is unusual in meeting both natural and cultural resource criteria for designation as a World Heritage Site. The Grand Canyon is internationally recognized for its scenic vistas. Its ever-changing and colorful scenery make it one of the world's most spectacular natural areas. The great variety of scenery includes canyons, deserts, plains, plateaus, streams, waterfalls, and geologic/volcanic features. National Park Service is tasked with management responsibility to preserve and protect its natural and cultural resources, ecological processes, and scenic and scientific values.

The Colorado River through the Park, the longest stretch of recreational whitewater in the world, offers one of the most sought-after river trips in the United States.[1]

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[1] Colorado River Management Plan for Grand Canyon National Park, NPS, 1989

Badger Creek Rapid is formed by the debris fan emanating from Jackass Canyon and is the first major rapid encountered by river parties boating down the Grand Canyon.

Jackass Canyon is a rugged sandstone canyon that steeply descends from Highway 93 to the Colorado River. Scenic slot canyons like Jackass Canyon are relatively few in number on the Colorado Plateau; therefore, Jackass Canyon is singled out for description in several hiking guides for the area. Hiking Jackass Canyon requires a permit from the Navajo Tribe. The canyon is also used by tribal members to access the river for fishing.

3.2.2 Potential Effects

Short Term

It is expected that construction of the directional drill hole, infiltration gallery, and pumping plant would take approximately 3 months. During construction, there would be short-term impacts to boaters on the Colorado River and to hikers and fishermen that descend Jackass Canyon. Heavy construction equipment would need to be helicoptered in or barged downriver to the debris fan emanating from Jackass Canyon.

Construction of the infiltration gallery and pumping plant would require excavating a 200-foot by 200-foot area on the debris fan, which would create substantial noise and dust. Use of the debris fan area for camping and fishing would be restricted and aesthetically displeasing.

Most boaters will not appreciate having to view a construction zone as they begin their whitewater experience in what is supposed to be the wilderness of the Grand Canyon. Some parties stop on the opposite shore to scout their way through the rapid and would spend even more time with the construction zone in view.

The number of hikers and boaters impacted by construction would be decreased if the facilities were constructed during the winter.

Long Term

The infiltration gallery, directional drill hole, and rim storage tank would not be visible to rafters on the river or hikers or fishermen descending Jackass Canyon. The pumping plant could blend in with the surrounding terrain on the debris fan but would be visible. Rafters floating by would probably not notice the pumping plant; however, rafters stopping to scout the rapid, as well as the hikers and fishermen that descend Jackass Canyon, would likely notice the pumping plant. Because of the noise of the rapid, rafters would not be expected to hear the pumping plant in operation. However, hikers, especially those desiring to camp in the area of the debris fan, would likely notice the noise and be bothered by it.

3.3 Wilderness

3.3.1 Existing Conditions

More than 1 million acres in the Park meet the criteria for wilderness designation and are proposed as wilderness; the Colorado River through Grand Canyon is proposed potential wilderness[4]. According to NPS policies, proposed and proposed potential wilderness are to be managed "in expectation of eventual wilderness designation" and the Park is directed to "take no action that would diminish the wilderness suitability of any area possessing wilderness characteristics" (NPS Management Policies 2001, 2000. U.S. Department of the Interior. Washington, D.C 137 pp). In the area for the proposed infiltration gallery and pumping plant, the river corridor and the canyon slopes from the river to the rim are managed by NPS as "potential wilderness."[5]

The Colorado River and most of its tributaries in the Park meet the criteria for wild river designation as part of the National Wild and Scenic River System. NPS is in the process of completing the eligibility study for the tributaries and the mainstem.

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[4] Final Wilderness Recommendation, 1993 Update, Grand Canyon National Park, Arizona, National Park Service, U.S. Department of the Interior.

[5] The Navajo Nation does not recognize the location of the Park boundary 1/4 mile east of the river on the east side.

3.3.2 Potential Effects

Locating an infiltration gallery and pumping plant on the debris fan emanating from Jackass Canyon would be inconsistent with wilderness values. Designation of this area as "proposed potential wilderness" would have to be reconsidered.

It is unknown wether or not construction of the infiltration gallery and pumping plant would impact the eligibility of this stretch of the river for designation as wild and scenic.

3.4 Cultural Resources

The identification, eligibility assessment, and mitigation of construction effects to cultural resources are important parts of any future planning phase for the proposed Peabody Coal Lower Basin Project. At this early level of project planning, however, only some general assumptions and observations can be provided concerning cultural resource issues.

Cultural resources include both prehistoric and historical sites, as well as traditional cultural properties, sacred sites, and cultural landscapes. The Section 106 process, defined in the 1966 National Historic Preservation Act (NAPA) and subsequent amendments to it, is designed to ensure that cultural resources are considered during project planning. A critical aspect of the Section 106 process is the determination of which cultural resources meet certain criteria that make them historic properties and, therefore, eligible for nomination to the *National Register of Historic Places (National Register)*. Any project that is federally funded, licensed, or permitted requires the lead Federal agency to take into account how project impacts affect historic properties and how to mitigate impacts to the properties.

The Section 106 process consists of five steps: (1) identify and evaluate historic properties; (2) assess effects; (3) consult with the State and/or Tribal Historic Preservation Officer; (4) obtain comment by the Advisory Council on Historic Preservation (ACHP); and (5) proceed with the activity. Revisions to the 1966 NHPA have streamlined the process by encouraging greater consultation among the lead agency, interested parties, and, in the case of the Peabody Coal Lower Basin Pipeline Project, the Navajo Nation Tribal Historic Preservation Office (NNTHPO), with minimal input by the ACHP.

3.4.1 The Section 106 Process

Identify and Evaluate Historic Properties

The lead Federal agency reviews all available information about the cultural resources in the project area, including traditional cultural properties (TCPs), sacred sites, and cultural landscapes. If adequate data are not available, intensive cultural resource and, if required, ethnographic surveys are conducted to provide these data. All cultural resources are evaluated in terms of their significance, and any properties eligible for the listing in the *National Register* are identified.

Assess Effects

The lead agency determines which eligible historic properties will be affected by the proposed activity. In consultation with the NNTHPO, the agency determines whether there is a "No Effect," "No Adverse Effect," or "Adverse Effect" to the properties. A "No Effect" determination means that the project will not impact any eligible properties and the project can proceed. A "No Adverse Effect" determination means that there could be an effect, but that it is not harmful, and with NNTHPO (and possibly ACHP) concurrence, the project proceeds. A finding of "Adverse Effect" means the historic property or properties will be harmed. The agency initiates consultation with the NNTHPO (and possibly the ACHP).

Consultation

The lead agency looks at acceptable methods to mitigate the harmful effects of its project to the historic properties. The agency develops a mitigation plan to reduce or eliminate the harmful effects and seeks concurrence from the NNTHPO (and possibly the ACHP) to implement the mitigation plan well in advance of the construction activity. An acceptable mitigation alternative results in a Memorandum of Agreement (MOA) between all consulting parties that stipulates the steps that will be taken to reduce the harmful effects to the historic properties.

ACHP Review and Comment

Unless the ACHP was a consulting party to the development of the MOA, the lead agency requests the ACHP to review and comment on the signed MOA. If an acceptable mitigation plan cannot be agreed upon, the ACHP issues written comments to the head of the agency.

Proceed with Activity

If the Section 106 process results in a signed MOA, the lead agency proceeds with the terms of the MOA. Without a signed MOA, the lead agency must take into account the ACHP's written comments and decide about how (or whether) to proceed with the proposed activity.

3.4.2 Timeframes

The amount of time required to complete any surveys or other investigations needed to identify and evaluate cultural resources is dependent on any number of variables: project size, amount and accuracy of previous research in the project area, number and kind of cultural resources, available funding, and so forth.

Once the lead agency has initiated consultation with the NNTHPO, the NNTHPO has 30 days from the time it receives the consultation request (for example, a request to review a survey report and concur with cultural resource *National Register* eligibility determinations, or to review and comment on or sign an MOA) to respond to the lead agency. When an agency submits a signed MOA to the ACHP for review, the ACHP has 30 days in which to reply. If there is no MOA, the ACHP has 60 days from receipt of pertinent documentation to respond to an agency's request for comments.

Mitigation requirements may involve a considerable amount of effort and time to carry out. To avoid construction delays, it is important to begin cultural resource investigations as early as possible in the planning process.

3.4.3 Minimum Cultural Resource Requirements for the Peabody Coal Lower Basin Pipeline Project

At this early stage of the project, it is not possible to provide specific information on the number and kinds of cultural resources that will be affected by the proposed pipeline project. Suffice it to say, the area through which the proposed pipeline may be constructed is rich in prehistoric and historic cultural resources going back perhaps as far as 10,000 years. A project of this magnitude will have an adverse affect on cultural resources. Until reasonably reliable maps are available that show the proposed pipeline route(s), any attempt to try to quantify what is currently known about cultural resources in the project area is not recommended. Once reasonably reliable maps are available, a site records check can be undertaken to determine what is known about the cultural resources along the proposed route(s), as well as some idea of potential cultural resource issues.

At some point, intensive class III surveys must be undertaken along the preferred pipeline route. Other areas that can be identified as necessary for construction (staging areas, contractor use areas, borrow areas, and so forth) will also need to be surveyed. Consultation with affected Native American groups (and possibly other non-Indian groups, such as Mormons) to identify traditional cultural properties and sacred sites must be initiated early in the planning process. An ethnographic survey for traditional cultural properties and sacred sites may be required. Once the surveys are completed, the identified sites will be evaluated in terms of their significance and eligibility for nomination to the *National Register*.

Avoidance of historic properties is the preferred mitigation option. When avoidance is not possible, the next option is usually data recovery through excavation, artifact analysis, and publication of a final report.

3.4.4 Potential Cultural Resource Costs

It is too early in the project to provide more than very general guidelines about the costs for completing the required cultural resource investigations. Many factors can affect the cost, and much depends on the final pipeline route. Under ideal conditions (for example, level terrain, low site density, good access and ground visibility, good weather), the standard for survey is 40 acres per person per day (ppd). As field and other conditions deteriorate, this figure can be reduced as low as 10 acres ppd. Again, assuming reasonably good field conditions exist, per-acre costs range from $20 to $75+. The more isolated, inaccessible, and rugged the project area, the higher the per-acre cost. There are other factors that can also increase per-acre cost, such has high site density requiring considerable recording time.

The potential cost for identifying TCPs and sacred sites is more difficult to determine. The size of the project area will be an important factor. On the Navajo Reservation, Elders and Medicine Men from each Chapter through which the pipeline crosses will likely need to be consulted. This can involve numerous meetings and can be very time consuming.

Finally, by law, up to 1 percent of project cost can be expended for cultural resource mitigation. The preferred, and least costly, mitigation option is avoidance. If avoidance is not possible, then excavation is the usual mitigation solution. Usually, only samples of the significant cultural resources that will be directly or indirectly affected by project construction are excavated as mitigation. However, this sample can include a large number of sites on projects that affect hundreds of significant cultural resources. If the 1-percent limit needs to be exceeded in order to complete mitigation requirements, a petition can be filed with the NPS' Consulting Archaeologist to exceed the 1-percent ceiling.

Current construction cost estimates for the pipeline range from $38 million to $58 million, making between $380,000 and $580,000 available for cultural resource mitigation (this does not include any survey costs).

3.5 Social Analysis and Environmental Justice

3.5.1 Existing Conditions

To the greatest extent practicable and permitted by law, and consistent with the principles set forth by the National Performance Review, each Federal agency shall make achieving environmental justice part of its mission by identifying and addressing, as appropriate, disproportionately high and adverse human health or environmental effects of its programs, policies, and activities on low-income and minority populations in the United States and its territories and possessions. Environmental justice and equity includes the fair treatment of people of all races, cultures, incomes, and educational levels with respect to the development, implementation, and enforcement of environmental laws, regulations, and policies. Fair treatment implies that no racial, ethnic, or socioeconomic group should bear a disproportionate share of the negative environmental consequences resulting from the operation of industrial and commercial enterprises and from the execution of Federal, State, and local programs and policies.

3.5.2 Potential Effects

This section discusses whether the proposed facilities would have a disproportionately high and adverse effect on human health or environmental effect on minority or low-income populations. Before it can definitively be stated that there are no environmental justice impacts, it will be necessary to analyze the impacts of the overall project, and not just this segment. While construction activities associated with this project will principally affect minority populations, these same populations will also benefit in terms of job creation, etc. Additional assessment will be required.

3.6 Indian Trust Assets

3.6.1 Existing Conditions

Indian Trust Assets (ITAs) are legal interests in assets held in trust by the U.S. Government for Indian Tribes or individual Indians. Assets are anything owned that has monetary value. The asset need not be owned outright, but could be some other type of property interest, such as a lease or a right-of-use. Assets can be real property, physical assets, or intangible property rights. Common examples of ITAs include lands, minerals, water rights, hunting rights, and rights to other natural resources, or claims. The United States, with the Secretary of the Interior as the trustee, holds many assets in trust for Indian Tribes or individual Indians.

Legal interest means there is a primary interest for which a legal remedy, such as compensation or injunction, may be obtained if there is improper interference with the ITA. ITAs do not include things in which a Tribe or individuals have no legal interest, such as off-reservation lands defined as sacred by an Indian Tribe, in which the Tribe has no legal property interest.

The United States has an Indian trust responsibility to protect and maintain rights reserved by, or granted to, Indian Tribes or individual Indians by treaties, statutes, and Executive Orders, which rights are sometimes further interpreted through court decisions and regulations. This trust responsibility requires that all Federal agencies take actions reasonably necessary to protect ITAs.

3.6.2 Potential Effects

Since the pipeline facilities would be located principally on Navajo Reservation lands, there would be some ITA impacts. However, it is anticipated that acceptable mitigation can be found.

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APPENDIX A

Construction Costs

Annual Operation, Maintenance, Replacement and Energy Costs

The Reclamation computer program PMPOM generated annual operation, maintenance, replacement, and energy (OMR&E) costs for pumping plants. The computer program is derived from information in *A Guidelines for Estimating Pumping Plant Operation and Maintenance Costs*, at by John Eyer; 1965, Bureau of Reclamation. 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 x Eff)

Where: HP = Horsepower
Q = Flow in ft3/s
H = Pump head in feet
Eff = 0.8 (Assumed combined pump and motor efficiency)

kW = 0.746 HP

Where: kW = Kilowatts of energy

For each alternative, Reclamation was given the annual diversion in acre feet/year and the peak flow requirement in cubic feet /second. After converting the peak flow requirement to acre feet/year, Reclamation determined that the annual diversion could be delivered by pumping at the peak demand for100 percent of the time (total hours in a year). The energy cost was determined using a rate of 55.5 mils/kW-hr, a demand charge of $15.4/kW-month and a service pass thru of 0.5 mils/kW-yr. This gives an average cost of power per kW equal to:

Energy cost ($/year) = $.081 * kW

This cost was based on Southern California Edisons's input on approximate energy costs they are currently paying. An energy cost of 65 mils was used by HKM Engineering in a recent North Central Arizona Water Supply Study. Both numbers were included in the report to give a range of possible costs until a firm energy cost number can be determined

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 ft^3/s 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, it 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 7000 horsepower (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 operation and maintenance costs for pipelines can be determined as a percentage of the initial costs. These vary from 0.25 to 0.50 percent of the initial pipe cost. Pipeline maintenance represents a very small portion of the OMR&E cost for the system and a detailed analysis of this item was judged to be unnecessary.

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 2 years.

Table A-1.—Summary of Pumping Plant OMR&E Costs

Q=11.22 ft^3/s

Option / Item	Jackass Creek diversion	Rim Pumping Plant	Echo Cliffs	Kaibito Pumping Plant	Total annual costs
Annual operation	$11,132	$10,371	$13,439	$8,835	$43,777
Maintenance	$66,653	$59,609	$89,698	$46,294	$262,254
Energy costs	$223,239	$170,126	$460,923	$91,958	$945,616
Totals	$301,024	$240,106	$564,060	$147,087	$1,251,647

Q=22.68 ft^3/s

Option / Item	Jackass Creek Diversion	Rim Pumping Plant	Echo Cliffs	Kaibito Pumping Plant	Total annual costs
Annual operation	$15,555	$14,622	$18,785	$12,390	$61,352
Maintenance	$97,599	$88,530	$131,422	$68,179	$385,730
Energy costs	$453,244	$357,349	$936,343	$188,720	$1,935,656
Totals	$566,398	$460,501	$1,086,550	$269,289	$2,382,738

APPENDIX B

Hydraulic Calculations

		TOTAL Q =	11.34	CFS			
OPERATING COSTS							
Site		JACKASS PP	RIM PP	ECHO PP	GRAVITY1	KAIBITO PP	GRAVITY2
Construction Method		Drill + Overland	Overland	Drill	Overland	Overland	Overland
Pipe dia. (in)		12	24	12	24	24	21
Q(CFS)		11.34	11.34	11.34	11.34	11.34	11.34
Velocity		14.4	3.6	14.4	3.6	3.6	4.7
Total Length		1400	19000	3000	68640	25350	83250
Overland		0	19000	0	68640	25350	83250
Drill		1400	0	3000	0	0	0
Friction Loss	143	60.52	28.09	129.69	94.03	37.48	235.81
Begin El		3120	3850	4400	5905	5810	6085
End El.		3850	4400	5905	5810	6085	5705
Static Head (ft)		730	550	1505	95	275	380
Begin HGL		3911	4428	6035	5904	6122	6085
End HGL		3850	4400	5905	5810	6085	5705
Pump Lift		791	578	1635	0	312	0
HP		1271	929	2628	0	502	0
KWH		948	693	1961	0	375	0
KW-hr/yr		8,306,288	6,074,174	17,176,253		3,283,286	
Friction/Static		8%	5%	9%	0%	14%	0%
Total Head	feet	791	578	1635	189	312	380
	psi	342	250	708	82	135	165
Thickness	in	0.11	0.16	0.23	0.05	0.09	0.09
Pipe Excavation	cy	0	19969	0	72141	26643	79504
Pipe Backfill	cy	0	16967	0	61296	22638	69014
Pipe CBF	cy	0	3867	0	13971	5160	14952
		Directional	drill using	18.25" hole			
CONSTRUCTION COSTS							
Pumping Plant Cost		$1,000,000	$1,035,000	$1,950,000	$0	$1,225,000	$0
Power Line Costs		$800,000	$400,000	$2,400,000	$0	$200,000	$0
Pipe Cost	$1.50	$32,997	$1,256,925	$147,548	$1,478,318	$903,758	$2,781,240
Pipe Excavation	$20.00	$0	$399,380	$0	$1,442,813	$532,857	$1,590,075
Pipe Backfill	$3.25	$0	$55,143	$0	$199,210	$73,572	$224,296
Pipe CBF	$15.00		$58,008	$0	$209,561	$77,395	$224,284
Directional Drill Costs		$1,360,000	$0	$2,320,000	$0	$0	$0
Storage Tank Costs		$0	$130,000	$130,000	$1,290,000	$130,000	$600,000
Total Construction Costs		$3,192,997	$3,334,456	$6,947,548	$4,619,902	$3,142,582	$5,419,896
ANNUAL COSTS							
Demand Charge	15.400	$175,229	$128,140	$362,348		$69,264	
Service pass thru	0.005	$34,610	$25,309	$71,568		$13,680	
Energy Charge	0.0550	$456,846	$334,080	$944,694		$180,581	
Cost of Power ($/yr)		$666,684	$487,529	$1,378,610		$263,525	
Energy Charge	0.0650	$539,909	$394,821	$1,116,456		$213,414	

Subtotal	Mobilization 5%	Construction Cost Unlisted items 15%	Field Cost Contingencies 25%	Project Cost Non-contract 24.50%
$26,657,380	**$27,990,249**	**$32,188,786**	**$40,235,982**	**$50,093,798**

Total Annual Power Cost

$2,796,348

$2,264,600

OPERATING COSTS		**TOTAL Q =**	22.68	CFS			
Site		JACKASS PP	RIM PP	ECHO PP	GRAVITY1	KAIBITO PP	GRAVITY2
Construction Method		Drill*	Overland	Drill*	Overland	Overland	Overland
Pipe dia. (in)		17	27	17	33	30	27
Q(CFS)		22.68	22.68	22.68	22.68	22.68	22.68
Velocity		14.4	5.7	14.4	3.8	4.6	5.7
Total Length		1400	19000	3000	68640	25350	83250
Overland		0	19000	0	68640	25350	83250
Drill		1400	0	3000	0	0	0
Friction Loss	143	40.06	57.14	85.85	71.99	45.63	250.35
Begin El		3120	3850	4400	5905	5810	6085
End El.		3850	4400	5905	5810	6085	5705
Static Head (ft)		730	550	1505	95	275	380
Begin HGL		3890	4457	5991	5882	6131	6085
End HGL		3850	4400	5905	5810	6085	5705
Pump Lift		770	607	1591	0	321	0
HP		2476	1952	5116	0	1031	0
KWH		1847	1456	3816	0	769	0
KW-hr/yr		16,182,649	12,758,795	33,431,234		6,738,051	
Friction/Static		5%	10%	6%	0%	17%	0%
Total Head	feet	770	607	1591	167	321	380
	psi	333	263	689	72	139	165
Thickness	in	0.15	0.19	0.32	0.07	0.11	0.12
Pipe Excavation	cy	0	22249	0	97881	32828	97486
Pipe Backfill	cy	0	18430	0	77289	26567	80753
Pipe CBF	cy	0	4419	0	20039	6639	19361

*Directional drill using 2 - 18.25" holes and 12" casing pipe

CONSTRUCTION COSTS		JACKASS PP	RIM PP	ECHO PP	GRAVITY1	KAIBITO PP	GRAVITY2
Pumping Plant Cost		$1,400,000	$1,873,000	$3,090,000	$0	$1,225,000	$0
Power Line Costs		$800,000	$400,000	$2,400,000	$0	$200,000	$0
Pipe Cost	$1.50	$63,047	$1,663,903	$281,638	$2,441,489	$1,437,581	$4,551,319
Pipe Excavation	$20.00	$0	$444,980	$0	$1,957,613	$656,565	$1,949,715
Pipe Backfill	$3.25	$0	$59,898	$0	$251,188	$86,342	$262,446
Pipe CBF	$15.00		$66,280	$0	$300,580	$99,587	$290,412
Directional Drill Costs		$2,720,000	$0	$4,640,000	$0	$0	$0
Storage Tank Costs		$0	$130,000	$130,000	$3,010,000	$130,000	$600,000
Total Construction Costs		$4,983,047	$4,638,061	$10,541,638	$7,960,870	$3,835,075	$7,653,891

Subtotal	Mobilization 5%	Construction Cost Unlisted items 15%	Field Cost Contingencies 25%	Project Cost Non-contract 24.50%
$39,612,582	**$41,593,212**	**$47,832,193**	**$59,790,242**	**$74,438,851**

ANNUAL COSTS		JACKASS PP	RIM PP	ECHO PP	GRAVITY1	KAIBITO PP	GRAVITY2
Demand Charge	15.400	$341,387	$269,158	$705,262		$142,145	
Service pass thru	0.005	$67,428	$53,162	$139,297		$28,075	
Energy Charge	0.0555	$898,137	$708,113	$1,855,433		$373,962	
Cost of Power ($/yr)		$1,306,952	$1,030,433	$2,699,992		$544,182	
Energy Charge	0.0650	$1,051,872	$829,322	$2,173,030		$437,973	

Total Annual Power Cost
$5,581,559
$4,492,197

APPENDIX C

Photographs

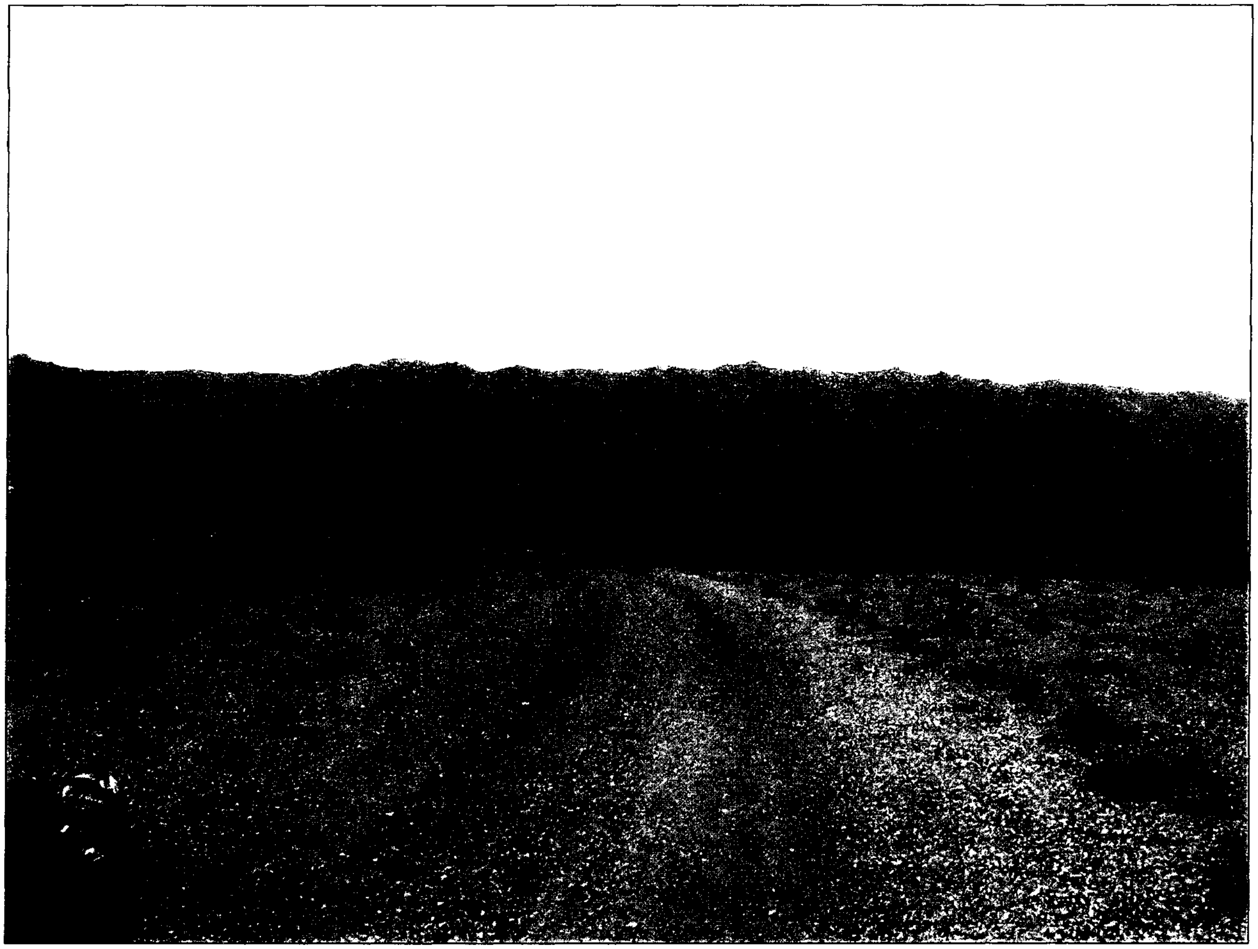

Photo 1.—Looking east towards Echo Cliffs along one possible pipeline alignment from above Jackass Canyon (about 500 feet behind photographer). This road runs along the Permian Kaibab Limestone. The base of the cliffs (foothills) is the Triassic Moenkopi and Chinle Formations, and the cliffs are the younger Glen Canyon Group (in ascending order: Wingate Sandstone, Moenave Formation, Kayenta Formation, and the main cliff former, the Navajo Sandstone).

Photo 2.—Looking west towards Marble Canyon (beyond the engineers pictured) with Vermillion Cliffs in the background, along one possible pipeline alignment. This alignment runs from the mouth of Jackass Canyon (visible at the left) at Colorado RM 8, up the Marble Canyon cliffs adjacent to Jackass Canyon, then along the light colored Kaibab Limestone flats in the foreground, to Echo Cliffs (shown in Photo1) and beyond.

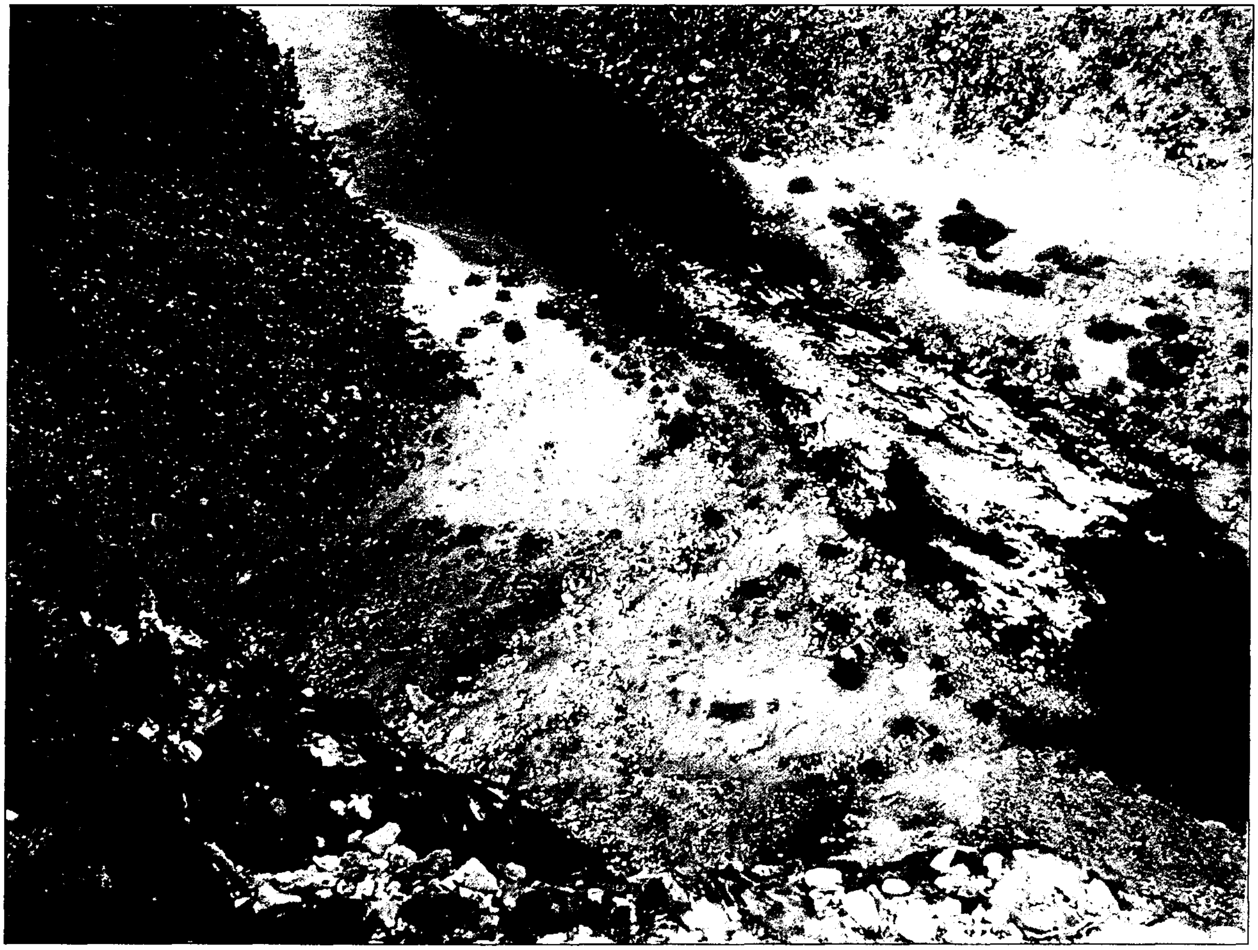

Photo 3.—Looking down at the Colorado River, some 700 feet, into Marble Canyon from its north rim. This is on the north side of Jackass Canyon at RM 8A, at the rapids of Badger Creek. River flow is from right to left. The debris fan exiting Jackass Canyon (the reddish brown gravel, cobbles, boulders and lighter colored delta bar of sand below the river in this picture) links with the debris fan from the mouth of Badger Canyon on the west side (above the river in this picture). Here the bedrock channel is filled with debris and creates the shallow rapids. An infiltration gallery might be constructed on this debris fan, possibly parallel to the rapids. The debris here is estimated to be up to 30-feet -thick, and possibly much more.

The debris is estimated here to be up to 30 feet thick, although it could be much more. Several geophysical refraction survey or E-M type survey transects, or possibly GPR (ground penetrating radar), would be useful in mapping the top of rock and thus the debris thickness. See also photos 5 and 6.

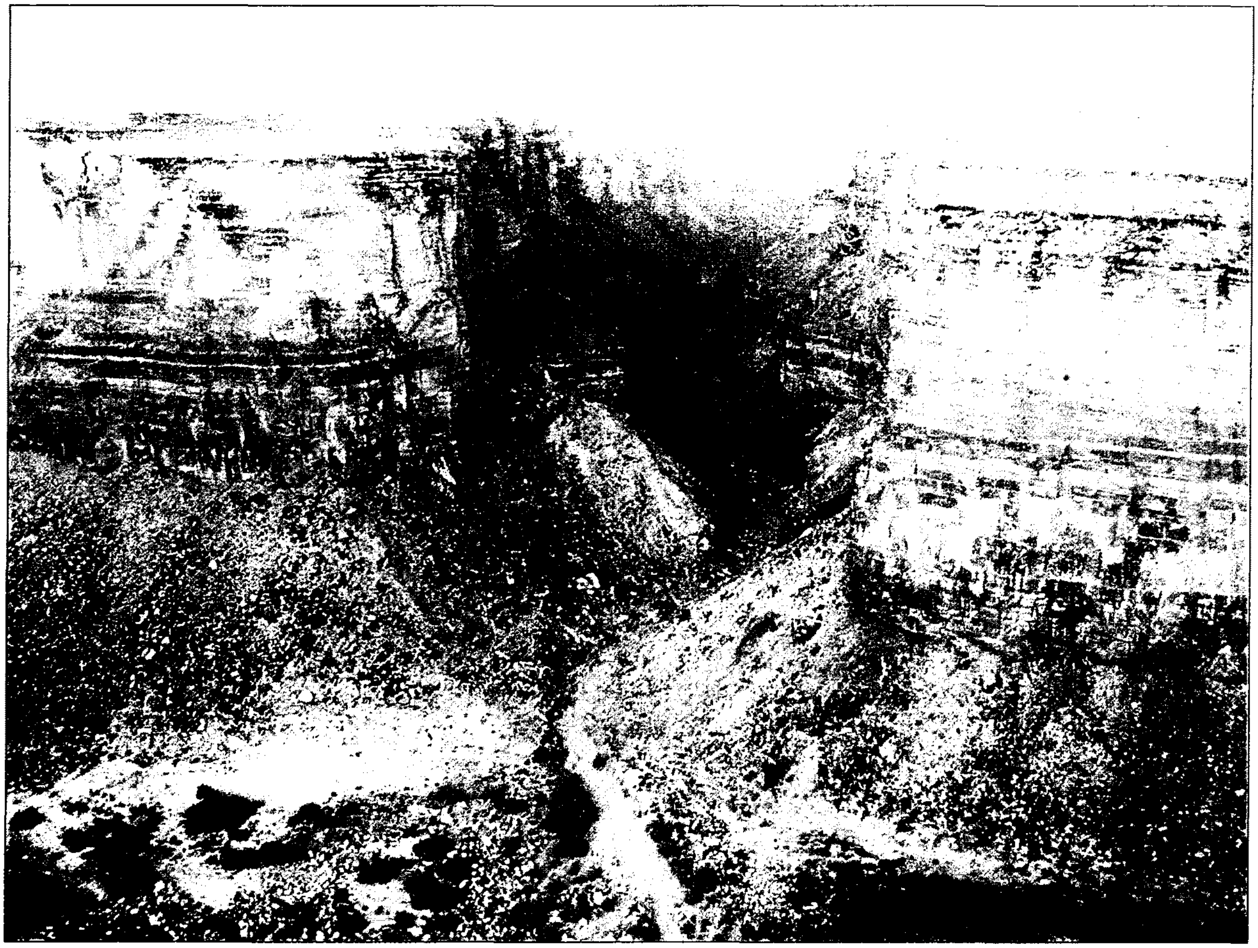

Photo 4.—Looking into Badger Canyon from the north rim of Marble Canyon. Note how well developed the debris is on the west side of the Colorado River. Badger Canyon Creek is running from recent rainfall.


Photo 5.—Another view looking down about 700 feet into Jackass Canyon from the north side, at the debris deposited by the Jackass Creek tributary of the Colorado River. Compared to Photo 3, this photo shows the debris fan extents further upward into the Jackass Canyon. Note the rim rock is jointed Kaibab Limestone.

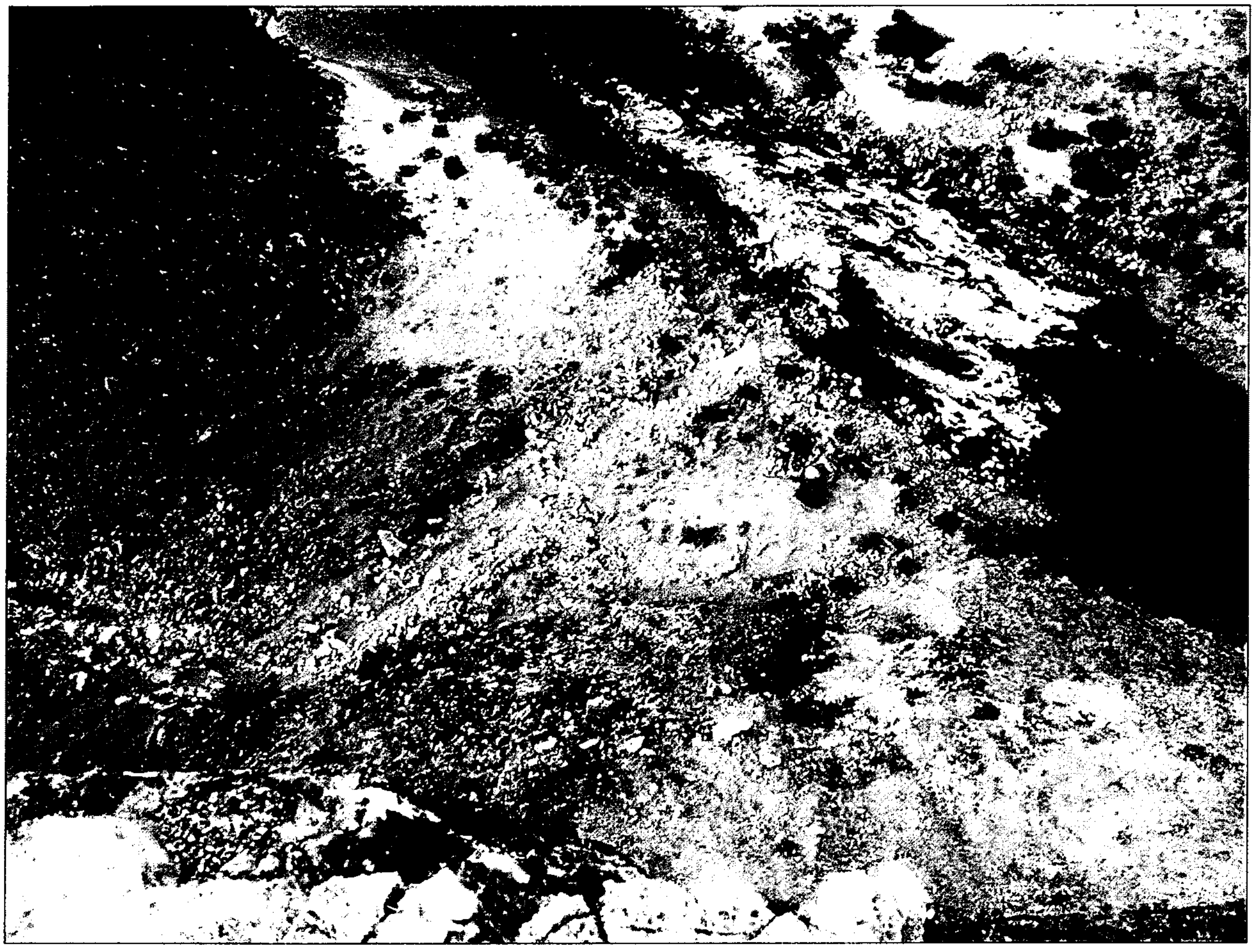

Photo 6.—Similar view to photo 5 looking down about 700 feet into Jackass Canyon from the north side.

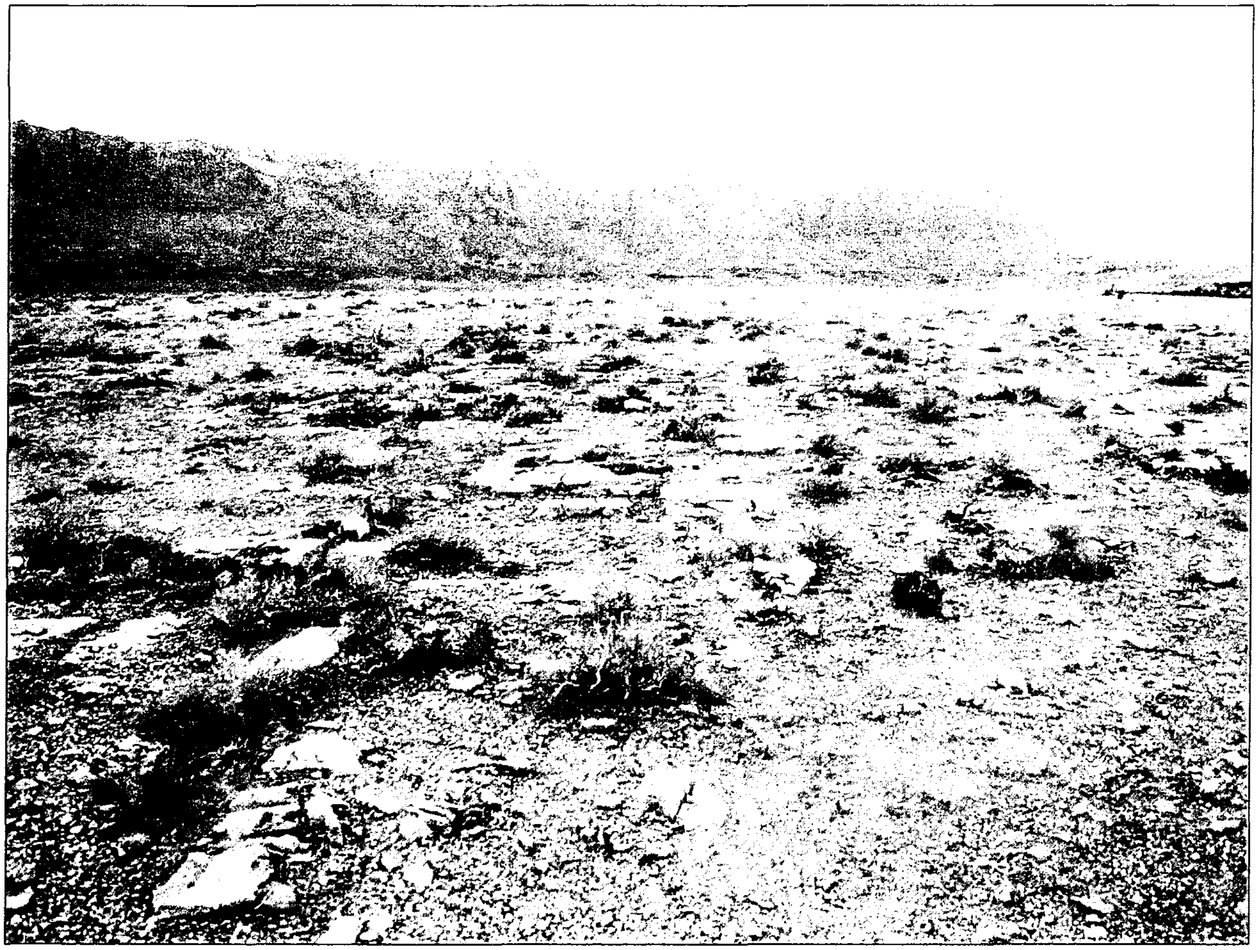

Photo7.—From a vantage point about 200 feet southeast of the nearest cliff of Marble Canyon (which would be to the lower left edge, off Photo 1), this view looks southeast towards Echo Cliffs. Although hard to discern, exposed Permian Kaibab Limestone shows the regional jointing pattern. One southeast striking, vertical dipping joint set parallels the photo direction. The other set is oriented southwest-northeast dipping vertically. This regional fracture system defines the regional drainage pattern best shown on 7.5-minute United States Geological Survey (USGS) quadrangles.

Photo 8.—Using photo 4 as a reference, this photo is a closer-up view looking into Badger Canyon from the north rim of Marble Canyon. Badger Creek rapids are just visible. Badger Canyon creek is running from recent rainfall. Note that the little delta is finer-grained than the general surface character of the debris fan, and incised, characterizing more recent but lower energy flash flooding events. Overall, the volume of sediments shed is greater from badger Canyon than Jackass Canyon.

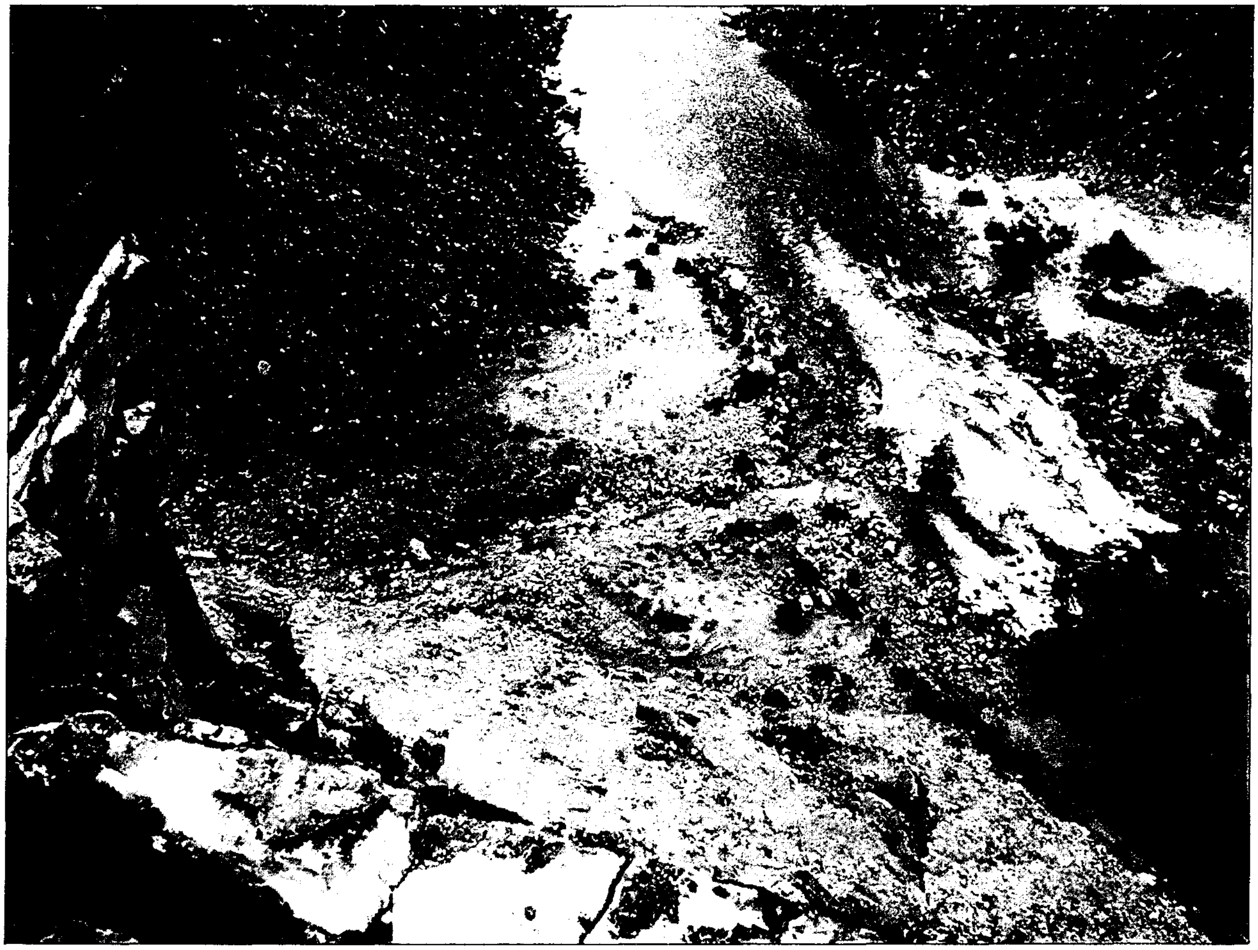

Photo 9.—Another perspective of the Jackass Canyon debris/ Badger Canyon rapids (see photos 3, 5, and 6).

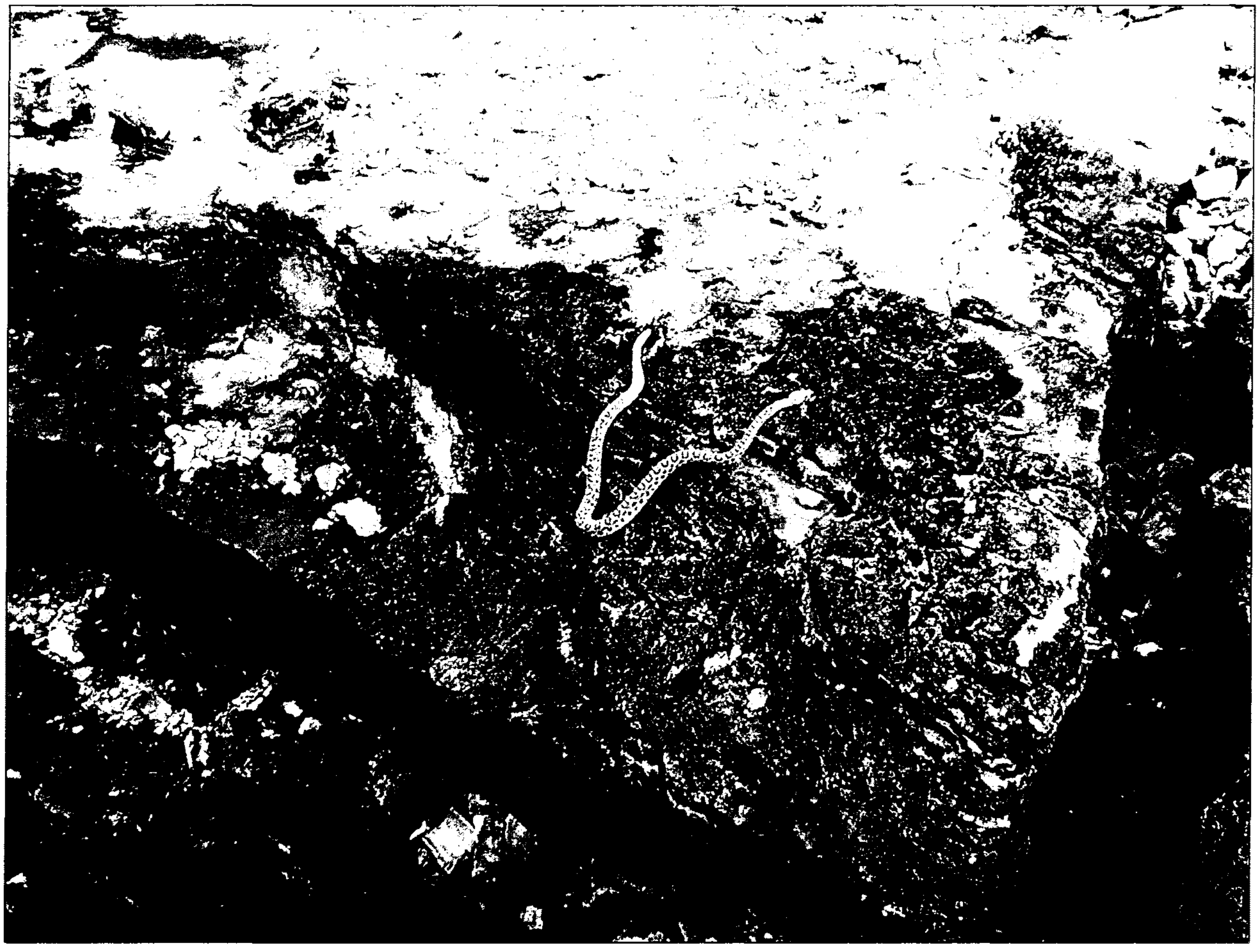

Photo 10.—Close-up of the weathered Kaibab Limestone (guarded by a little rattler). Dark hue is probably desert varnish (iron and manganese-oxides).


Photo 11.—From the helicopter, a general view of the Navajo Sandstone (Glen Canyon Group) surface to be excavated for a pipeline to Kaibito. Cross-bedding was apparent in most places indicating the Aeolian Navajo sandstone.

From the air many isolated, low-lying outcrops of the Navajo were evident with an estimated 1 to 10-feet of surficial soils filling intervening depressions, and/or remnants of Jurassic sediments from the San Rafael Group.