ALTERNATIVES CONSIDERED

This section describes three alternatives for future development of the NGS water intake system. Under Alternative A (No Action), the water intake site and operations at NGS would remain unchanged. Alternative B (Shaft and Lateral Microtunnels) would involve drilling a vertical shaft to the dead pool level of Lake Powell, the installation of a concrete shaft liner, and the excavation of up to three lateral microtunnels to establish connections to the lake. Alternative C (Directional and Conventional Inclined Drilling) would involve directional inclined drilling of five shafts that would enter Lake Powell below the dead pool level of the lake. This section also addresses alternatives that have been considered, explains why some alternatives are not considered feasible, and identifies the preferred alternative.

Alternatives Carried Forward

Alternative A (No Action)

The existing pump house facility is located immediately adjacent to Lake Powell (within 90 feet of the shoreline) on 1 acre of land leased to SRP by the Navajo Nation, at an elevation of 3,734 feet. To reduce visibility of the facility from the lake, construction of the existing pump house required extensive excavation of most of the 1-acre parcel to a depth of approximately 15–20 feet below the natural elevation. The current water intake system is a two-stage pumping system. The pump house contains electrical transformers, computers, and five horizontal second-stage booster pumps. Water is drawn from Lake Powell by five submersible first-stage pumps, with four of the water intakes located between 3,440 feet and 3,470 feet elevation and the fifth intake at approximately 3,380 feet. These pumps lift the lake water to the second-stage booster pumps through five independent pipelines. From the pump house, water is pumped approximately 3 miles to NGS via two 30-inch-diameter supply lines.

The entire make-up water requirement (fresh water added to the plant cooling system) for NGS is obtained from Lake Powell. The raw lake water withdrawn by the current pump system flows at rates as high as 28,000 gallons per minute (GPM), which is the maximum make-up flow requirement for the three generators of NGS. The current pump trains (a first-stage pump and a second-stage pump) operate singly or up to four pump trains in parallel, according to the immediate requirements of the plant cooling system (amount of make-up water required) and the lake level. One pump train is always available as standby, unless it is undergoing repairs or maintenance. Single pump train capacity varies from approximately 7,000 GPM at low lake levels to 10,000 GPM at high lake levels. Normally, four pump trains are required to provide the maximum make-up flow rate of 28,000 GPM. The pumps can be operated manually or automatically from the NGS control room using computers and a remote multiplexing system.

Under the No Action Alternative, current operations of the NGS water intake system would continue until the reservoir level reaches the elevation below the intakes where water can no longer be pumped. The existing water pipeline to NGS would be retained and continue to operate.

Site investigations associated with development of the initial water intake project in 2004–2005 identified three unstable blocks of Navajo sandstone that were partially detached from the cliff face adjacent to the pump station property. While these blocks of rock would eventually fall off naturally (Section III.C), they could eventually pose a safety hazard to water-based recreation on Lake Powell near the NGS pump station and intakes. As a result, the blocks were removed from the cliff face by blasting in the summer of 2005.

Alternative B (Shaft and Lateral Microtunnels [Action])

Alternative B would involve the construction of a large-diameter vertical shaft that would be connected to Lake Powell with two lateral tunnels (Hatch Mott MacDonald 2004) (Figure 3). A vertical shaft with lateral inlet tunnels, commonly referred to as a “lake tap,” is an established construction method that has been successfully implemented for several water supply projects, including those in Lake Havasu City, Arizona, and Las Vegas, Nevada. The specific construction techniques that would be used for the Action Alternative are described below.

Blind Shaft Drilling

Significant developments have been made in large diameter shaft drilling technology over the past 30 years since the original NGS water intake system was constructed in the early 1970s. Blind shaft drilling would involve drilling a pilot hole followed by reaming to create the full (approximately 18-foot) diameter. Site preparation prior to drilling would include construction of a reinforced concrete shaft collar and grouting for groundwater control to the full depth of the shaft. The blind shaft drill assembly would be fitted with steel weights to provide the downward force necessary to advance the cutterhead. Stabilizers located above and below the weight stack would ensure vertical boring. The drill cuttings would be removed from the shaft as slurry using reverse circulation air lift. The slurry would be pumped through a closed system to separator equipment at the surface where the cuttings are removed. Slurry fluids would be recirculated to the cutterhead and the cuttings trucked away to the disposal site.

The slurry fluids would be primarily water, but they may include inert polymers to aid in solids circulation. Because the vertical shaft would not be connected to the lake, there is negligible risk of fluid release into the lake. Prior to the drilling of the shaft, a “grout curtain” would be installed by drilling approximately 3-inch diameter holes around the circumference of the large shaft and filling them with grout. The grout would permeate the adjacent sandstone, creating a seal when the large shaft is drilled. As the shaft drilling progresses, any cracks would be sealed and the concrete liner would be placed, further reducing the risk of fluid release. Approximately 800,000 gallons (2.4 acre-feet) of slurry would be pumped out of the shaft upon completion and prior to the placement of the concrete liner and installation of the lateral connections to Lake Powell. While this fluid would be mostly made up of water, it could include fine sands and silt along with inert polymer drill fluids and would be deposited at the NGS ash disposal site.

Approximately 4,000 cubic yards of rock would be excavated from the shaft. A swell factor of 50 percent is applied to the in situ volume of rock for a total of 6,000 cubic yards of muck that would be hauled and disposed of at the NGS ash disposal site. The shaft would be flooded during drilling to provide additional support to the excavation. Once the cutterhead completes boring, the drill assembly would be extracted from the shaft and the shaft pumped out. Miners would then install a cast-in-place concrete liner, which would be constructed beginning at the top of the shaft and advanced down the shaft in 20- to 30-foot lifts. Average daily concrete liner placement advance would be approximately 20 feet. Approximately 800 cubic yards of concrete would be required to line the shaft (1-foot-thick liner).

The vertical shaft would function as a large diameter well operated in a flooded condition with all pumping equipment accessible from the surface. Under Alternative B, the bottom of the “well” would be at least as deep as elevation 3,325 feet, approximately 50 feet below the dead pool elevation of Lake Powell. The shaft would be approximately 18 feet in diameter and lined with concrete. New pumps and new transformers would be installed, but the existing pipeline to NGS would be retained. All construction would occur within the current water intake station property. Rock removed from the shaft would be hauled to the ash disposal pit at NGS.

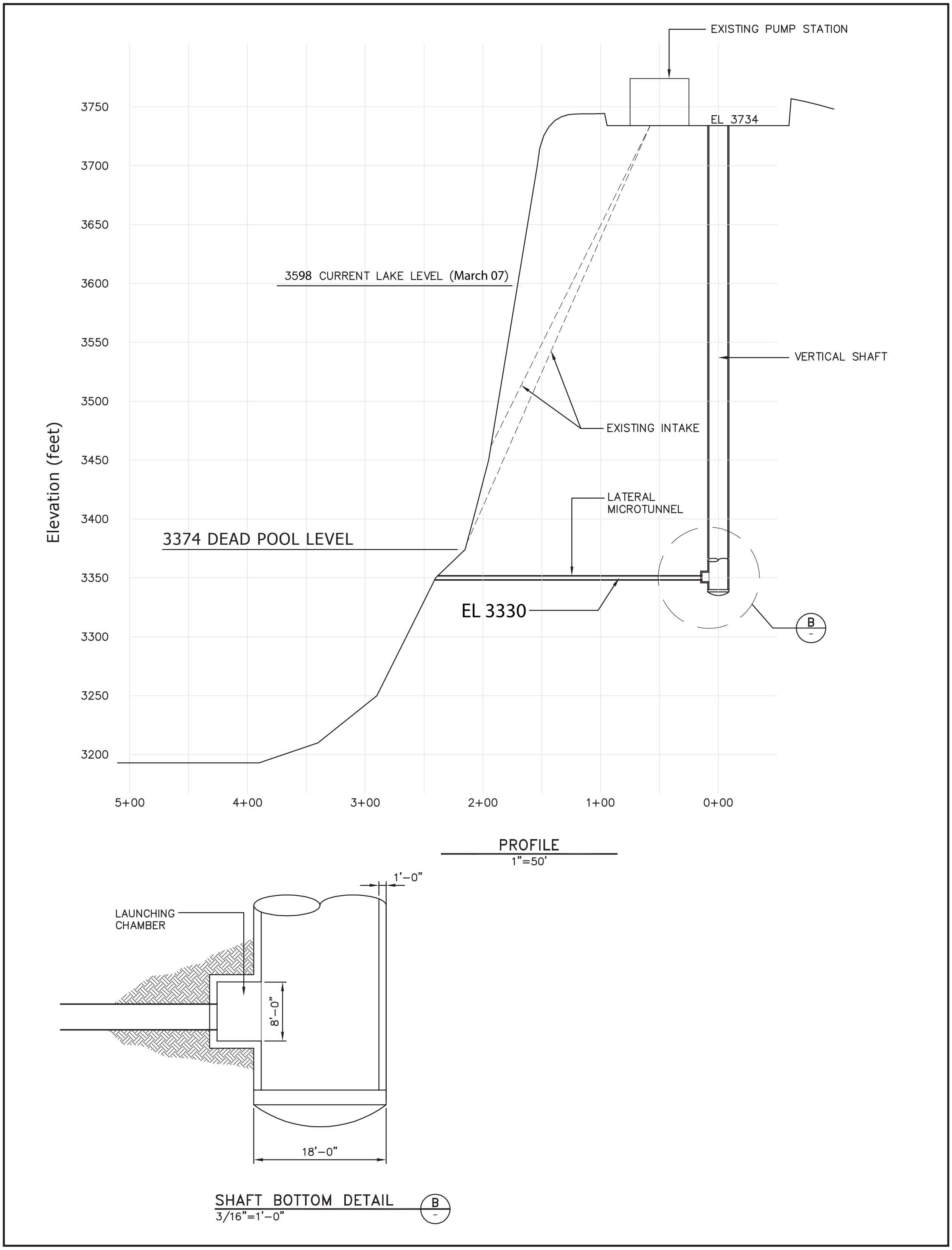


Figure 3. Schematic drawing of the vertical shaft with lateral microtunnel concept.

Lateral Microtunnels

The lateral connection of the shaft to the lake can be made using a variety of tunneling methods that are classified as either manned or remotely operated (microtunneling). Because the lateral tunnels would break through to the lake under as much as 250 feet of water, there is a substantial safety risk for mining crews, so only remotely operated options would be used. Divers and/or remotely operated vehicles (ROVs) would be needed to recover mining equipment and install permanent intake screens.

Lateral microtunnels would be constructed using a Microtunnel Boring Machine (MTBM), which excavates a circular tunnel with a rotating cutterhead. Thrust for advance is delivered by pipe jacked behind the MTBM using hydraulic cylinders located at the launch point. Muck would be transported away from the cutterhead by either screw auger or slurry pipe. MTBMs would be remotely controlled from an operating panel normally located at the launch point. The system would simultaneously install either precast concrete or steel pipe as muck is excavated and removed. Personnel entry is not required for routine operation. The method would provide continuous pressure to the face of the excavation to balance groundwater, earth, and lake pressures. Microtunnels can be excavated from a launch chamber for lengths in excess of the required tunnels.

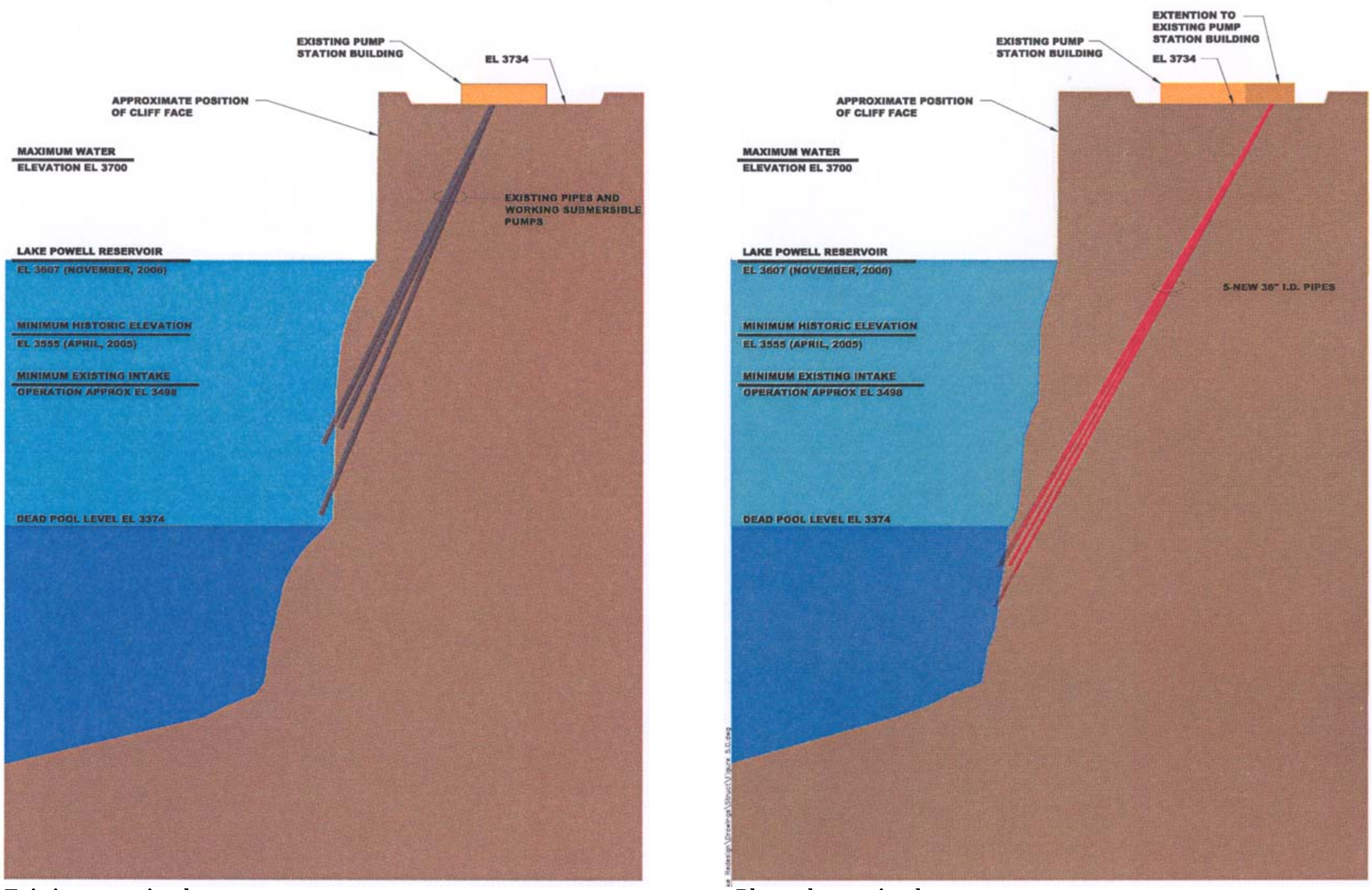
The microtunnel launch chamber at the base of the shaft would be excavated and concrete-lined after the vertical shaft is excavated. The MTBM would be lowered to the launch chamber and collared into the preformed seal with the shaft concrete liner. The MTBM would be advanced while jacking the watertight permanent tunnel lining and maintaining seals at the shaft and the cutterhead to prevent intrusion of the surrounding groundwater. MTBMs can be steered to achieve exact alignment (+/- 1 inch from design alignment). The MTBM would bore through into the lake at depth with minimal drilling fluid and cuttings introduced to the lake. Divers and/or ROVs operating from construction barges on Lake Powell would recover the MTBM and seal the end of the tunnel liner to permit installation of isolation valves at the connection between the lateral microtunnel and vertical shaft. The MTBM would be repositioned in the shaft for the next lateral tunnel drive. At the conclusion of the drives, the tunnels would be grouted and ready for pump installation from inside the vertical shaft. The barges would only be required during the construction period and would not be needed later for pump maintenance or replacement.

The diameter and number of lateral microtunnels required would be selected based on hydraulic requirements and the need for redundancy. Two lateral microtunnels approximately 5 feet in diameter would be constructed for the new water intake project.

Access to the existing pump station facilities would be maintained during construction, testing, and commissioning of the new intake system. Once the new intake system is operational, the existing first-stage pumps and related equipment would be abandoned and removed from the site. The pump house containing electrical transformers, computers, and the second-stage booster pumps would remain in place. The existing tunnel intake pipes would be cut off at the cliff face and covered by welded-in-place steel plates that would be encased in concrete. After dewatering, the interior of each existing intake shaft would be plugged with concrete to prevent above-ground runoff from entering the tubes and Lake Powell.

Alternative C (Conventional Inclined Drilling [Action])

An alternative approach would involve drilling five new inclined boreholes and the installation of water intake pumps 120 feet deeper, below the dead pool elevation of Lake Powell (Figure 4). The proposed new intake system would include the installation of five new submersible first-stage pumps, which would be installed at 3,339 feet and withdraw lake water down to approximately 3,374 feet. The new pumps would be installed in new 44-inch-diameter slant-drilled wells within the current water intake station property. The new wells would be approximately 500 feet long, with the pump suction approximately 25 feet below the dead pool elevation of 3,374 feet. The new pumps would have the same 7,000 GPM capacity as the current system, but they would be more powerful than the current first-stage pumps because of the need to pump lake water a greater distance upward to the pump house.



Existing water intakes. **Planned water intakes.**

Figure 4. Profile drawing of existing and planned water intakes.

The five corresponding horizontal second-stage booster pumps would remain in place, but new electrical transformers would be installed. The existing water pipeline to NGS would be retained and continue to operate.

Conventional Inclined Drilling

Conventional inclined drilling would involve drilling a large diameter borehole along a constant declination to the lake cliff face. Alternative C would drill five shafts 44 inches in diameter and install 36-inch outside-diameter steel pipes to house five submersible borehole pumps. All but the last few feet of the inclined shafts would be drilled using directional and conventional inclined drilling methods. Directional drilling technology would be used to first drill a small diameter pilot borehole (typically 8 to 12 inches) within an alignment tolerance of 1 percent. The pilot borehole would be drilled to the target elevation to within a few feet of the cliff face, without penetrating the cliff face. The pilot borehole would be reamed to the final diameter into the lake using conventional inclined drilling, and then the steel casings would be installed.

During the inclined drilling, drilling fluid would be circulated to cool the drill bit and remove cuttings from the drill hole. Each inclined intake shaft would be completed by first drilling a small diameter pilot borehole at an approximate angle of 30º from vertical to the target elevation to within 20 feet of the lake cliff face but not penetrating the cliff face. Steerable drilling tools, frequent downhole surveys, and directional drilling methods would be used to maintain the alignment of the inclined borehole to within 1 percent of the specified tolerance.

The lengths of the pilot boreholes are estimated to be approximately 460 and 490 feet. If the pilot borehole alignment and projected exit point at the cliff face are within the specified tolerance, the pilot borehole would be reamed to the final diameter (44 inches maximum) in one or more passes.

Drill cuttings from the pilot borehole and reaming operations would be recovered using separation equipment at the surface and the drilling fluid recirculated. Conventional inclined drilling utilizes drilling fluids commonly used in the water well and environmental industry. For conventional drilling, the borehole is kept full of drilling fluid and is “over-pressured” with respect to the groundwater level in the formation to help stabilize the borehole during drilling. The over-pressured drilling fluid constitutes a risk of communication of drilling fluids into Lake Powell. The over-pressure would result in drilling fluid being driven into the formation. To minimize this risk, the drilling contractor will use water and air as the only ingredients in the drilling fluid. If this mixture is not sufficient to circulate the cuttings up and out of the drilled shaft, inert additives (e.g., bentonite) will be added to the water-air drilling fluid. If that occurs, the drilling would stop near the end of each shaft and the drillers will switch to the water-only drilling fluid for the last 40 feet of drilling to where the shaft penetrates the cliff wall into the lake. Commonly used drilling fluids appropriate for this project are water-based or air-based. The water- or air-based drilling fluids used in conventional inclined drilling are inert and do not contain organic matter that could decompose and produce gases or inhibit bacterial activity. In addition, appropriate spill prevention plans would be instituted to make sure surface materials would not flow into nearby washes or the lake.

After reaming, the drilling fluid would be flushed from the drill hole and clean water used to drill the remaining approximately 40 feet of the hole to penetrate the cliff face. A steel casing would be installed to the full depth of the completed bore hole and protrude approximately 8 to 12 feet into the lake. The casing would be cement-grouted into place using two packers or grout baskets to seal the annular space between the casing and borehole wall to prevent grout from reaching the lake. The cement grout–filled annular space would be fitted with ¾- and 1-inch diameter CPVC pipes for cathodic protection, water quality sampling/monitoring, and potential future quagga mussel control measures (Section III.B). A protective grill will be attached to the assembly for the submersible pump in each shaft and the entire assembly lowered into place from the surface. An additional detachable grill may also be installed on the mouth of each shaft where it ends in the lake.

The tops of the inclined shafts would be located inside the limits of the existing SRP lease, approximately 20 feet from the south wall of the existing pump station building. The shafts would be oriented at azimuths between 58 and 65 degrees to break out at the cliff face east of the pump station within the NPS easement, where the cliff face is nearly vertical well below dead pool level (Figure 5). This arrangement permits the shafts to exit at the required elevation below the dead pool and avoids the issues associated with the haunch at the bottom of the cliff immediately in front of the pump station (Figure 6). This haunch feature effectively prevents drilling to the north, in front of the pump station. Because the haunches slope in the same direction as the proposed boreholes, it is possible that the boreholes would never penetrate the underwater cliff face. Therefore, the shafts would leave the pump station and angle to the east. The intersection of the SRP lease and the new NPS easement at the top of the cliff results in a narrow corridor through which the shafts must pass. Therefore, the five shafts would have to exit in two banks, with three shafts at the required level of the bottoms of the pumps below dead pool and the remaining three pumps located 35 feet deeper (Figure 4).

A houseboat would be needed on Lake Powell to support ROV-mounted cameras used for inspection of operations as each hole is drilled into the lake and during the initial grouting operations.

A total of five boreholes would be drilled with a maximum diameter of 44 inches and an estimated length of 490 to 530 feet. Based on these assumptions and a swell factor of 50 percent, it is estimated that a total of approximately 1,500 cubic yards of drilled cuttings would be produced and disposed of at the NGS landfill.

The footprint and drilling appurtenances can be set up in the available space at the pump station site. Off-site staging is available at NGS.

The primary wastes generated by directional and conventional inclined drilling methods are drilling cuttings and drilling fluids. All drilled cuttings and drilling fluids would be deposited at the NGS ash landfill in accordance with applicable local, state, and federal regulations. Approximately 1 acre-foot of drilling fluids would be disposed of at the NGS landfill. Only benign, inert additives would be used in the drilling fluids to prevent any environmental impacts from their use and disposal. Leach testing of the Navajo sandstone beneath the pump house site indicated that no metals would leach out during drilling or after disposal of the drilled cuttings.

For most conventional drilling techniques, a general guideline for estimating the volume of the drilling fluid reserve tanks is to multiply the final borehole volume by 1.5 to 3. To be conservative, it is estimated that the volume of drilling fluid reserve tanks required is equal to three times the final borehole volume. Because drilling fluids contained in the reserve tanks can often be used on successive holes during multiple hole drilling projects, the total estimated quantity of drilling fluids is approximately eight borehole volumes (i.e., 1 borehole volume for each intake tunnel, and three borehole volumes for the reserve tanks). One borehole volume is approximately 40,000 gallons, and eight borehole volumes are approximately 320,000 gallons, which is approximately 1 acre-foot.

There is a concern about the release of 1 borehole volume (i.e., 40,000 gallons) of drilling fluids to enter Lake Powell for each intake, as a result of an unprecedented loss of fluid through a fault in the rock connecting to the lake. The release could initially occur into the rock formation, where natural fractures within layers of the Navajo sandstone formation could transmit drill fluids from the drill hole into Lake Powell and allow discharge directly into the lake. While possible, this outcome is unlikely and is clearly a worst-case scenario. Drilling fluids are assumed to be water- or air-based, inert, and free of any substance that constitutes an unacceptable risk to human health or the environment. Less than 3 cubic yards of Navajo sandstone cuttings per shaft, or a total of 15 cubic yards, would enter Lake Powell during breakout of the inclined shafts, and the drilling fluid entering the lake with this sandstone would be water only.

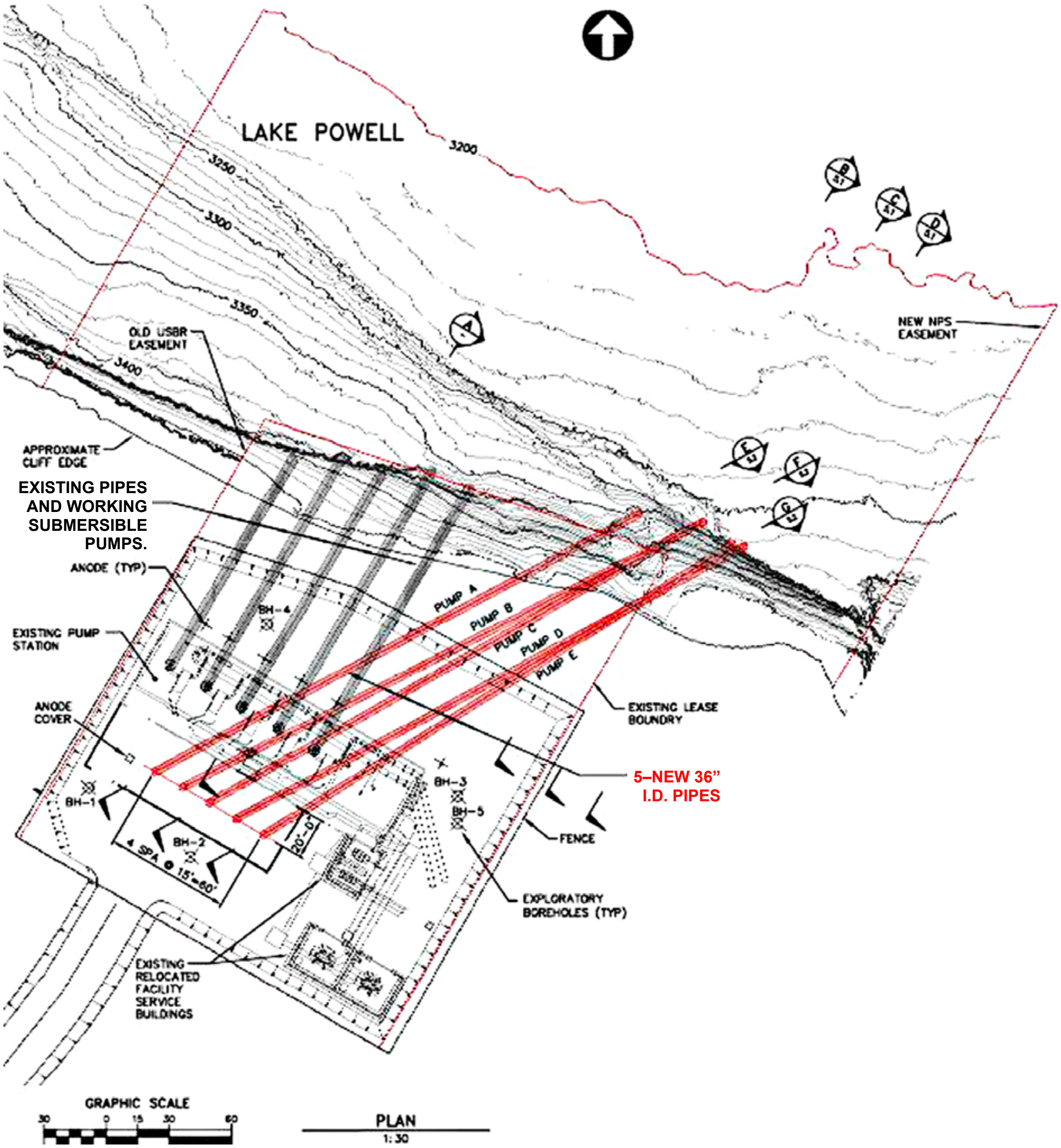


Figure 5. Plan view of pumphouse and water intakes.

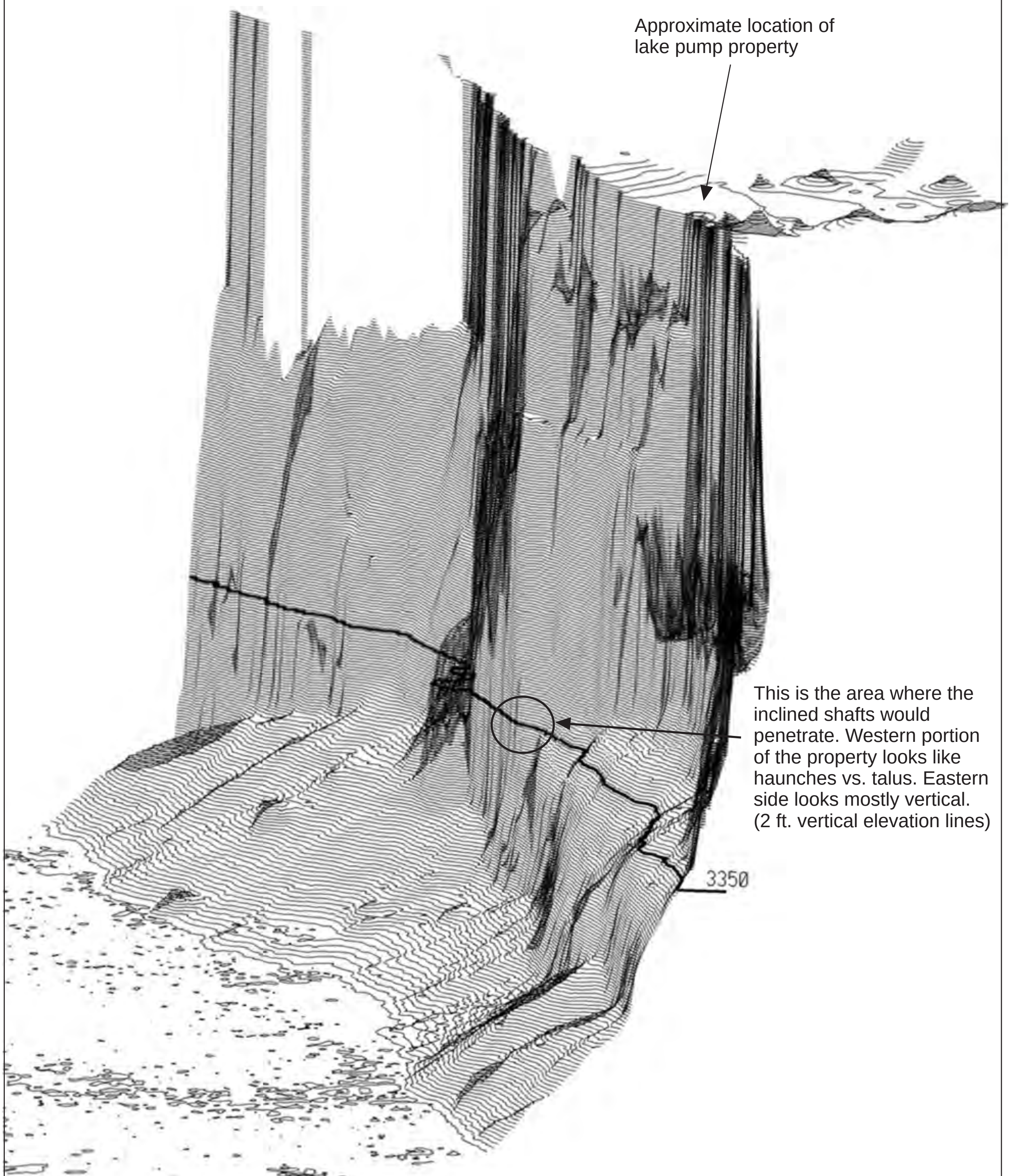


Figure 6. NGS Lake Pump Station cliff face profile and underwater survey.

Access to the existing pump station facilities would be maintained during construction, testing, and commissioning of the new intake system. Once the new intake system is operational, the existing first-stage pumps and related equipment would be abandoned and removed from the site. The pump house containing electrical transformers, computers, and the second-stage booster pumps would remain in place. The existing tunnel intake pipes would be cut off at the cliff face and covered by welded-in-place steel plates that would be encased in concrete. After dewatering, the interior of each existing intake tunnel would be plugged with concrete to prevent above-ground runoff from entering the tubes and Lake Powell.

Alternatives Considered and Dismissed

Conventional Excavation

Another construction approach would involve conventional vertical shaft excavation that would be performed by the repetition of a cycle of construction activities. The construction cycle would include drilling a pattern of vertical or near-vertical small diameter holes 8 to 13 feet deep, loading the holes with explosives, detonating the explosives, excavating and hauling out muck, and installing rock support. This cycle would be repeated on average once per day. Other activities performed during each cycle would include surveying, extending utilities (e.g., electrical power, compressed air, ventilation duct, communications), and surface activities, such as hauling muck to the disposal site and maintaining equipment.

The drill-and-blast method would create a shaft with a rough excavated surface that typically requires rock bolts, structural steel rings, and/or shotcrete for ground support. Drill-and-blast shafts are excavated by small crews of miners working in a confined space. Consequently, daily advance rates of 3 feet to 6 feet for drill-and-blast shaft excavation are relatively slow in comparison to shaft drilling advance rates.

Approximately 4,000 cubic yards of rock would be excavated from the shaft. A swell factor of 50 percent is applied to the in situ volume of rock, for a total of 6,000 cubic yards of muck that would be hauled to the NGS ash disposal site. The Navajo sandstone is composed of 99 percent silica sand and is considered inert. However, the muck would contain negligible amounts of residue from the explosives and nonelectric blast initiation components and would require testing.

The vertical shaft would be dewatered and then permanently supported with a cast-in-place concrete liner placed after the excavation reached full depth. The concrete liner would be constructed beginning at the bottom of the shaft and advanced up the shaft in 20- to 30-foot lifts. Average daily concrete liner placement advance would be approximately 20 feet. Approximately 1,000 cubic yards of concrete would be required to line the shaft.

This alternative method of construction is not feasible because the shaft formed would be less stable than a shaft constructed by the blind shaft method. In addition, a potentially serious negative impact associated with conventional drill-and-blast shaft excavation would be vibration-induced damage to sensitive pump station equipment. Because explosives generate substantial transient high-frequency ground vibrations, these vibrations would adversely impact the sensitive equipment, controls, and computer equipment and require replacement of damaged equipment. In contrast, vibrations due to blind shaft drilling and lateral microtunneling are considered comparable to the vibrations generated from the existing pumps and related equipment and would not affect the sensitive equipment.

This excavation technique could result in the inflow of groundwater into the vertical shaft during excavation of the shaft above the groundwater level. Below the water table, a greater volume of groundwater would likely seep into the shaft until it could be sealed by installing the concrete liner. The groundwater would be collected from the vertical shaft and pumped to the surface for disposal at the NGS ash pit.

Finally, blasting may have negative environmental impacts on the rock and soils at the water intake site. Like the blind shaft drilling method, approximately 6,000 cubic yards of muck would be hauled away and disposed of at the NGS ash disposal site. The Navajo sandstone is composed of 99 percent silica sand and is considered inert. However, muck from the drill-and-blast method would contain trace amounts of residue from the explosives and nonelectric blast initiation components.

Curved Boreholes by Conventional Directional Drilling

Conventional directional drilling would be similar to conventional inclined drilling described above (see Alternative C), with the exception that the resultant hole has a declination angle that is increased as the borehole is advanced. Drilling a curved borehole involves commencing drilling operations at a certain declination angle and as the borehole is advanced, increasing the declination angle using steerable drilling tools and methods (Figure 7).

Conventional directional drilling utilizes the same water- or air-based drilling fluids described above for conventional inclined drilling.

Curved boreholes by conventional directional drilling are not preferred because the final curved section of the shafts could not be lined.

Underbalanced Drilling

Underbalanced drilling would be similar in concept to conventional inclined and directional drilling except that the borehole would not be over-pressured with drilling fluids. The term “underbalanced” is used to describe the condition where the borehole pressure at the drill bit is less than the surrounding formation, as opposed to conventional “overbalanced” drilling. This condition would be accomplished through the use of lightweight drilling fluids, which usually consist of nitrogen gas injection down the drill pipe or a parasite string. Nitrogen gas is typically used because of its relatively low generation cost, scale control, and low potential for down-hole fires.

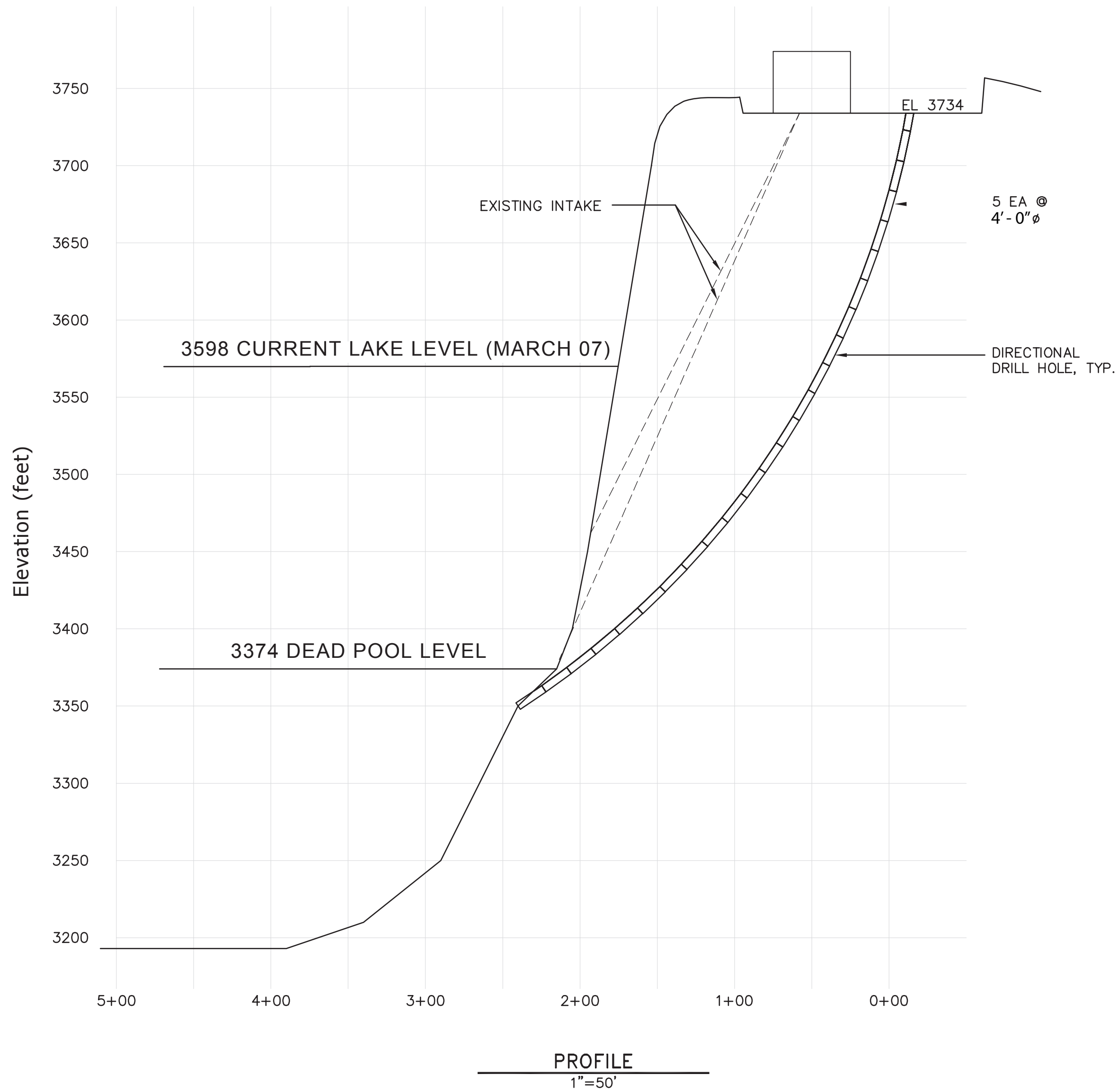


Figure 7. Schematic drawing of the directional drilling concept.

Alternative Summaries

Table 1 summarizes the components of the alternatives. Table 2 summarizes and compares the potential environmental consequences associated with each alternative. The detailed results of the impact analysis are presented in the Environmental Consequences section.

Table 1. Comparison of Alternatives.

Component	Alternative A (No Action)	Alternative B (Shaft with Laterals)	Alternative C (Inclined Shafts)
Elevation of Intakes	3,470 feet (maximum).	3,330 feet. This alternative would permit continued NGS operations even if Lake Powell reaches its dead pool elevation of 3,374 feet, where there will be water remaining in the lake.	3,339 feet. This alternative would permit continued NGS operations even if Lake Powell reaches its dead pool elevation of 3,374 feet, where there will be water remaining in the lake.
Water Intakes	Retain existing intakes.	Install new water intakes by constructing a “lake tap” vertical shaft with lateral microtunnels.	Install new water intakes by constructing five inclined shafts into Lake Powell.
Pump system	Existing pumps would be retained.	New pumps would be installed and connected to existing water distribution lines to NGS.	New pumps would be installed and connected to existing water distribution lines to NGS.
Flow rate	28,000 gallons per minute.	28,000 gallons per minute.	28,000 gallons per minute.

Table 2. Summary of Environmental Consequences.

Resource	Alternative A (No Action)	Alternative B (Shaft with Laterals)	Alternative C (Inclined Shafts)
Natural Environment	Negligible impact to wildlife due to possible fish entrainment.	Reduced fish entrainment due to lowered intakes; a possible benefit.	Reduced fish entrainment due to lowered intakes; a possible benefit.
Geology	No impact.	No impact.	No impact.
Water Quality	Long-term, negligible impact on downstream salinity.	Long-term, negligible impact on downstream salinity. Negligible impact associated with the discharge of Navajo sandstone into Lake Powell.	Long-term, negligible impact on downstream salinity. Negligible impact associated with the discharge of Navajo sandstone into Lake Powell.
Cultural Resources	No impact.	No impact.	No impact.
Socioeconomics and Environmental Justice	Possible major, long-term impacts if declining water levels force closure of NGS.	Potential minor beneficial impact associated with project construction.	Potential minor beneficial impact associated with project construction.
Land Use	No impact.	Negligible impact of increased easement size (0.3 acre).	Negligible impact of increased easement size (3.76 acres).

Table 2. Summary of Environmental Consequences.

Resource	Alternative A (No Action)	Alternative B (Shaft with Laterals)	Alternative C (Inclined Shafts)
Visual Resources	Negligible impact because part of pump house is visible from the lake. Potential negative impact if existing water intakes become visible due to declining lake level.	Negligible impact because part of pump house is visible from the lake, and cliff face color after rock removal will contrast with adjacent area. Potential negative impact if existing water intakes become visible due to declining lake level.	Negligible impact because part of pump house is visible from the lake. Potential negative impact if existing water intakes become visible due to declining lake level.
Hazardous Materials	No impact.	No impact.	No impact.
Recreational Resources	No impact.	No long-term impact; short-term impact associated with temporary lake closure during rock blasting.	No long-or short-term impact.
Construction-Related Impacts	None.	Short-term impacts will include noise impacts from rock drilling; visual impacts from light intrusion due to night work, crane/drill rig use, and barges on lake; recreation impact from barge use on Lake Powell; air quality impacts from dust from drilling and traffic on the unpaved access road. Increased traffic on Antelope Point Road may temporarily impact recreationists.	Short-term impacts will include noise impacts from rock drilling; visual impacts from light intrusion due to night work, crane/drill rig use, and a houseboat on lake; recreation impact from houseboat use on Lake Powell; air quality impacts from dust from drilling and traffic on the unpaved access road. Increased traffic on Antelope Point Road may temporarily impact recreationists.
Cumulative and Secondary Impacts	None.	Negligible cumulative effect with other planned actions on Lake Powell. No secondary impacts.	Negligible cumulative effect with other planned actions on Lake Powell. No secondary impacts.

Environmentally Preferred Alternative

The environmentally preferred alternative is determined by applying the criteria suggested in the National Environmental Policy Act of 1969 (NEPA), which is guided by the Council on Environmental Quality (CEQ). CEQ directs that the environmentally preferred alternative is the alternative that will promote national environmental policy as expressed in Section 101 of NEPA:

- Fulfill the responsibilities of each generation as trustee of the environment for succeeding generations
- Assure for all generations safe, healthful, productive, and aesthetically and culturally pleasing surroundings

- Attain the widest range of beneficial uses of the environment without degradation, risk of health or safety, or other undesirable or unintended consequences
- Preserve important historic, cultural, and natural aspects of our national heritage and maintain, wherever possible, an environment that supports diversity and variety of individual choice
- Achieve a balance between population and resource use that will permit high standards of living and a wide sharing of life's amenities
- Enhance the quality of renewable resources and approach the maximum attainable recycling of depletable resources (42 USC 4321-4370d)

Alternative A, the No Action Alternative, would result in the least direct impact to existing resources and would not necessitate any new construction. However, Alternative A would not ensure a continued cooling water supply for NGS, which would not allow NGS to remain operational under conditions of ongoing drought; therefore, Alternative A would not achieve the project purpose and need. Furthermore, under conditions of persistent drought, this alternative could result in the closure of NGS, a scenario with serious and far-reaching negative socioeconomic impacts.

Formerly, the environmentally preferred alternative was Alternative B, the construction of a vertical shaft with lateral microtunnels. The vertical shaft "lake tap" concept was thought to be the preferred alternative for engineering and environmental reasons. The vertical shaft would have been constructed entirely isolated from Lake Powell and, thus, would have a minimal environmental impact.

NPS completed an Environmental Assessment/Assessment of Effect that evaluated the environmental impacts of Alternative B in March 2005. The blocks of Navajo sandstone were removed from the cliff face adjacent to the project area in 2005, and construction began on the vertical shaft in 2006, when a series of holes were drilled through highly porous sandstone to form the perimeter of the shaft. At approximately 365 feet below the surface of the cliff, a fault in the sandstone was encountered. Attempts to pump grout into the perimeter holes to support the shaft were unsuccessful due to the fault and the porous character of the rock formation. It was determined that the newly detected fault might be connected to the lake. In addition, the fault could present problems in drilling the lateral tunnels that were planned to intersect the vertical shaft at approximately 380 feet below the cliff surface. The use of ground-freezing techniques might permit the grouting and shaft drilling to proceed as originally planned but would create significant project delays and extraordinary costs.

At this point, construction on Alternative B was abandoned, and efforts were focused on finding a new alternative. A total of 15 alternatives, ranging from an overland pipeline from Glen Canyon Dam to a set of exposed pipes running down the cliff face to several different drilling options, were considered. Exposed pipelines were rejected for their impacts on recreation and aesthetics. Among the drilling options, Alternative C was selected for engineering and environmental reasons.

For Alternative C to be viable, it is necessary that the cliff face be virtually vertical at the proposed location of the shaft inlet structures. To verify the cliff geometry, a new survey of the cliff face, extending 200 feet on each side of the centerline of the new NPS easement, was completed in January 2007. The results of the survey confirmed the position of the vertical cliff face east of the pump station and, therefore, the technical feasibility of this alternative (Figure 6). In addition, an exploratory borehole indicated that the porous stratum that was encountered in previous borings was not encountered in this location.

The new environmentally preferred alternative is Alternative C, the construction of five inclined shafts using directional and conventional inclined drilling methods. The inclined shaft concept is the preferred alternative because of the difficulties associated with the construction of a vertical shaft. In addition, the inclined shafts would be constructed to minimize impacts of drilling fluids and drill cuttings on Lake Powell and, therefore, would have a minimal environmental impact.

Alternative C was identified after logistical difficulties with water disposal made Alternative B unfeasible, but Alternative C is also an environmentally benign alternative. The size of the drilled shafts and the amount of Navajo sandstone to be removed and disposed of is much less under Alternative C. With the use of water as a drilling fluid for the last few feet of shaft construction and the resulting pressure differences between the drilled shaft and the lake, only very small amounts of drilling fluids or drill cuttings would be released into the lake. No explosives would be used, reducing the possibility of damaging the Navajo sandstone underlying the water intake site and reducing noise impacts to recreationists and wildlife. The implementation of Alternative C would avoid the major socioeconomic impacts that could result from the shutdown of NGS under the No Action Alternative. Therefore, Alternative C would best accomplish the project purpose and need with the least possible environmental impact.

Mitigation Measures

The following mitigation measures apply to implementation of Alternative C, the environmentally preferred alternative:

- To prevent the potential spread of the quagga mussel, the hulls, engines, and other submersible parts of any boats that are used during project construction and any other equipment that will be used in Lake Powell must be pressure-washed with hot water before entering the lake.
- Prior to the start of construction, personnel monitoring California condor locations and movement will be contacted to determine the locations and status of condors in the project vicinity.
- If a condor occurs at the construction site, construction will cease until the condor leaves on its own or until techniques are employed by permitted personnel that result in it leaving the area.
- Construction workers and supervisors will be instructed to avoid interaction with condors and to immediately contact the appropriate GCNRA personnel if or when condors occur at the construction site.
- The construction site will be cleaned up (e.g., trash removed) at the end of each day that work is being conducted to minimize the likelihood of condors visiting the area. Site visits will ensure that adequate cleanup measures are taken.
- To prevent water contamination and potential poisoning of condors, a vehicle fluid leakage and spill plan shall be developed and implemented. The plan should include provisions for immediate cleanup of any hazardous substance and define how each hazardous substance will be treated in case of leakage or spill.
- If previously unidentified cultural resources are discovered during construction-related activities, construction activities will be halted and NPS will be notified immediately and arrangements will be made for the appropriate assessment and treatment of those resources.
- During construction, diesel fuel and hydraulic fluids would be stored in sealed containers within an isolated area on the project site.
- To reduce the visual impacts of lights used during nighttime drilling, light shields will be used at the construction site.
- To control the dust associated with increased vehicle traffic on the unpaved access road to the pump station, water or an environmentally approved dust palliative will be applied to the road regularly during construction of the vertical shaft.
- To lessen noise impacts to recreational users on Lake Powell, sound barricades of sufficient height will be erected to direct noise away from Lake Powell to the south of the pump station site during construction.