RECLAMATION

Managing Water in the West

San Juan – Mexican Hat to Kayenta Regional Water Supply Appraisal Study

Report Prepared for Navajo Nation

Bureau of Reclamation
Upper Colorado Region, Provo Area Office

U.S. Department of the Interior
Bureau of Reclamation
Provo Area Office, Utah

~~June 2014~~ March 2015

Mission Statements

The mission of the Department of the Interior is to protect and provide access to our Nation's natural and cultural heritage and honor our trust responsibilities to Indian Tribes and our commitments to island communities.

The mission of the Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public.

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Acronyms and Abbreviations

ADWR	Arizona Department of Water Resources
ALP	Animas-La Plata Project
APE	area of potential effect
AWWA	American Water Works Association
BIA	Bureau of Indian Affairs
$CaCO_3$	calcium carbonate
cfs	cubic feet per second
CRSP	Colorado River Storage Project
DIP	ductile iron pipe
DBPs	disinfection byproducts
EA	environmental assessment
ESA	Endangered Species Act
fps	feet per second
gpcd	gallons per capita per day
gpm	gallons per minute
HHS	persons per household
HHY	median household income
IHS	Indian Health Service
kW	kilowatt
kW-h	kilowatt-hours
M&I	municipal and industrial
MCL	maximum contaminant level
NF	Nanofiltration
MG	million gallons
MGD	million gallons a day
mg/L	milligrams per liter
MPa	Megapascal
NEPA	National Environmental Policy Act
NHPA	National Historic Preservation Act
NIIP	Navajo Indian Irrigation Project
NNEPA	Navajo Nation Environmental Protection Agency
NNHPD	Navajo Nation Historic Preservation Department
NTS	Not To Scale
NTU	Nestler Turbidity Units
NTUA	Navajo Tribal Utility Authority
NWS	National Weather Service
O&M	operation and maintenance
P	average price water
Plateau	Colorado Plateau
PPSA	Pigging Products & Services Association
Proposed project	San Juan River to Kayenta Pipeline Project
psi	pounds per square inch
PWCC	Peabody Western Coal Company
Reclamation	Bureau of Reclamation

RO	Reverse Osmosis
SCADA	Supervisory Control and Data Acquisition
SDWA	Safe Drinking Water Act
Service	U.S. Fish and Wildlife Service
SHOP	State Historic Preservation Office
SJRBRIP	San Juan River Basin Recovery Implementation Program
SLB&M	Salt Lake Base & Meridian
SWTR	Surface Water Treatment Rule
TDH	total dynamic head
TDS	total dissolved solids
TOC	total organic carbon
TSC	Technical Service Center
USBR	United States Bureau of Reclamation
U.S.C.	United States Code
USGS	U.S. Geological Survey
UV	ultraviolet
WAPA	Western Area Power Administration

1.0 Introduction

The Office Engineering Division of the Provo Area Office, Upper Colorado Region of the Bureau of Reclamation has been tasked by the Navajo Department of Water Resources to perform a regional water study. The study will focus on investigating water supply needs for the Oljato and Kayenta Chapters of the Navajo Nation which lie in and around the Monument Valley area (Figure 1-1, Spangler, 1999). The Kayenta and Oljato Chapters encompass lands in both Utah and Arizona. The primary purpose for this Rural Water Supply Appraisal Study is to identify and analyze alternatives that can provide an adequate water supply of sufficient reliability and quality to support the current and anticipated population growth and associated municipal and commercial needs within the study area. The investigation is focused on evaluating existing water sources and infrastructure, determining water demands for the future population, designing a new water supply system including a San Juan River intake structure, pipelines and new treatment facilities, and finally unifying the existing and proposed distribution and storage systems.

Figure 1-1. Location of the Navajo Indian Reservation and the Monument Valley Area.

1.1 Purpose and Need for the Proposed Project

Economic development is critical for this area to become a prosperous and permanent homeland for the Navajo people, and to reversing out-migration that has occurred during the recent years due to loss of mining jobs in the area. To change this trend, the Navajo Nation recently opened up a new hotel at the Monument Valley Tribal Park. In 2012 the park itself hosted more than 350,000 visitors and the hotel was a major part of the attraction due to the stunning views of the park. A new elementary and middle school and teacher housing was recently constructed in Monument Valley to complement the existing High School, making it a regional center for education for the San Juan School District. The Kayenta/Monument Valley area has been identified by the Navajo Nation as a major development area. The Kayenta Township is making numerous substantial efforts to expand the opportunities for Navajo people to find livelihoods in the area. Tourism and outdoor recreation supports the majority of the employment in the area. All of this development supports the need for a reliable and improved water infrastructure. These statements are particularly applicable to the Monument Valley region of the Navajo Nation. As research of the existing groundwater sources continue to show limited potential for sustaining future growth and as the population increases, securing a reliable, long-term water supply is critical. The scenery of the Monument Valley area is a valuable resource for future development in the area and it is within this context that the current water study is being evaluated. Goulding's management at Monument Valley have express an interest in growing their business, but it will take a sustainable water supply to allow them move forward with their plans.

The study area is a remote, but lightly populated, portion of the Navajo Nation. The population in 2010 was approximately 6,591over 600 square miles. The majority of the population in the area is located in Kayenta (population 5,443). Based on population, approximately 83 percent of the projected water supply demand for the region is in the community of Kayenta, Arizona. The smallest communities in the area are Halchita (population 279) and Cane Valley (population 48). The region has seen changes in the employment in the area with closure of a portion of Black Mesa Coal Mine in 2005, where approximately 260 employees were laid off, due to the closure of the Mohave Powerplant in Arizona, which the mine supplied through a slurry line. The closer of the mine had a significant effect on the employment in the area and as a result the population of the area dropped in the 2010 census reflecting this impact. Water is important to the area to provide a stable employment base for the area.

A Regional Water Supply would provide a comprehensive approach to rural domestic water supplies and eliminate the need for individual, unconnected water resource management actions. In 2005, Navajo Nation President Joe Shirley, Jr. stated that, 'municipal water development is a very high priority of the Navajo Nation' (NNDWR, 2007, p. 1). According to the *Water Resource Development Strategy for the Navajo Nation*, 'The lack of adequate domestic and municipal water is the greatest water resource problem facing the Navajo Nation.' It also states that 'The Navajo Nation has severe water infrastructure deficiencies that impact the health, economy, and welfare of the Navajo people' (NNDWR, 2000, p. ES-1).

1.2 Project Sponsors and Partners

This study has a large number of sponsors and partners. In addition, the Navajo Nation Department of Water Resources, Reclamation, Indian Health Service, the State of Utah Office of the State Engineer, and the Navajo Tribal Utility Authority (NTUA) established a

Technical Advisory Group (TAG) to coordinate short term, midterm and long term alternatives. The following list identifies some of the sponsors and partners:

- Navajo Nation – sponsor
- Utah Area Chapters – sponsors
- State of Utah, Office of the State Engineer – partner
- Indian Health Service – partner
- Navajo Tribal Utility Authority – partner
- USDA Rural Development – partner
- USDA Natural Resources Conservation Service – partner
- Environmental Protection Agency – partner
- Bureau of Indian Affairs – partner

1.3 The Proposed Project

The proposed San Juan River to Kayenta Pipeline Project (proposed project) can provide the reliable, long-term supply of municipal and industrial (M&I) water that is needed to support the current population and future growth. Based on a projected regional population of nearly 12,572 (based on 1.3% growth rate) in the year 2060 and water use of 160 gallons per capita per day (gpcd), approximately 2,255 acre-feet of water would be required annually at full build-out.

Groundwater sources can continue to be used conjunctively with the San Juan River water in order to most effectively utilize the available supplies. In the short-term, groundwater supplies would continue to be used during implementation of the proposed project. In the long-term, they would provide a level of redundancy during emergency and maintenance situations, as well as help to meet extreme summer peak demands during periods of drought.

For the purposes of this study, however, the full annual demand of 2,255 acre-feet would be assumed to be provided by the San Juan River. This would be accomplished by constructing a direct intake structure on the bank of the river across from Mexican Hat, Utah and providing initial sediment removal. From here, raw water would be treated at the river and pumped approximately 40 miles to two proposed secondary filter/chlorination sites. Treated water would subsequently be distributed to the various communities through existing distribution systems.

1.4 Project Location

Covering more than 27,000 square miles, the Navajo Nation is located in northwest New Mexico, northeast Arizona, and southeast Utah (Navajo Nation, 2005). This water supply study is being conducted for the Monument Valley area on the Arizona – Utah border. Various Navajo communities are included in the study with the two largest being Kayenta and Oljato (Figure 1-2, Gorman, 2008). For the purposes of this study, the Oljato area would include Monument Valley Tribal Park, Monument Valley Elementary, Middle and High School, Goulding’s, and Douglas Mesa (Figure 1-3).

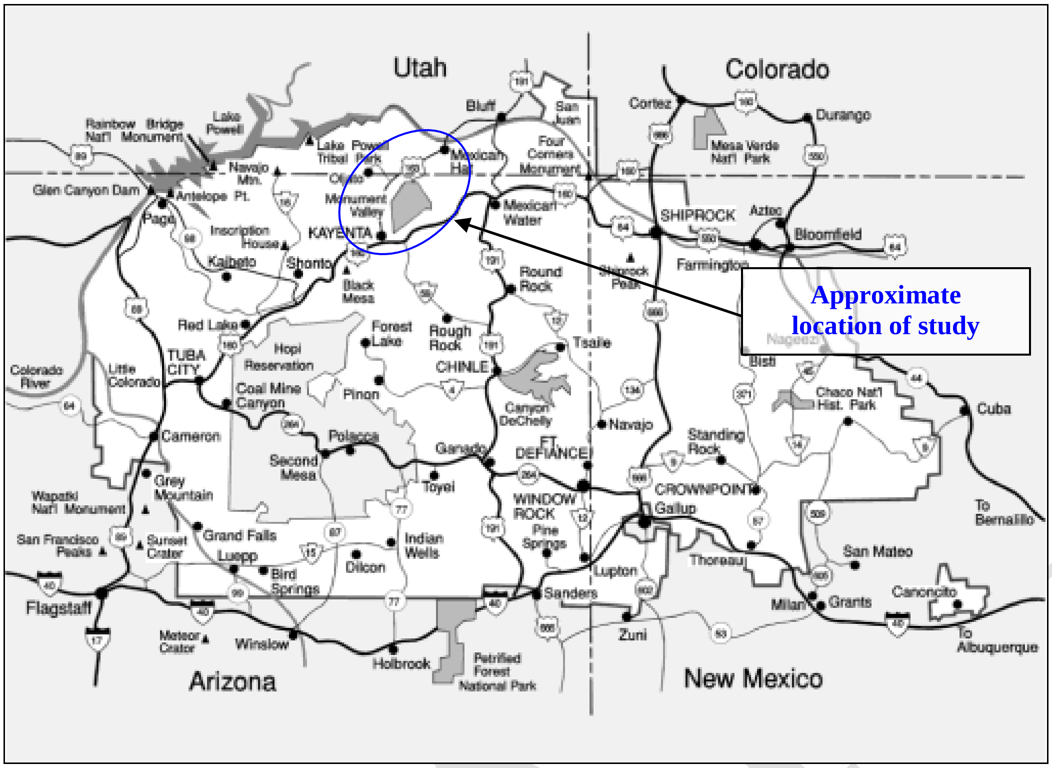


Figure 1-2. Map of the Navajo Nation.

Figure 1-3. Surrounding Navajo Nation Chapters Map.

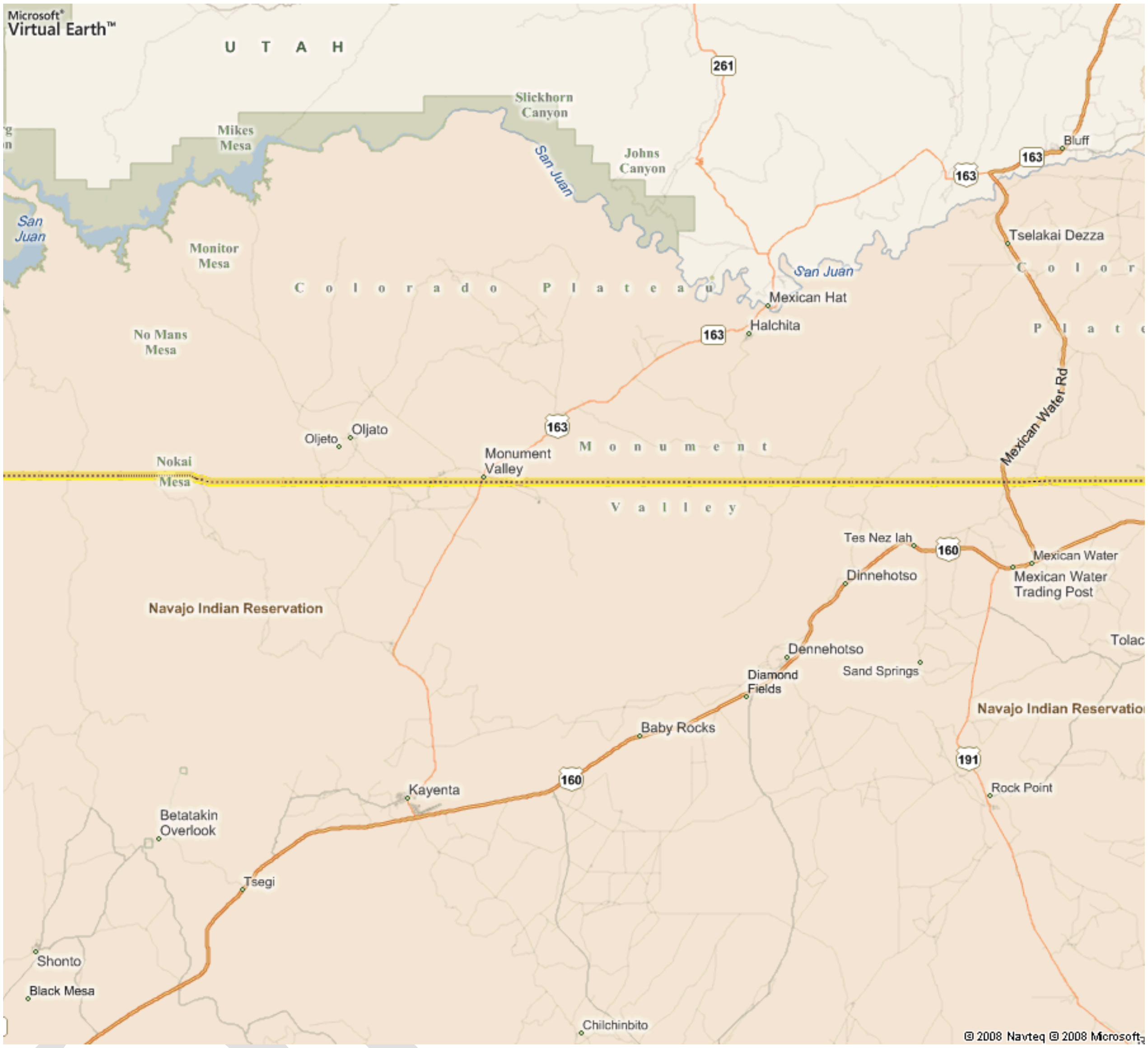


Figure 1-4. Halchita, Monument Valley, Oljato and Kayenta Vicinity Map.

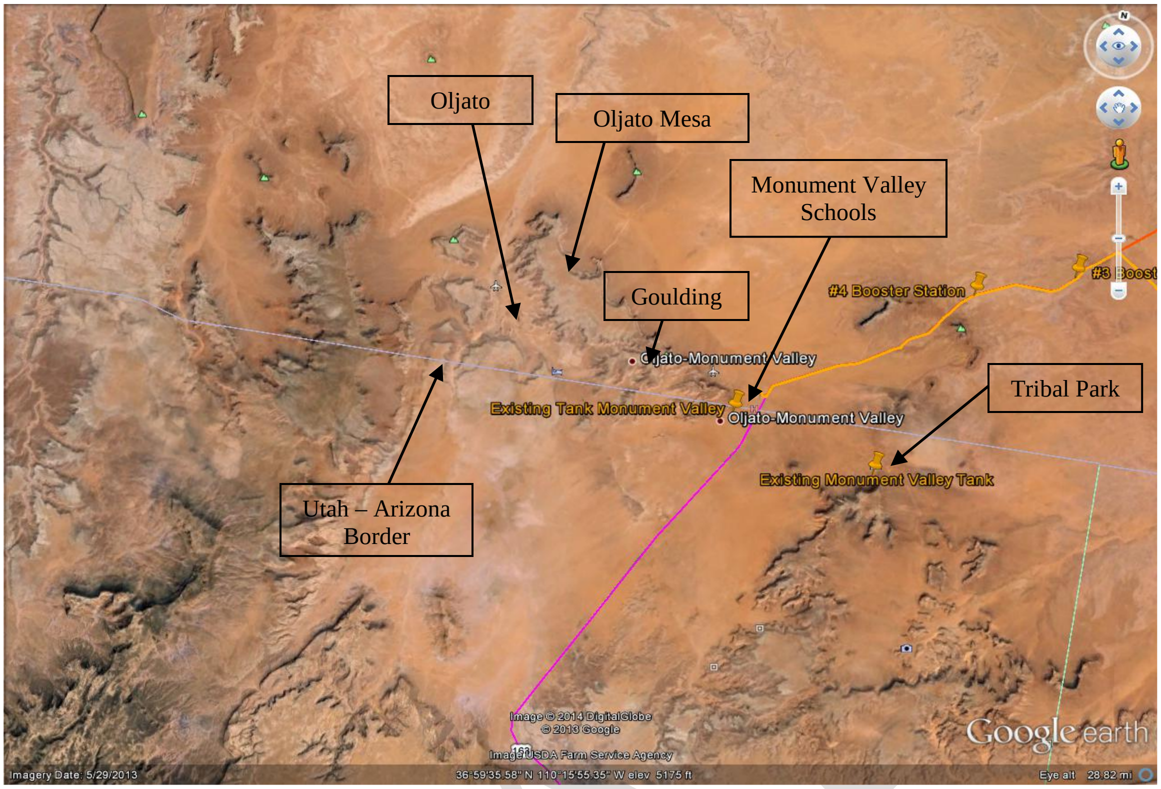


Figure 1-5. Oljato and Monument Valley Area.

Figure 1-6. Kayenta Area.

1.5 Previous Studies

The Navajo Nation has completed a number of studies that document inadequate water supplies in the Study Area. It is a priority for the Nation to provide domestic water in the Study Area. Although this is the first study specifically dedicated to investigating a regional water supply from the San Juan River to Monument Valley and Kayenta, various other reports and memorandums pertaining to Navajo Nation municipal water issues in this region have been written. Several of these provided valuable information for the present study. These include *Utah Navajo Municipal Water Projects, April, 2007, Monument Valley Tribal Park and Oljato Water Supply Alternative Study, February, 2008*, and *Water Resource Development Strategy for the Navajo Nation, 2000*, all of which were prepared by the Navajo Nation Department of Water Resources.

Other documents which proved helpful to the current study were the *Final Navajo-Gallup Water Supply Project – Planning Report and Draft Environmental Impact Statement (PR/DEIS), July 2009,* the *Southwestern Navajo Rural Water Appraisal Study, August 2011*, prepared by the Bureau of Reclamation in cooperation with the Navajo Nation, the City of Gallup, and the Jicarilla Apache Nation, and the *DRAFT-Water Plan for Kayenta Chapter and Township, January 31, 2013*, prepared by Brown and Caldwell for Kayenta Chapter and Township and Navajo Nation Department of Water Resources. The Navajo-Gallup Water Supply Project involved investigating the option of providing an M&I water supply from the San Juan River to portions of the Navajo Nation in New Mexico and eastern Arizona, the Jicarilla Apache Nation, and the city of Gallup, New Mexico. The Southwestern Navajo Rural Water Appraisal Study focused on identifying rural water supply problems and determining the Federal and Local commitment to participate in a cost shared feasibility study in the 10 Chapters located in the southwestern portion of the Navajo Nation. Although they focus on different regions within the Navajo Nation, many similarities exist between these projects.

2.0 Statement of Problems, Needs, and Opportunities

In 2005, Navajo Nation President Joe Shirley, Jr. stated that, ‘municipal water development is a very high priority of the Navajo Nation’ (NNDWR, 2007, p. 1). According to the *Water Resource Development Strategy for the Navajo Nation*, ‘The lack of adequate domestic and municipal water is the greatest water resource problem facing the Navajo Nation.’ It also states that ‘The Navajo Nation has severe water infrastructure deficiencies that impact the health, economy, and welfare of the Navajo people’ (NNDWR, 2000, p. ES-1). These statements are particularly applicable to the Monument Valley region of the Navajo Nation. As existing groundwater sources continue to be depleted and the population increases, securing a reliable, long-term water supply is critical. It is within this context that the current water study is being evaluated.

Groundwater sources can continue to be used conjunctively with other sources in order to most effectively utilize the available supplies. In the long-term, the existing water supply would provide some level of redundancy during emergency and maintenance situations, as well as help to meet extreme summer peak demands during periods of drought.

2.1 Existing Conditions

Halchita Water Treatment Plant

Background

The water treatment plant on the San Juan River across from Mexican Hat, Utah was originally constructed to provide water for the uranium processing operations in Halchita. Once the mining operations were discontinued in the area the water treatment plant was turned over to the Navajo Tribe to provide water for the community. Operation of the plant is being provided by the Navajo Tribal Utility Authority (NTUA). Water is currently treated and pumped to two storage tanks overlooking Halchita to the east (Figure 2-1).

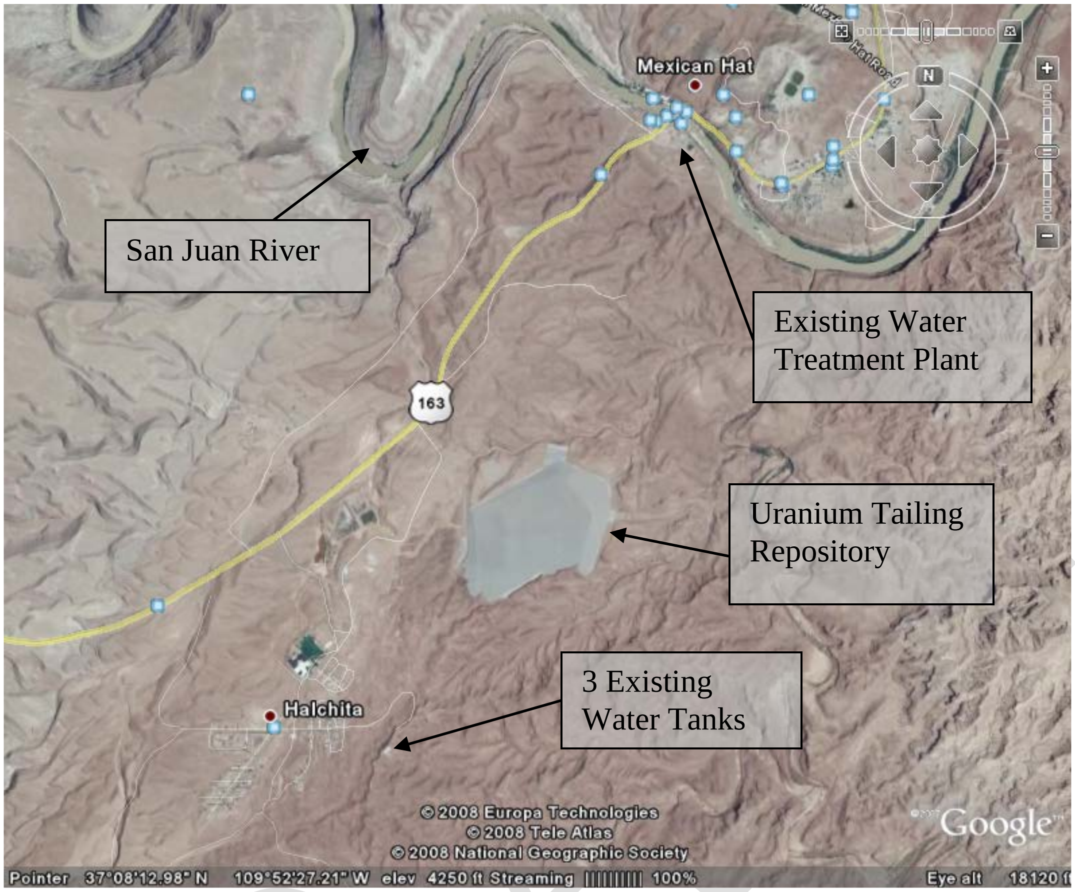


Figure 2-1. Aerial View of Mexican Hat and Halchita, Utah.

The plant consists of a river intake pump, pre-sedimentation tank, chemical contact tank, sand filter, chlorine injection and a clearwell. Sediment is flushed from the pre-sedimentation tank back into the river every couple of hours.

Current Operation

The Navajo Tribal Utility Authority (NTUA) currently operates the plant. According to their operators, they are barely breaking even financially on the operation of the plant. A significant amount of operator time is required. During the summer they need to stay there overnight to oversee the higher demand and watch the water quality due to the higher levels of sediment in the river. According to the operators the plant is shut down at times due to high level of sediment in the river. These periods can last several days. When working on the intake structure or during other hazardous operations, two operators are frequently required as a safety precaution. The maximum capacity of the plant is 140 gallons per minute (gpm); however, in a recent Reclamation report, *Halchita Water Treatment Plant Trip Report, October 28, 2011* by Steve Dundorf and Roger Hanson it stated that the design capacity of the water treatment plant is 250,000 gpd and is currently producing between 30,000 to 80,000 gpd one or two days a week.

Deficiencies

Reclamation has been requested to perform a review of the operation of the Halchita Water Treatment Plant to help restore maximum water output and improve overall efficiency. There are several safety issues concerning the intake structure, sump area and plant operation that need to be addressed as well.

Deficiencies Identified by NTUA

1. Run a service line from 200 yards up stream of the main line to the first customer's residence to meet contact time requirements. Recommendation made by NNEPA.
2. Put baffle inside clearwell for longer chlorine contact time.
3. Build another pre-sedimentation tank. This would prevent shut down time for cleaning the existing tank when water demand is high, especially during the summer months.
4. Upgrade the river tower for a safer working area. Fall prevention devices and a safer guardrail system should be installed at the top of the tower. Remove some of the unnecessary abandoned equipment. Install a better ladder to the top of the tower to change out the light bulbs or lower light fixtures.
5. Install some removable screens for the inlet portholes.
6. Contact Mexican Hat on the north side of the river to determine the possibility of connecting the systems together to allow for the exchange of water if one of the systems is shut down. This would help by allowing winter shut down for maintenance.
7. Clean the water mains of silt build up inside the 6-inch mains.
8. Renovate the old abandoned water storage tank east of Halchita for extra storage during high demand.
9. Replace the old and obsolete inlet water meter. Provide for flow measurement and recording to keep better track of production rates through the plant.
10. Replace the Alum and Polymer chemical injection pumps and upgrade the whole injection piping system.
11. Upgrade the automatic sludge dumper for both the pre-sedimentation tank and chemical contact tank.
12. Replace the old heating and cooling system in the main plant room and office.
13. Hook up to the Oljato water system, which includes wells, for contingency plan purposes. This would be from the Cane Valley or Douglas Mesa water extensions.
14. Replace the lab cabinets and air line from the air compressor unit.
15. Replace the 10-inch 90-degree elbow inside the building.
16. Replace the scrapper pin for the pre-sedimentation tank with a stainless steel pin. Other pins keep shearing off and a stronger material is needed. The pin connects the drive motor and shafts for the bottom scraper in the tank.
17. Replace the old heavy-duty hoist above the river tower.
18. Install a smaller hoist to connect and disconnect the 4-inch flexible hose connected to the sump pump.
19. Clean out the waste pond east of the water treatment plant.

20. Stairs leading down to the intake tower are steep and a safety issue, especially in the winter when ice builds up.

The Technical Service Center (TSC) of the Bureau of Reclamation in Denver evaluated the deficiencies and necessary upgrades for the Halchita Water Treatment Plant. The findings from that evaluation are found in the *Mexican Hat Water Treatment Plant Appraisal Level Design Study dated October 2009*. The Reclamation evaluation of “deficiencies and necessary upgrades” was funded by Reclamation’s Native American Affairs Office. This study may result in a Preliminary Engineering Report that would be the basis for an application to the USDA Rural Development Program for upgrades to the current intake and treatment system.

Mexican Hat Water Treatment Plant

In about 2002, a new reverse osmosis (RO) treatment plant was constructed for the community of Mexican Hat, Utah. The water supply for this new facility and subsequently Mexican Hat is obtained from two wells which were originally developed by the oil industry. These wells, each approximately 100-feet deep, are located near the San Juan River and likely have influence from the river. The two wells produce 40 and 70 gallons per minute flow. A third well was drilled but has never had to be used.

Blanding City, Utah contracts with Mexican Hat for the operation of the new RO treatment plant. According to the plant operator, the plant has a rated capacity of about 80 gpm with current operation at 60 gpm. Summer months have the highest demand, largely the result of tourism at the hotels in Mexican Hat. A 120,000 gallon storage tank is located near the plant (Fleming, D., 2008, pers. comm. 9 Sep).

One option considered as part of this study was to utilize the Mexican Hat Treatment Plant to supply Halchita. In the short-term, this could allow for the existing Halchita treatment plant to be upgraded and its deficiencies addressed. In the long-term, it could potentially eliminate the need for a proposed new water treatment plant that would serve Halchita, but a new plant for Halchita could also be a redundant supply for Mexican Hat if built to provide for a redundant water system to help both communities. At the very least, having the ability to obtain water from the Mexican Hat Treatment Plant would allow for redundancy during emergency or maintenance situations.

The recent closer of the elementary school in Halchita, which was moved to the Monument Valley area, has reduced the water demands for the community and the option of supplying the water needs of Halchita year round from the Mexican Hat plant needs to be studied closer for the best economical solution.

The preceding considerations are based on general information. Further investigation is required in evaluating this option prior to final design. Also, discussion with the appropriate entities, namely, *Mexican Hat Special Service District* and *San Juan County Commissioners*, would need to be undertaken. Whether or not this option is deemed feasible and acceptable by the applicable parties does not necessarily change the proposed project.

Groundwater

With the exception of the Halchita system as described above, all of the communities in the study area rely primarily on wells for their water supply. Wells in the area utilize the DeChelly and Navajo Sandstone formations for fresh water aquifers for culinary use. The DeChelly formation is called the C-Aquifer and the Navajo formation is the N-Aquifer. Currently, the water supply and distribution systems for the Kayenta, Oljato, Douglas Mesa and Cane Valley areas are separate. Each system consists of wells, distribution pipelines, powerlines, pumps, and storage tanks.

The Oljato Wash alluvial aquifer provides the current water supply for the public water systems in the Monument Valley area, which includes Oljato, Monument Valley Tribal Park, Goulding's, Monument Valley Elementary, Middle and High Schools and Monument Valley Mission and Hospital. This aquifer is sensitive to drought conditions because of its limited depth and aerial extent (NNDWR, 2008, p. 1).

The USGS and Navajo Department of Water Resources has done extension research of the aquifer in the Oljato area of Monument Valley. Figure 2-2 shows the overall map and direction of groundwater flow that originates in Mystery Valley and exists at Oljato Wash. Shallow wells in the alluvium provide water for the residents, schools and businesses in the area. More details of the report are listed in the USGS Water-Resources Investigation Report 99-4074 dated 1999 prepared by L.E. Spangler, U.S. Geology Survey and M.S. Johnson, Navajo Nation Department of Water Resources. Potential estimated average discharge from aquifer is 160 acre-feet/year. Current use today is pushing this limit with no available alternatives for increased use by residents and businesses in the area. During periods of drought this average yield of the aquifer can be affected. Goulding's operation would like to expand and have calculated that they would need approximately 500 acre-feet per year for the planned expansion. The existing aquifer will not support little expansion at this time.

Developing additional groundwater in the area will not meet the future needs of the area.

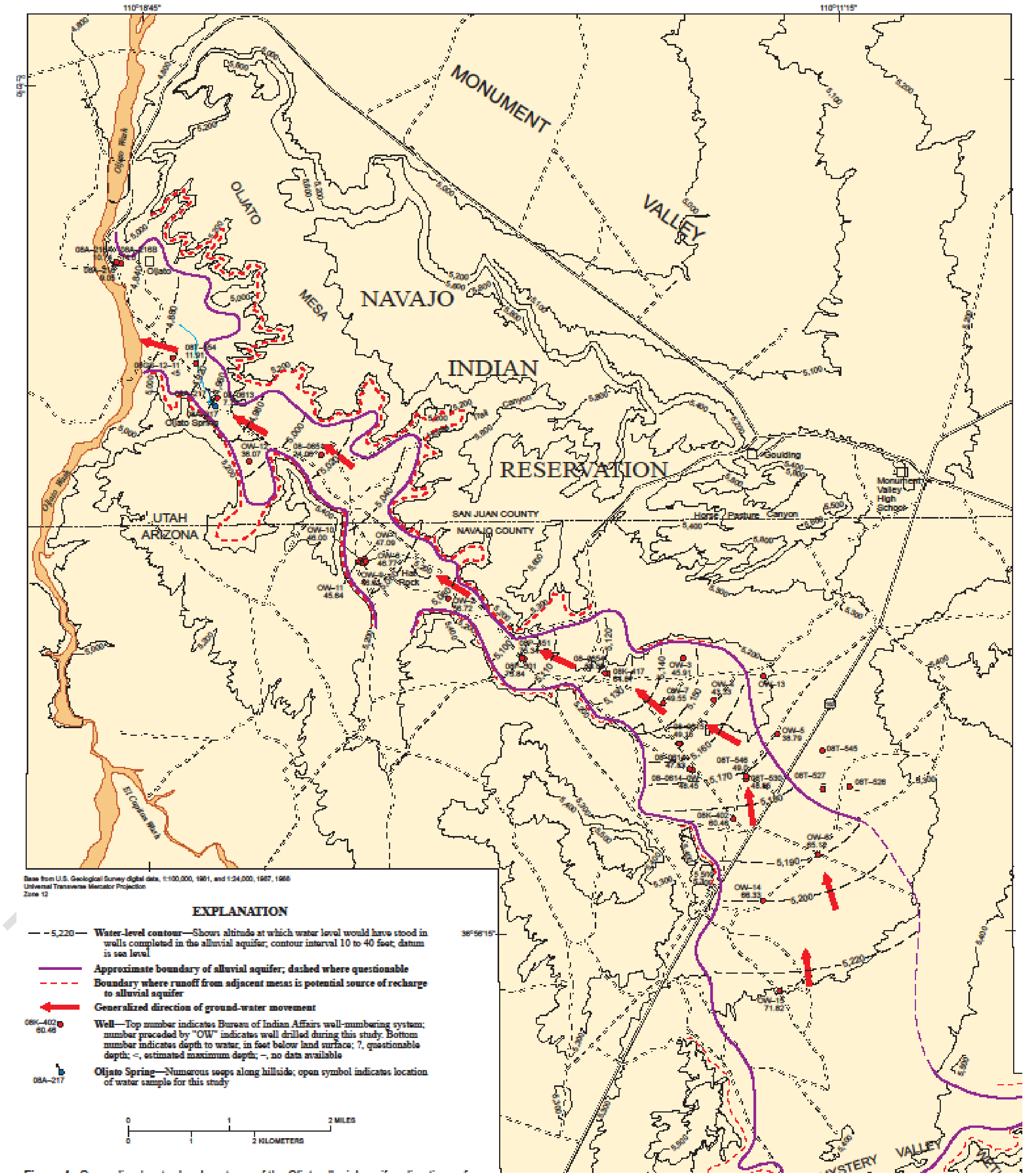


Figure 2-2. Direction of Groundwater Movement in Oljato Area.

NN4900224 Oljato, Utah

CONTAMINANT	VIOLATION YES OR NO	LEVEL DETECTED	UNIT OF MEASUREMENT	MCLG	MCL	LIKELY SOURCE OF CONTAMINATION	POTENTIAL HEALTH EFFECTS FROM EXPOSURE ABOVE THE MCL
MICROBIOLOGICAL CONTAMINANTS							
Total Coliform Bacteria	No	Absent	Present or Absent	0	No more than one sample month can be present with Total Coliform.	Naturally present within the environment.	Coliforms are bacteria that are naturally present in the environment and are used as an indicator that other potentially harmful, bacteria may be present.
E. Coli Bacteria	No	Absent	Present or Absent	0	0	Human and animal waste.	E.Coli is bacteria whose presence indicates that the water may be contaminated with human or animal wastes. Microbes in this waste can cause short-term effects, such as diarrhea, cramps, nausea, headaches or other symptoms.
INORGANIC CONTAMINANTS							
Chromium	No	0.0017 (Annual Average)	mg/L	0.1	0.1 mg/L	Erosion of natural deposits and discharge from steel and pulp mills	Extensive period of exposure above the Chromium MCL potentially increase the risk of allergic dermatitis.
Nitrate	No	0.80 (Annual Average)	mg/L	10.0	10.0mg/L	Erosion of natural deposits, runoff from fertilizer use and leaching from septic tanks and sewage.	Infants who consume drinking water above the Nitrate MCL over an extensive period are potentially at risk for shortness of breath and blue-baby syndrome.

KEY: **MCL** (Maximum Contaminant Level); **MCLG** (Maximum Contaminant Level Goal); **pCi/L** (Picocuries per Liter (a measure of (radioactivity); **mg/L** (Milligrams per liter or parts per million (ppm)); and **ug/L** (Micrograms per liter or parts per billion ppb)

Figure 2-3. Oljato Well Water Quality – Source NTUA 2012.

Kayenta, Arizona currently obtains its water supply from the Navajo Sandstone Aquifer (Figure 2-2, Littin, 1999) as shown in Figure 2-3. In 1968, the Peabody Western Coal Company (PWCC) began strip mining operations in the northern part of the Black Mesa, which is located south of Kayenta. On average, about 3,800 acre-feet of water was used annually by the mine for slurry operations (Littin, 1999). The Navajo Nation became concerned about the long-term effects of withdrawals from the N-Aquifer on available water supplies and, in 1971 a program was established to monitor the water resources in the Black Mesa area. This program is led by the U.S. Geological Survey (USGS) in cooperation with the Arizona Department of Water Resources (ADWR) and the Bureau of Indian Affairs (BIA). In 2004, total industrial and municipal withdrawals were 7,210 acre-feet (Truini, 2006, p. 4). Results from the monitoring program show that N-Aquifer levels have dropped approximately 100 feet since the 1960's (NNDWR, 2008, p. 7). Since the slurry line shut down in 2005, a recent USGS Open File Report *Ground-water, Surface-water and Water-chemistry Data for the Black Mesa Area in Arizona* showed that the total N-aquifer pumping in 2009 was 4,230 acre-feet. Peabody pumping was reduced by almost 70 percent, after the Mohave Power Generation Station shutdown in 2005 and is now withdrawing only 1,200 ac-ft/acre. Based on its location at the edge of the aquifer, Kayenta's ability to withdraw well water could be impacted by further drops in the N-Aquifer levels.

A recent study performed by Brown and Caldwell for the Navajo Nation shows that there is approximately 1,000 acre-feet of sustainable groundwater to be developed from the N-Aquifer in the vicinity of Kayenta. The N-Aquifer supplies water for many communities on the Navajo Nation, therefore, it is a limited resource that will not supply the needed future water demands. Their study also looked at other potential groundwater development outside of the regional that could be piped and used for delivery of water to the region and no sustainable sources were identified expect for the San Juan River.

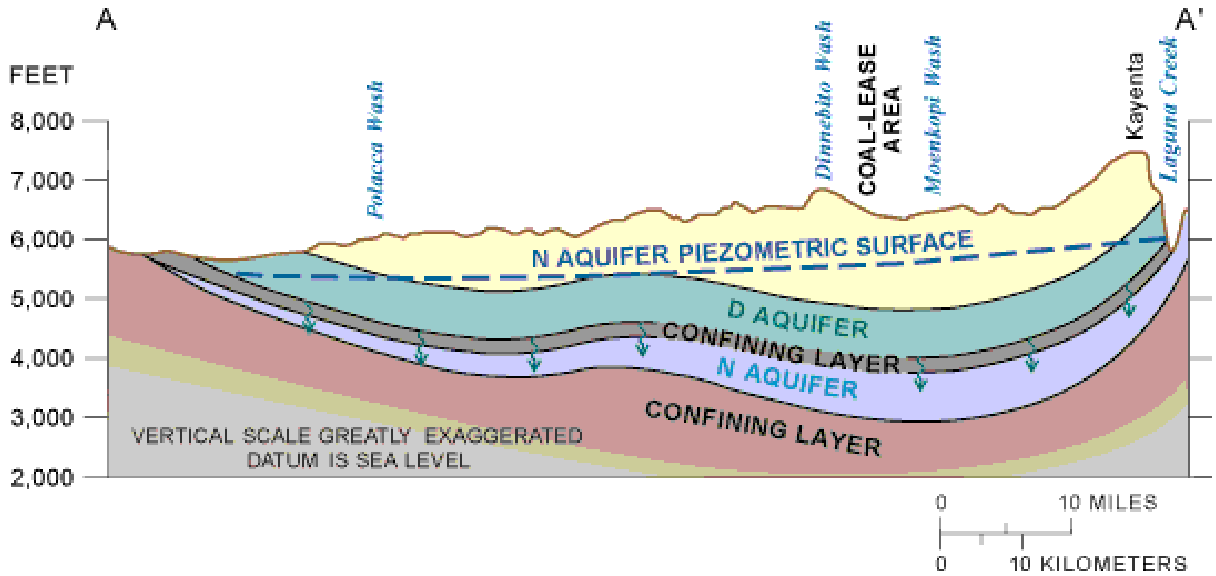


Figure 2-4. Conceptual hydrogeologic profile.

Table 2-1 describes the existing water wells supplying the study area. The average yearly supply for the Kayenta, Oljato, and Cane Valley wells are based on well data collected between 2001 and 2005. Data for the remaining wells were characterized based on pump test data and a twelve hour operation rate. As can be seen, the total average yearly supply from the listed wells is less than 750 acre-feet per year. Although this is not necessarily the maximum amount of water that can be obtained from the groundwater supplies in the study area, it does fall well short of the projected demands for 2060 of 2,255 acre-feet per year.

Table 2-1 Existing water well supply in the study area.

Well Name	Tribal Number	Aquifer	Average Yearly Supply (ac-ft/yr)
Kayenta:			
Kayenta 1	08SS-450	N-Aquifer	56
Kayenta 2	08T-555	N-Aquifer	12
Kayenta 3	08PH-517	N-Aquifer	91
Kayenta/Peabody 4	08T-544	N-Aquifer	73
Kayenta 5	08T-551	N-Aquifer	116
Kayenta 6	08T-552	N-Aquifer	78
Kayenta 7	08T-550	N-Aquifer	84
Monument Valley:			
Oljato 1	08A-216B	Alluvium	4
Oljato 2	08T-554	Alluvium	22
Oljato 3	08-0613	C-Aquifer	30
Monument Park*	08T-546	Alluvium	35
High School 1*	08-0614	Alluvium	32
High School 2*	08-0615	Alluvium	12
Boot Mesa**	08-0612	C-Aquifer	69
Gouldings*	08K-0417	Alluvium	45
Cane Valley:			
Cane Valley	08T-543	C-Aquifer	3
		Total:	**732**

*Separate distribution systems not serviced by NTUA
**Not being utilized

NN0403003 Kayenta, Arizona							
CONTAMINANT	VIOLATION YES OR NO	LEVEL DETECTED	UNIT OF MEASUREMENT	MCLG	MCL	LIKELY SOURCE OF CONTAMINATION	POTENTIAL HEALTH EFFECTS FROM EXPOSURE ABOVE THE MCL
MICROBIOLOGICAL CONTAMINANTS							
Total Coliform Bacteria	No	Absent	Present or Absent	0	No more than one sample month can be present with Total Coliform.	Naturally present within the environment.	Coliforms are bacteria that are naturally present in the environment and are used as an indicator that other potentially harmful, bacteria may be present.
E. Coli Bacteria	No	Absent	Present or Absent	0	0	Human and animal waste.	E.Coli is bacteria whose presence indicates that the water may be contaminated with human or animal wastes. Microbes in this waste can cause short-term effects, such as diarrhea, cramps, nausea, headaches or other symptoms.
INORGANIC CONTAMINANTS							
Arsenic	No	0.0032	mg/L	0	0.010 mg/L	Erosion of natural deposits, runoff from orchards, and runoff from electronics production waste.	Extensive period of exposure above the Arsenic MCL potentially increases the risk of circulatory system problems, skin damage, and cancer.
Chromium	No	0.0020 (Annual Average)	mg/L	0.1	0.01 mg/L	Erosion of natural deposits and discharge from steel and pulp mills.	Extensive period of exposure above the Chromium MCL potentially increases the risk of allergic dermatitis.
Lead	No	0.001	mg/L	0	0.015 mg/L (Action Level)	Corrosion of household systems and erosion of natural deposits.	Extensive period of exposure above the Lead Action Level potentially increases the risk of delayed physical or mental development in infants and children, kidney problems and high blood pressure in adults.
Nitrate	No	0.77 (Annual Average)	mg/L	10.0	10.0 mg/L	Erosion of natural deposits, runoff from fertilizer use, and leaching from septic tanks and sewage.	Infants who consume drinking water above the Nitrate MCL over an extensive period are potentially at risk for shortness of breath and blue-baby syndrome.
RADIONUCLIDE CONTAMINANTS							
Total Uranium Mass	No	4.0	ug/L	0	30.0 ug/L	Erosion of natural deposits.	Extensive period of exposure above the Uranium Mass MCL potentially increases the risk of cancer and kidney toxicity.

KEY: **MCL** (Maximum Contaminant Level); **MCLG** (Maximum Contaminant Level Goal); **pCi/L** (Picocuries per Liter (a measure of (radioactivity); **mg/L** (Milligrams per liter or parts per million (ppm)); and **ug/L** (Micrograms per liter or parts per billion ppb)

Figure 2-5. Kayenta Water Quality – Source NTUA 2012.

Storage Tanks

Existing storage tank information for the various communities was obtained from the Indian Health Service (IHS) – Kayenta Office. Currently, there is nearly 3,000,000 gallons of storage in the project area consisting of 11 tanks (Table 2-1, S Russell, 2008, pers. comm. 4 Sep). There are three tanks in the Oljato area, two tanks in Halchita, and six in the Kayenta area. According to Devin White of NTUA, the condition of these various tanks are in fairly good condition and may be utilized in the final design of this system. Any necessary upgrades or repairs would need to be determined by the Navajo Nation.

Table 2-2. Existing storage conditions in the study area.

Tank	Number	Capacity (gallons)	Approximate Elevation (ft)
Oljato #1	1	100,000	5,125
Oljato #2	1	100,000	5,405
Oljato #3	1	50,000	5,885
Halchita	2	200,000	4,495
Kayenta	2	500,000	5,785
Kayenta	1	500,000	5,800
Kayenta	1	1,000,000	unknown
Kayenta	2	500,000	6,125
Total	**11**	**2,950,000**	

As part of the proposed project, a new storage tank would be located within the vicinity of the proposed water treatment facilities near the point of delivery. These tanks would initially be sized to meet 2020 storage requirements with the intention that it would be enlarged at that time to meet future growth. The existing individual community storage tanks listed in Table 2-2 would provide the added benefit of additional, redundant storage. This additional storage could potentially allow for the shutdown of the river intake structure during times of high sediment load in the San Juan River, resulting in significant cost savings.

2.2 Population and Water Demands

Population Projections

As part of this study, the projected population growth out to the year 2060 was estimated in order to calculate future water demands in the study area and evaluate water supply systems to meet the future needs. The projected population increase was characterized based on the 2010 Census counts in the Monument Valley area consisting of Oljato, Cane Valley, and Halchita as listed in Table 2-3. The 2010 Census count population was projected using an annual growth rate of 1.3 percent. These values include a 4.9% undercount based on the Census Bureau estimates of undercount in the 2010 Census in the coverage of American Indian and Alaska Natives population living on reservations released on May 22, 2012. These values are based on information presented in the previously mentioned technical memorandums titled; *Northern Arizona Water Demand Analysis, Hopi/Western Navajo Water Supply Study* and *in accordance with the USBR Technical Service Center recommendation.*

Table 2-3. Population and Projected Growth

Year	2010	2020	2030	2040	2050	2060
Oljato-MV, Az:	162	184	209	238	271	308
Oljato-MV, Ut:	707	805	915	1,042	1,185	1,349
Halchita, Ut:	279	318	361	411	468	532
Kayenta, Az:	5,443	6,194	7,048	8,019	9,125	10,383
Total:	6,591	7,501	8,533	9,710	11,049	12,572

The projected total study area population for the year 2060 is 12,572. Kayenta's projected population of 10,383 makes up 83% of this total. The population in Arizona makes up 85 percent of the total, with the population in Utah the other 15 percent of the total.

Projected Water Demands

The future annual water demand was characterized based on the projected population growth for the study area and a per capita use rate of 160 gallons per capita per day (gpcd). Similar to the annual growth rate and undercount factor, the per capita use rate was obtained from the previously mentioned Navajo Department of Water Resources technical memorandums. The 160 gpcd has two components of 105 gpcd per capita use and 55 gpcd for business and industrial use per capita.

Table 2-4. Projected Annual Water Demands (gpcd)

	2010	2020	2030	2040	2050	2060
Oljato-MV, Az:	25,920	29,440	33,440	38,080	43,360	49,280
Oljato-MV, Ut:	113,120	128,800	146,400	166,720	189,600	215,840
Halchita, Ut:	44,640	50,880	57,760	65,760	74,880	85,120
Kayenta, Az:	870,880	991,040	1,127,680	1,283,040	1,460,000	1,661,280
Total (gpd)	1054560	1200160	1365280	1553600	1767840	2011520
(MGD)	1.05	1.20	1.37	1.55	1.77	2.01
(gpm)	732	833	948	1079	1228	1397
(cfs)	1.6	1.9	2.1	2.4	2.7	3.1
(acre-ft/yr)	1182	1345	1530	1741	1982	2255

As shown in Table 2-4, the projected water demand for the year 2060 is 2.01 million gallons a day (MGD) and 2,255 acre feet per year. For the purposes of this study, it would be assumed that the full future water demand (2,255 acre-feet/year) would need to be supplied from the San Juan River and that existing groundwater supplies would not be taken into account and would be used as a conjunctive use to surface supplies during periods of high sediment in the river or during periods of low flows in the river. Using this average demand, up to an additional 35 percent of water may be needed above this amount due to processes used in micro and nanofiltration that form concentrates that cannot be used in the drinking water supply and would be wasted. Pilot testing of the water treatment processes would provide a more definitive percentage of water that would be wasted during treatment process. Adding the 35 percent to the average demand for the region would be approximately 3,044 acre-feet per year that would need to be diverted from the river, with a percentage of it wasted during the water treatment process. As discussed previously, existing groundwater supplies would need to be used in the short-term during implementation and construction of the project. It is anticipated that in the long-term the existing wells would be available for redundancy and/or emergency purposes. In large part, it would be up to the Navajo Nation to determine to what extent the existing groundwater supplies are used in the future. Once the project is completed and demand is met, it is likely that the aquifers would be replenished to some extent for long term water management. Issues of differences of water quality between the groundwater chemistry and the surface water would need to be studied further during feasibility review to determine if there would be any adverse effects from using water from the different sources. The groundwater system would also have to be continually maintained to be operational for an immediate backup to the surface water supply.

As stated above, 2,255 acre-feet represents the average amount of water that would be needed annually. A peaking factor of 1.3 needs to be applied to the annual demand values in order to ensure adequate capacity to meet seasonal fluctuations in water use. Table 2-5 shows the maximum peak day demand values using the 1.3 peaking factor. The resulting demand of 2.61 MGD (4.05 cfs and about 1816 gpm) would be used to design a new water supply alternative.

Table 2-5. Maximum Peak Day Demand (gpcd).

	2010	2020	2030	2040	2050	2060
Oljato-MV, Az:	33696	38272	43472	49504	56368	64064
Oljato-MV, Ut:	147056	167440	190320	216736	246480	280592
Halchita, Ut:	58032	66144	75088	85488	97344	110656
Kayenta, Az:	1132144	1288352	1465984	1667952	1898000	2159664
Total (gpd)	1370928	1560208	1774864	2019680	2298192	2614976
(gpm)	952.03	1083.48	1232.54	1402.56	1595.97	1815.96
(MGD)	1.37	1.56	1.77	2.02	2.30	2.61
(cfs)	2.12	2.4	2.7	3.1	3.6	4.05
(acre-ft/yr)	1537	1749	1989	2264	2576	2931

A separate peaking factor of 1.5 is used to calculate peak delivery demands to the end user. Shown in Table 2-6, the resulting value of 3.02 MGD (4.1 cfs and about 2,095 gpm) would be used to size the pipelines in the distribution system from the water storage tanks to the various communities.

Table 2-6. Peak Delivery Demand (gpcd).

	2010	2020	2030	2040	2050	2060
Oljato-MV, Az:	38880	44160	50160	57120	65040	73920
Oljato-MV, Ut:	169680	193200	219600	250080	284400	323760
Halchita, Ut:	66960	76320	86640	98640	112320	127680
Kayenta, Az:	1306320	1486560	1691520	1924560	2190000	2491920
Total (gpd)	1581840	1800240	2047920	2330400	2651760	3017280
(gpm)	1098.50	1250.17	1422.17	1618.33	1841.50	2095.33
(MGD)	1.58	1.80	2.05	2.33	2.65	3.02
(cfs)	2.4	2.8	3.2	3.6	4.1	4.67
(acre-ft/yr)	1773	2018	2295	2612	2972	3382

Storage Requirements

Typically, water storage is provided to maintain system pressure, allow for more routine pumping cycles, meet peak demands, provide for firefighting storage, and for emergency situations such as power and equipment failures (Ruekert & Mielke, Inc., 2007, p. 155). With adequate storage, pumps can operate at their design point for longer periods of time without cycling. Level controls at the storage tank(s) normally activate the pumps, not fluctuations in demand (Tullis, 1989, p. 39).

Storage requirements in this section pertain to the proposed water storage tanks to be located in the vicinity of the proposed secondary treatment and distribution points. As mentioned in Section 2.3, there are numerous existing community storage tanks which would provide additional redundant storage.

Storage capacity for the tanks are based on the average daily demands multiplied by five days (NNDWR, 2007, p. 6). This method of determining storage capacity is consistent with the Navajo – Gallup Water Supply Project (Reclamation, 2007, p. F-13). Required storage capacity is shown for the years 2020, 2040, and 2060 in Table 2-7. Initially, the tanks could be constructed based on 2020 demands with the capability of enlargement in the future as demand increases. It is possible that existing community storage tanks can be utilized to postpone required enlargement of the proposed tanks, resulting in some cost savings. Table 2-8 shows the breakdown of the required storage by area for informational purposes.

Table 2-7. Projected regional storage tank capacity.

Year	Storage Capacity (gallons)	
		rounded
2020	6,000,800	6,000,000
2040	7,768,000	8,000,000
2060	10,057,600	10,500,000

Table 2-8. Projected storage tank capacity by area.

Year	Kayenta	Oljato	*Halchita
2020	4,955,200	791,200	294,400
2040	6,415,200	1,024,000	368,800
2060	8,306,400	1,325,000	465,600

**Includes 40,000 gpd of current use.*

Based on a projected regional population of nearly 12,600 in the year 2060 and water use of 160 gallons per capita per day (gpcd), approximately 2,255 acre-feet of water and 10.5M gallons of storage would be required annually at full build-out.

Storage of water for the area is very important due to vary degrees of water quality in the river and periods of shutdown of the river intake may be prudent during periods of high sediment load or during low flow periods in the river.

2.3 Water Rights

San Juan River – According to reports from the San Juan River Recovery Implementation Program (Holden, 1999) the median annual flows of the San Juan River at Bluff, Utah is 1,620,000 acre-feet. The Navajo Nation has the paramount water claim from the San Juan River, but these water rights are unquantified. A limiting factor for water development in this basin is the protection of the endangered Colorado pike minnow and the razorback sucker. The presence of these species may reduce the water availability for the Navajo Nation and may restrict future development.

In an August 4, 2008, phone conversation, Mr. John Leeper, Manager, Water Management Branch, Navajo Nation Department of Water Resources indicated that the proposed project would divert water under the Navajo Nation's reserved water rights. Mr. Leeper also indicated that these reserved water rights would be administered by the Navajo Nation and their use would remain entirely within the Nation's jurisdiction. Currently, the Navajo Nation is negotiating with Utah and Arizona to quantify these reserved water rights. The Nation is claiming sufficient water from the San Juan and its tributaries in Utah and Arizona to create a permanent homeland for the Navajo people. Although these negotiations are ongoing, Mr. Leeper indicated that the amount of water required by this project falls well within the amounts being considered by both parties.

The priority dates for these reserved water rights may date from the time treaties, statutes, and executive orders established reservations of land for the Tribe and are typically senior to other rights within the Basin. The Navajo Nation reserved water rights were established by the treaty between the United States of America and the Navajo Tribe of Indians, which was signed, ratified, and proclaimed between the years of 1849 and 1868. Given the seniority of the Navajo reserved water rights the proposed project should be able to divert water even during times of drought and low flows.

Water depletions from the proposed project could be counted against Arizona's and Utah's depletion allotments in the Upper Colorado River basin under the 1948 Upper Colorado River Compact. This compact, among other things, divides depletions apportioned to the Upper Basin States in the 1922 Colorado River Compact. Under these compacts Arizona is entitled to deplete 50,000 acre-feet in the upper basin and Utah is allowed to deplete 23 percent of the total water allocated to the upper basin states.

The Department of Interior has appointed a Federal team to work on the water rights issue and the State of Utah has passed legislation to support this effort. It should also be noted that the Navajo Nation and the State of Utah have a MOU in place supporting this study.

2.4 Water Quality

San Juan River Water Quality

Water quality data for the San Juan River was obtained from USGS Gage #09379500. This gage is located across from Mexican Hat a short distance upstream from the existing treatment plant and the proposed intake structure site. The data is based off of field samples collected from as early as 1928 to as recent as August of 2008, depending on the parameter. While this data can provide some valuable general information for the preliminary design of the new treatment plant and intake structure, further investigation and sampling is required for the final design to ensure the most effective treatment system.

Table 2-9 shows the monthly mean water temperatures in the San Juan River. This is just one indication of the variability of water quality parameters that needs to be taken into account in the design of the water treatment plant.

Table 2-9. Monthly mean San Juan River water temperatures (°F).

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Max	40.0	44.3	54.8	60.1	66.3	72.7	80.8	79.3	70.8	60.1	47.2	39.5
Min	33.2	38.0	44.3	50.9	56.8	61.7	67.1	67.2	61.8	53.2	42.9	34.5
Mean	36.1	41.0	49.5	56.1	61.7	66.7	76.1	75.0	67.6	57.4	44.8	36.7

Source: USGS, 2008

The San Juan River basin carries a tremendous amount of sediment, particularly at the lower reaches through the study area. Because of the significant cost and difficulties involved with sediment removal, it is important to determine as much as possible the quantities and timing of the sediment load in the river at Mexican Hat. Fortunately, the USGS gage near Mexican Hat has information available from hundreds of field samples taken between 1943 and 2000 for sediment concentrations as well as sediment discharges. This information proved helpful in drawing some general conclusions regarding sediment issues for this study. Once again though, further research and sampling should be completed prior to final design.

Table 2-10. San Juan River Water Quality Data.

	Historic Data	
Parameters	**Average**	**Range**
Temperature (°F)	57.7	33.2 – 80.8
Specific Conductance	655	155 – 983
Sediment Concentration (mg/L)	9,549	5 – 155,000
Sediment Discharge (tons/day)	96,422	3 – 7,170,000
Turbidity (NTU)	613	2 – 11,000
pH	7.8	6.6 – 8.9
Nitrogen (mg/L)	2.6	0.3 – 36.0
Chloride (mg/L)	20.3	2.0 – 325.0
Sulfate (mg/L)	312.7	25.0 – 1,070.0
Hardness (mg/L)	328.3	100.0 – 1000.0

Source: USGS, 2008

As can be seen in Table 2-10, an extremely wide range in both sediment concentrations (5 – 155,000 mg/L) and discharges (3 – 7,170,000 tons/day) exists in the San Juan River at Mexican Hat. This gives an indication of the difficulty in designing an effective intake structure and sediment removal system. Although high flows in this section of the river occur in May and June during spring runoff, the highest values for both sediment concentration and discharge are during the late summer and early fall (Figure 2-6). This is likely due to the monsoon season over the southwestern U.S. and resulting sediment laden inflow from side drainages. Current operations of the river intake see high sediment amounts also during low flow and river depth, so periods of low flow can also have high sediment concentrations that would need to processed during treatment operations.

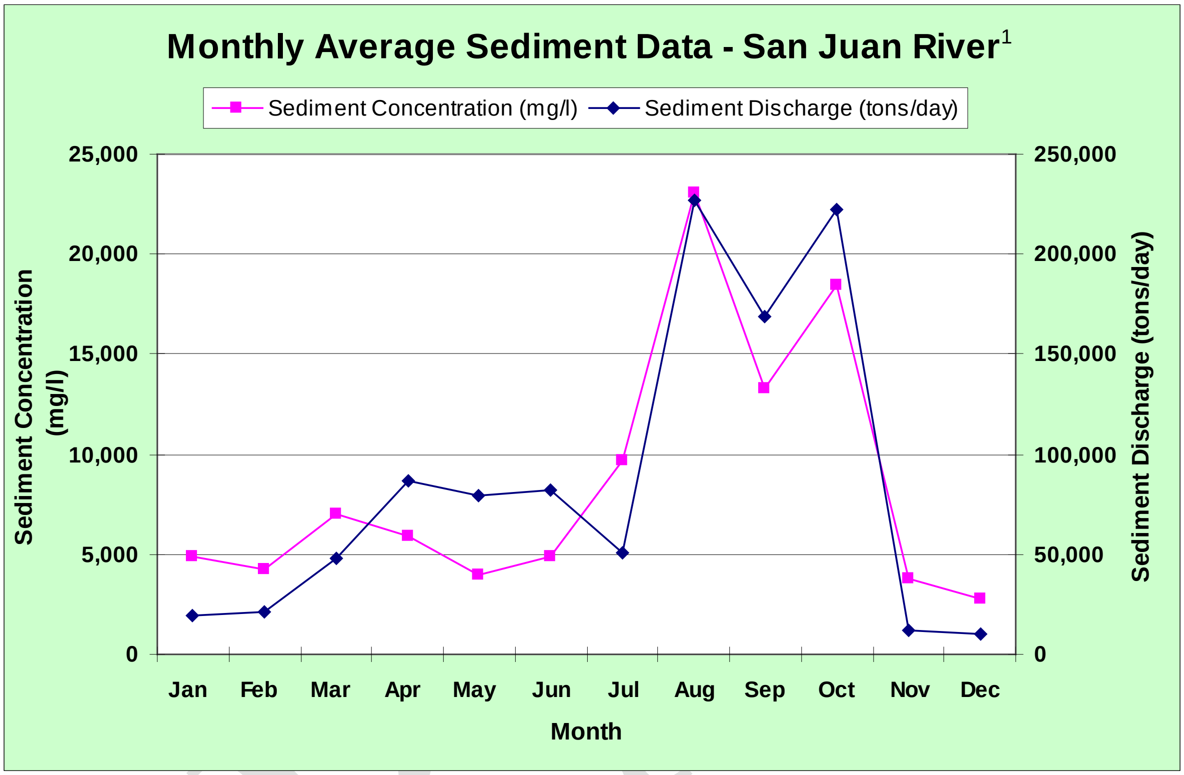


Figure 2-6. Monthly average sediment data on the San Juan River.

[1]Sediment concentration based on 978 field samples between 1945 and 2000 and sediment discharge data based on 1285 field samples between 1943 and 2000, both collected at USGS Gage #09379500 near Bluff, UT

Something else to consider is the sediment distribution during the year. Figure 2-7 (USGS, 2008) shows San Juan River data between 1942 and 1967. As can be seen, generally, over 50% of the sediment discharge would occur in only 10% of the year, and in some years the value is much higher. Even more significant is the percentage of annual sediment discharge that occurs in just 1% of the year. In some years this amount approaches 50%. Although none of the data is recent, it is assumed that this trend continues today.

If the proposed project can be designed with sufficient storage to allow for complete shut down of the river intake during these short time periods, sediment removal requirements as well as wear on equipment can be significantly reduced. In turn, this would result in annual operation and maintenance (O&M) cost savings. In order for this scenario to work, an accurate and working Supervisory Control and Data Acquisition (SCADA) system would be needed as well as frequent communication with the National Weather Service (NWS).

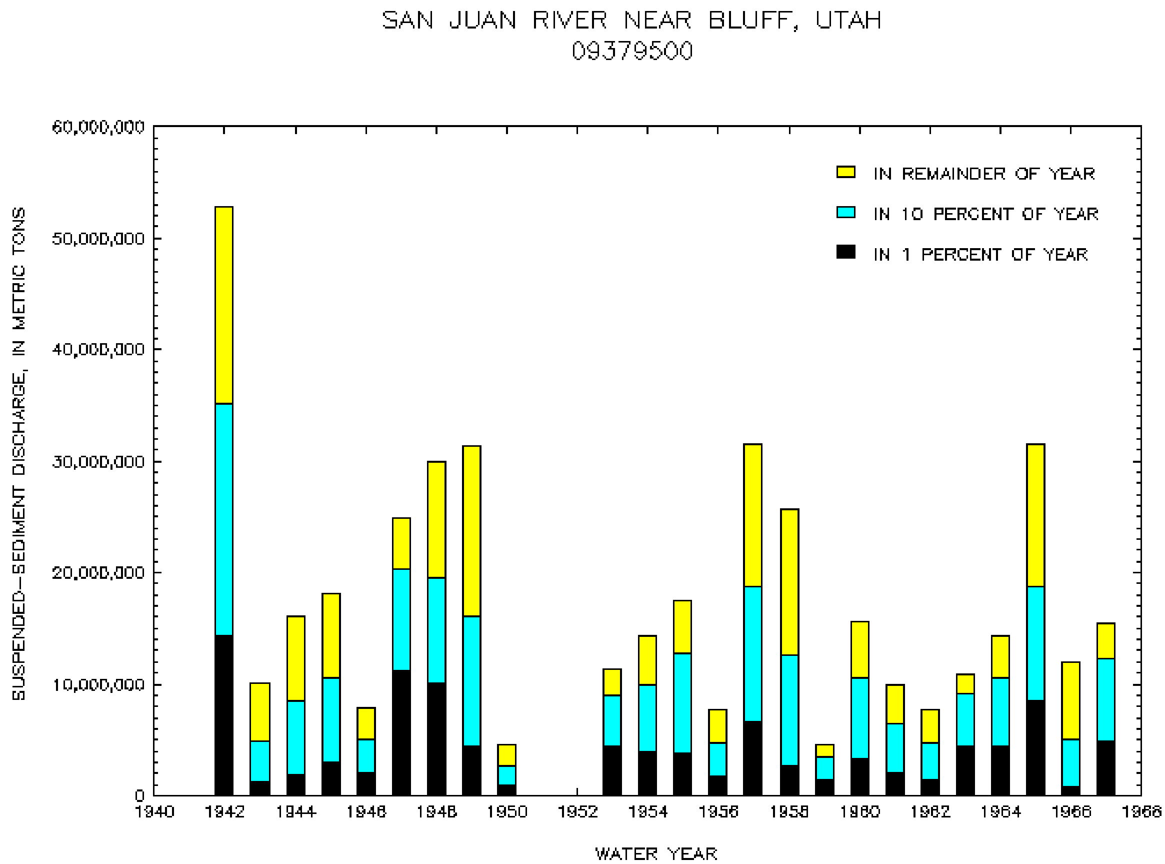


Figure 2-7. Histogram of suspended sediment discharge on the San Juan River.

These historic values could be slightly affected by the operation of Navajo Dam for endangered fish. The timing of releases to produce reduced base flow and increased spring runoff will result in the winter flows containing a higher percentage of return flows in the lower reaches. Higher summer base flows reduce the portion of return flows for a potential improvement in water quality in these post-runoff months. However, measurements over the last seven years of modified flows have not detected a measurable change in water quality due to this change in flow regime. There are return flow points from municipal, industrial and irrigation uses along most of the length of the River. However, most of the return flow points occur between Bloomfield and Shiprock, New Mexico. The water quality of the San Juan River steadily decreases moving downstream. For example, the salt content continually increases going downstream from Navajo Reservoir to Mexican Hat. This happens as the San Juan River collects water from the Animas, LaPlata, and Mancos Rivers and from numerous smaller intermittent streams and washes, is depleted for irrigation and other uses and receives return flows. The water quality can also fluctuate quickly due to storm runoff from small streams and washes entering the river. Table 2-11 summarizes the water quality measurements found in the combined STORET-Reclamation-BIA water quality database. Above Farmington, NM, there are a few historic exceedences in the San Juan River for aluminum, mercury, selenium, cadmium and lead. The number of exceedences increase between Farmington and Shiprock, NM including several for copper and zinc. At Four Corners, the number of exceedences decreases. Per Utah's regulations there were additional exceedences at Mexican Hat (near Bluff) in nutrients and total suspended solids.

Table 2-11. Historical (1950-98)Water Quality Measurements on San Juan River.

	Farmington		Shiprock		Four Corners		Bluff	
Parameter	n	Mean	n	Mean	n	Mean	n	Mean
Alkalinity total (mg/L as $CaCO_3$)	607	114	646	119	59	121	2,333	147
Aluminum dissolved (µg/L as Al)	34	34.4	138	58.5	40	63.9	174	64.1
Aluminum total (µg/L as Al)	30	5,283	83	15,636	30	11,373	134	20,500
Arsenic dissolved (µg/L as As)	76	1.9	267	2.3	78	1.8	345	1.9
Arsenic total (µg/L as As)	78	2.8	224	4.4	72	3.8	309	4.3
Boron dissolved (µg/L as B)	315	49.5	678	103.9	45	126.0	1,720	68.7
Cadmium dissolved (µg/L as Cd)	11	0.8	71	0.9	15	1.2	56	1.0
Cadmium total (µg/L as Cd)	12	5.7	29	3.6	7	3.7	15	3.7
Calcium dissolved (mg/L as Ca)	859	61.6	1,178	72.4	135	65.6	2,627	93.8
Calcium total (mg/L as Ca)	5	71.5	12	70.8	6	78.8	23	88.8
Chloride total in water (mg/L)	830	9.8	1,084	16.9	104	13.5	2,568	20.6
Chromium dissolved (µg/L as Cr)	4	11.3	53	3.2	4	2.9	48	2.5
Chromium total (µg/L as Cr)	9	51.8	25	22.5	5	17.0	17	52.1
Cobalt dissolved (µg/L as Co)	9	1.5	67	1.4	10	1.6	53	1.5
Cobalt total (µg/L as Co)	13	44.4	29	22.9	7	10.6	21	41.7
Copper dissolved (µg/L as Cu)	45	3.8	165	4.2	48	5.0	203	4.9
Copper total (µg/L as Cu)	45	29.5	121	35.5	42	20.8	163	35.8
Fecal coliform (counts/100 mL)	93	10,588	162	1,040	23	256	72	185
Hardness calc. (mg/L as $CaCO_3$)	859	189	1,154	237	123	222	2589	326
Hardness total (mg/L as $CaCO_3$)	824	189	969	245	45	224	2423	336
Iron dissolved (µg/L as Fe)	164	47.2	251	31.2	42	22.0	69	30.5
Iron total (µg/L as Fe)	15	25,691	39	30,449	13	13,405	201	4,809
Lead dissolved (µg/L as Pb)	67	0.7	256	1.5	70	0.8	343	1.0
Lead total (µg/L as Pb)	79	30.3	222	27.6	71	23.6	305	26.1
Magnesium dissolved (mg/L as Mg)	859	8.4	1,176	13.4	135	14.4	2,628	25.0
Magnesium total (mg/L as Mg)	5	11.9	12	14.0	6	17.4	23	27.1
Manganese dissolved (µg/L as Mn)	26	22.3	110	45.0	30	6.3	86	6.1

Historical (1950–98) water quality measurements on the San Juan River (continued)

	Farmington		Shiprock		Four Corners		Bluff	
Parameter	n	Mean	n	Mean	n	Mean	n	Mean
Manganese total (µg/L as Mn)	20	852	56	978	27	449	39	1,109
Mercury dissolved (µg/L as Hg)	70	0.12	254	0.13	75	0.10	338	0.11
Mercury total (µg/L as Hg)	78	0.14	225	0.15	71	0.13	309	0.14
Nickel dissolved (µg/L as Ni)	28	6.1	146	4.6	36	5.2	184	4.6
Nickel total (µg/L as Ni)	28	6.8	105	12.1	39	9.7	144	15.5
Nitrite + nitrate total (mg/L as N)	47	0.27	98	0.39	27	0.74	55	0.78
Oxygen dissolved (mg/L)	251	9.5	455	9.8	159	9.5	478	9.2
pH lab (standard units)	879	7.81	1,097	7.89	107	8.25	1,357	7.78
pH field (standard units)	60	8.13	190	8.26	60	8.25	285	8.20
Phosphorus total (mg/L as P)	59	0.27	164	0.32	31	0.37	95	0.58
Residue total filtrable (dried at 180 °C) (mg/L)	374	382	667	498	102	422	1,313	656
Selenium dissolved (µg/L as Se)	81	0.6	277	1.0	78	1.3	349	1.1
Selenium total (µg/L as Se)	76	0.7	227	0.9	71	1.6	309	1.4
Selenium total recoverable (µg/L as Se)	10	0.5	29	1.0	10	0.9	47	0.8
Silver dissolved (µg/L as Ag)	2	0.75	51	0.56	n/a	n/a	45	0.56
Silver total (µg/L as Ag)	2	0.75	10	1.10	n/a	n/a	9	2.06
Sodium dissolved (mg/L as Na)	836	44.7	951	64.6	112	49.3	2,047	79.2
Sodium total (mg/L as Na)	5	37.7	12	38.5	6	43.8	23	58.2
Solids susp.-residue on evaporation at 180 °C (mg/L)	59	242	191	956	60	663	283	934
Specific conductance (µmhos/cm at 25 °C)	905	550	1136	716	112	644	2,020	931
Sulfate total (mg/L as SO_4)	827	154	1,083	225	104	193	2,568	329
Turbidity (NTU, FTU, JTU)	117	158	142	527	104	406	92	503
Water temperature (°C)	60	10.6	227	12.2	79	12.4	343	12.6
Zinc dissolved (µg/L as Zn)	80	9.2	268	9.2	77	7.8	346	15.7
Zinc total (µg/L as Zn)	75	92.9	224	114.1	71	204.0	306	109.6

Source: Final Supplemental Environmental Impact Statement, Animas-La Plata Project, Technical Appendices, Water Quality Analysis (, 2000a).

Table 2-12. Water Quality Data at Four Corners Bridge 1994 to 2004.

Parameter	1994-2003 N of Cases	Minimum	Maximum	Mean	Standard Dev	2004 N of Cases	Minimum	Maximum	Mean	Standard Dev
Bicarbonate (mg/l)	53	67.0	214.0	118.8	29.9	4	84.0	146.0	125.5	28.4
Alkalinity (mg/l)	53	67.0	214.0	119.3	30.1	4	84.0	148.0	126.8	29.1
Arsenic dissolved (µg/l)	82	0.3	17.2	1.9	1.9	4	0.3	1.0	0.6	0.3
Arsenic total (µg/l)	82	0.5	19.0	3.9	3.9	4	0.6	5.0	2.0	2.1
Calcium dissolved (mg/l)	53	31.7	99.9	66.4	18.8	4	43.9	86.1	70.7	19.6
Copper dissolved (µg/l)	53	1.0	16.2	4.2	3.0	4	*0.6*	1.5	1.2	0.4
Copper total (µg/l)	53	2.5	130.0	25.4	25.2	4	1.8	50.0	15.9	23.0
Hardness ((mg/l)	53	103.0	340.0	222.6	66.4	4	139.0	293.0	234.3	69.3
Mercury dissolved (µg/l)	82	*0.1*	0.3	*0.1*	0	4	*0.1*	*0.1*	*0.1*	0
Mercury total (µg/l)	82	*0.1*	0.8	*0.1*	0.1	4	*0.1*	*0.1*	*0.1*	0
Magnesium dissolved (mg/l)	53	5.5	23.8	13.8	5.1	4	7.0	19.0	14.0	5.1
Sodium dissolved (mg/l)	30	12.6	70.3	44.6	16.7	4	16.1	60.9	46.8	21.1
Lead dissolved (µg/l)	82	*0.1*	14.4	0.7	1.7	4	*0.1*	0.7	0.3	0.3
Lead total (µg/l)	82	0.5	271.0	21.9	40.6	4	1.0	11.6	6.3	4.4
Selenium dissolved (µg/l)	82	*0.5*	2.0	*0.8*	0.5	4	*0.5*	*0.5*	*0.5*	0
Selenium total (µg/l)	82	*0.5*	4.0	1.0	0.6	4	*0.5*	1.0	*0.6*	0.3
Selenium total recoverable (µg/l)	32	*0.5*	2.0	*0.8*	1.4	4	*0.5*	1.0	*0.6*	0.3
Total dissolved solids (mg/l)	52	110.0	640.0	389.2	131.9	4	190.0	540.0	405.0	151.5
Total suspended solids (mg/l)	82	2.5	11700.0	750.5	1822.4	4	38.0	348.0	132.5	146.1
Turbidity (NTU)	80	2.0	60500.0	1230.5	6834.5	4	17.9	277.0	91.0	124.7
Zinc dissolved (µg/l)	82	5.0	30.0	7.6	5.5	4	5.0	5.0	5.0	0
Zinc total (µg/l)	82	*5.0*	920.0	88.2	131.8	4	*5.0*	60.0	25.0	26.1
Temperature (°C)	82	0	26.3	12.5	7.5	2	15.4	22.5	19.0	5.0
pH	82	6.8	8.8	8.2	0.4	2	8.3	8.5	8.4	0.1
Conductance (µmhos/cm)	82	251.0	870.0	587.3	177.3	2	339.0	656.0	497.5	224.2
Redox Potential (mv)	80	189.0	592.0	395.3	82.6	2	401.0	422.0	411.5	14.8
Oxygen dissolved (mg/l)	81	4.3	12.7	9.3	2.1	2	8.1	8.4	8.2	0.2

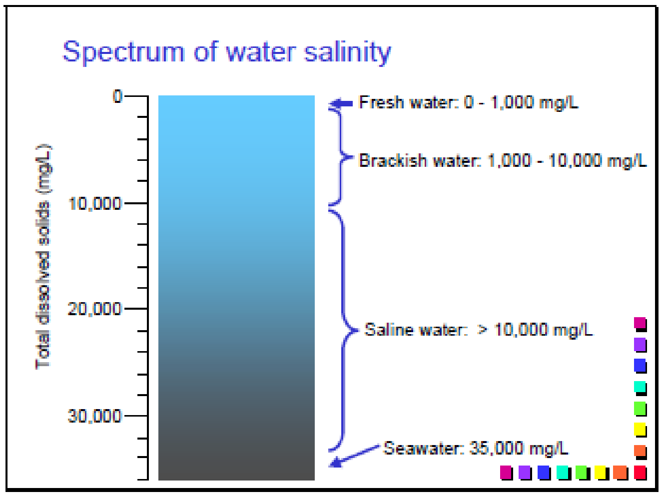
Source: San Juan River Basin Recovery Implementation Program – Hydrology/Geomorphology/ Habitat Studies 2004 Annual Report

Table 2-13. Water Quality Data at Mexican Hat Bridge 1994 to 2004.

Parameter	1994-2003 N of Cases	Minimum	Maximum	Mean	Standard Dev	2004 N of Cases	Minimum	Maximum	Mean	Standard Dev
Bicarbonate (mg/l)	50	71.0	1070.0	147.6	135.6	4	86.0	144.0	122.5	27.7
Alkalinity (mg/l)	50	71.0	1070.0	147.6	135.6	4	86.0	144.0	124.0	27.4
Arsenic dissolved (µg/l)	79	0.5	2.5	1.8	0.8	4	0.3	1.0	0.6	0.3
Arsenic total (µg/l)	79	0.8	75.7	5.6	10.3	4	0.8	5.0	2.2	2.0
Calcium dissolved (mg/l)	50	32.7	164.0	76.6	24.9	4	46.5	103.0	80.1	28.0
Copper dissolved (µg/l)	50	1.5	13.0	4.3	3.0	4	*0.7*	1.8	1.2	0.5
Copper total (µg/l)	50	1.5	255.0	26.5	43.4	4	1.9	50.0	16.6	22.8
Hardness ((mg/l)	50	108.0	530.0	275.8	95.6	4	139.0	369.0	285.5	108.4
Mercury dissolved (µg/l)	79	*0.1*	*0.1*	*0.1*	0	4	*0.1*	*0.1*	*0.1*	0
Mercury total (µg/l)	79	*0.1*	1.1	*0.1*	0.2	4	*0.1*	*0.1*	*0.1*	0
Magnesium dissolved (mg/l)	50	6.2	43.8	20.5	8.9	4	7.4	28.4	20.8	9.4
Sodium dissolved (mg/l)	27	12.8	113	52.9	22.5	4	15.1	72.7	49.1	24.6
Lead dissolved (µg/l)	79	*0.1*	1.0	0.4	0.2	4	*0.1*	0.6	0.3	0.2
Lead total (µg/l)	79	0.5	327.0	23.4	51.0	4	0.3	15.3	4.6	7.2
Selenium dissolved (µg/l)	79	*0.5*	4.0	*0.9*	0.6	4	*0.5*	*0.5*	*0.5*	0
Selenium total (µg/l)	79	*0.5*	7.0	1.2	1.1	4	*0.5*	1.0	*0.6*	0.3
Selenium total recoverable (µg/l)	29	*0.5*	9.0	1.5	1.9	4	*0.5*	*0.5*	*0.5*	0
Total dissolved solids (mg/l)	49	170.0	1050.0	487.3	181.8	4	220.0	640.0	477.5	196.0
Total suspended solids (mg/l)	79	*1.0*	16800.0	1385.8	3170.4	4	14.0	254.0	92.5	109.1
Turbidity (NTU)	77	1.0	24700.0	1057.2	3244.4	4	13.4	91.3	61.5	33.1
Zinc dissolved (µg/l)	79	*5.0*	100.0	9.0	12.0	4	*5.0*	*5.0*	*5.0*	0
Zinc total (µg/l)	79	*5.0*	1620.0	118.0	249.2	4	*5.0*	80.0	23.8	37.5
Temperature (°C)	79	0.1	29.8	12.6	7.9	2	16.3	22.4	19.3	4.4
pH	79	7.0	8.6	8.1	0.3	2	8.3	8.6	8.4	0.2
Conductance (µmhos/cm)	79	273.0	1452.0	701.8	226.8	2	335.0	669.0	502.0	236.2
Redox Potential (mv)	78	140.0	537.0	392.3	89.0	2	373.0	390.0	381.5	12.0
Oxygen dissolved (mg/l)	78	5.8	12.9	9.1	2.0	2	7.7	8.3	8.0	0.4

Note: *Italics* indicate "below detection"

Source: San Juan River Basin Recovery Implementation Program – Hydrology/Geomorphology/ Habitat Studies 2004 Annual Report



Water salinity varies with the source of the water. Fresh water is generally considered to be that which has less than 1000 mg/L of total dissolved solids (TDS), whereas sea-water typically has 35,000 mg/L of TDS. Brackish and saline water falls between these values. The feasibility of using a particular water source for a potable supply depends on the salinity; the lower the TDS, the more feasible the supply.

Figure 2-8. Spectrum of Water Salinity.

Source: **TECHNICAL CHALLENGES TO CONCENTRATE DISPOSAL FROM INLAND DESALINATION Abstract by** Dr. Kerry J. Howe, P.E., Department of Civil Engineering, The University of New Mexico

As a comparison of levels of TDS in bodies of water, the levels are shown for fresh water in Figure 2-8. The water quality information shown indicates that the level of TDS varies at the intake location. The maximum levels of TDS in the river as shown in Table 2-13 have approached the lower limit for brackish water as shown in Figure 2-8. During these high periods of TDS their effect on the water treatment process and concentrate disposal will need to be determined. The recorded mean values appear to fit in the middle of the fresh water band as shown in Figure 2-8. The treatment system will need to be design to handle the fluctuations in the water quality and to assure that the membrane technology will not be affected by the varying water quality.

Water Quality Regulations

EPA water quality standards for drinking water production and regulation include both the National Primary Drinking Water Regulations (NPDWR) and the National Secondary Drinking Water Regulations (NSDWR) established under the Safe Drinking Water Act (SDWA). Treating water to meet NPDWR is required, and treating to meet NSDWR is recommended. Because the water supply would be taken from the San Juan River, the Surface Water Treatment Rule (SWTR) applies.

3.0 Resources

This section provides a preliminary assessment of impacts of the proposed project to biological and cultural resources. Information and analyses in this report are based on research and field surveys conducted in July 2008. The conclusions drawn are based on best available information regarding project design and are subject to revision or supplementation as additional project design information becomes available.

The surveys conducted provide a brief overview of possible environmental and cultural effects. Should a federal action/undertaking for this proposed pipeline be defined in the future, a formal analysis in compliance with the National Environmental Policy Act (NEPA) would be necessary with more in-depth biological and cultural surveys.

3.1 Biological Resources

This section addresses potential effects of the proposed project to biological resources within the project area. During July 2008, Reclamation conducted research of existing literature in order to identify plant and animal communities in the project area, including threatened, endangered, and sensitive species. Please refer to Appendices A and B for a complete list of these species.

A field trip and cursory biological evaluation of the project area was conducted by Reclamation on July 29, 2008. This was done to appraise the project area of potential significant biological issues. A formal biological survey of the entire project area would be necessary for NEPA compliance if this project is developed into a proposed Federal action. This formal biological survey must be accomplished during seasons appropriate and conducive to identifying species likely to be found in the area. This would ensure a complete and accurate report.

The entire proposed pipeline routes are over 40 miles in length. The total length of the pipeline was driven but not surveyed during the field trip on July 29, 2008. A subsample of the proposed corridor was surveyed. The area surveyed was approximately five acres or 0.8 miles of the proposed pipeline route. No threatened, endangered, or sensitive species; or other important biological resources were discovered during this field trip.

Temporary negative impacts that are minor in nature could occur to plant and animal species that may use or exist in the immediate area. Construction activities could cause minor short-term stress and discomfort to any wildlife in or near the project area due to noise, dust, displacement, and temporary loss of habitat until construction is completed and impacted areas are revegetated.

Vegetation

Vegetation in the project area is characteristic of the Colorado Plateau (Plateau) desert biotic community. Most of the area receives less than ten inches of rain each year, predominantly as snow. The Plateau's arid-adapted vegetation is a mixture of salt-desert shrubland dominated by blackbrush (*Coloeogyne ramosissima*), sand sagebrush (*Artemisia filifolia*), rabbitbrush (*Chrysothamnus spp*), fourwing saltbush (*Atriplex canescens*), shadscale (*Atriplex confertifolia*), broom snakeweed (*Gutierrezia sarothrae*), Mormon tea (*Ephedra viridis*), sagebrush (*Artemisia spp*), cliffrose (*Cowania mexicana*), serviceberry (*Amelanchier spp.*), turban oak (*Quercus turbinella*), skunkbrush sumac (*Rhus trilobata*), Navajo yucca (*Yucca navajoa*), desert holly (*Atriplex hymemelytra*), and associated grasses. Blackbrush dominates clay soils while sand sagebrush dominates sand soils. Species that can resprout after fires can be locally dominant such as rabbitbrushes and snakeweeds (*Xanthocephalum spp*). Plains pricklypear (*Opuntia macrorhiza*) is common.

The grass component of the area is diverse. Associations involving Indian ricegrass (*Oryzopsis hymenoides*), sand dropseed (*Sporobolus cryptandrus*), needleandthread (*Stipa comata*), threeawn (*Aristida longiseta*), galleta (*Hilaria jamesii*), and alkali sacaton (*Sporobolus airoides*) are common.

Forbs include globemallows (*Sphaeralcea spp*), desert trumpet (*Eriogonum inflatatum*) asters (*Aster spp*), and fleabane (*Erigeron spp*). The project occasionally traverses small stands of juniper (*Juniperus spp*) or Mexican cliffrose (*Cowania mexicana*).
The biota of the Plateau is isolated by the surrounding mountains which have permitted the evolution of many endemic plant species like locoweeds (*Astragalus spp*), cryptanthas (*Cryptantha spp*), and buckwheats (*Eriogonum spp*).

Weeds including Russian thistle (*Salsoa kali*), cheatgrass brome (*Bromus tectorum*), desert peppergrasss (*Lepidium fremontii*), bur buttercup (*Ranunculus testiculatus*), curlycup gumweed (*Grindelia squarrosa*), and halogeton (*Halogeton glomeratus*) are especially common along roadways. Tamarisk (*Tamarix ramosissima*) and Russian olive (*Elaeagnus angustifolia*) occur along drainages crossed by the proposed pipeline.

The potential effects of the proposed project to the vegetative communities of the area as a whole are expected to be minimal. Most areas within the proposed construction zone have been disturbed previously. Vegetation present along the sides of roads would be subject to temporary negative impacts due to construction activities. Construction would also traverse undisturbed sites for relatively shorter distances (1 mile or less). These impacts are deemed minimal since after construction activities are complete, areas disturbed by project construction would be contoured and native vegetation would be reestablished.

Wildlife Resources

Wildlife resources within the general area of the project include big game, smaller mammals, raptors, and a variety of other birds, reptiles, and amphibians.

Animals in this arid region of the Plateau include species that also have a wide distribution in the prairie grasslands and the Great Basin Desert. Unique to the Plateau are the White-tailed Prairie dog (*Cynomys leucurus*), plateau and northern whiptail lizards (*Cnemidophorus velox* and *Cnemidophorus tigris*), Painted Desert glossy snake (*Arizona elegans*), Mesa Verde night snake (*Hypsiglena torquata*), and midget faded rattlesnake (*Crotalus concolor*).

Mammals

Mammals found within the area include black–tailed jackrabbit (*Lepus californicus*), desert cottontail (*Sylvilagus audubonii*), white-tailed antelope squirrel (*Ammospermophilus leucurus*), white-tailed Prairie dog (*Cynomys leucurus*), ringtail (*Bassariscus astutus*), least chipmunk (*Eutamias minimus*), desert woodrat (*Neotoma lepida*), badger (*Taxidea taxus*), Coyote (*Canis latrans*), bobcat (*Lynx rufus*), and red fox (*Vulpes fulva*).

Mule deer (*Odocoileus hemionus*), pronghorns (*Antilocapra americana*), and wild burrows (*Equus assinus*) exist in the area.

Raptors and other birds

Raptors common to the project area include golden eagle (*Aquila chrysaetos*), red-tailed hawk (*Buteo jamaicensis*), American kestrel (*Falco sparverius*), Swanson's hawk (*Buteo swainsoni*), and turkey vulture (*Cathartes aura*).

The common raven (*Corvus corax*) is one of the most abundant bird species in the project area. Other birds occurring in the area are horned lark (*Eremophila alpestris*), sage thrasher (*Oreoscoptes montanus*), sage sparrow (*Amphispiza belli*), sage grouse (*Centrocercus urophasianus*), black-billed magpie (*Pica hudsonia*), and green-tailed towhee (*Pipilo chlorurus*).

Reptiles and Amphibians

Several desert reptile species are common including sagebrush lizard (*Sceloporus graciosus*), collared lizard (*Crotaphytus collaris*), tree lizard (*Urosaurus ornatus*), and side-blotched lizards (*Uta stansburiana*), plateau whiptail lizard (*Cnemidophorus velox*), northern whiptail lizards *Cnemidophorus tigris*), gopher snake (*Pituophis melanoleucus*), striped whipsnake (*Masticophis taeniatus*), western rattlesnake (*Crotalus viridis*), Great Basin gopher snake (*Pituophis melanoleucus*), Painted Desert glossy snake (*Arizona elegans*), Mesa Verde night snake (*Hypsiglena torquata*), and midget faded rattlesnake (*Crotalus concolor*).

Threatened, Endangered, Candidate and State Sensitive Species

Species lists from both the Navajo Tribe (Attachment 1) and State Threatened and Endangered Species Lists by County (Attachment 2) were reviewed in order to identify species of concern that might be affected by the proposed project. Regarding these attachments, a preliminary determination of the likelihood of species occurrence within the project area was made by Reclamation's biologist. Reclamation is currently awaiting a response from the Navajo Nation with their determination of species occurrence. Once this response is received, these attachments would be updated.

During Reclamation's preliminary biological evaluation on July 29, 2008, no threatened or endangered plants or animals were documented within the project area. Therefore, no known impacts to listed species are currently expected. Future formal surveys may discover listed species and necessitate changes to the proposed project to ensure no negative effects would occur to these species.

3.2 Endangered Species Act Considerations

The proposed project would divert water from the San Juan River, at approximately river mile 53 near Mexican Hat, Utah. The diversion location is approximately 170 river miles downstream from Navajo Dam and Reservoir located east of Farmington, New Mexico. Because several endangered fish species are native to the San Juan River, and critical habitat for these species has been designated on the river below the proposed point of diversion, consultation with the U.S. Fish and Wildlife Service pursuant to Section 7 of the Endangered Species Act (ESA) would be required in order to approve and implement this project.

Background

The San Juan River sub-basin is the second largest of the three sub-basins that comprise the Upper Colorado River Basin. It drains about 38,000 square miles of southwestern Colorado, northeastern Arizona, northwestern New Mexico, and southeastern Utah. From its origins in the San Juan Mountains of Colorado, the San Juan River flows approximately 31 miles to the New Mexico border, 190 miles westward to the Four Corners area, and another 136 miles to Lake Powell. In its upper reaches, the river traverses rugged terrain and has a relatively high gradient. The river emerges from canyon-bound reaches shortly after entering New Mexico and flows through a broad floodplain for much of its course in New Mexico and Utah. About 70 miles upstream of Lake Powell, the river again enters canyon reaches for the remainder of its course. The river is generally restricted to a single channel in canyon portions, but is often divided into several channels in floodplain reaches.

In 1922, the seven basin states of Utah, Colorado, Wyoming, New Mexico, Arizona, Nevada, and California signed a compact dividing the Colorado River between the Upper and the Lower Colorado River basins. In 1948, the upper basin states (Wyoming, Colorado, Utah, and New Mexico), together with Arizona, signed an agreement apportioning the upper basin share between the states. Each of the states and the Bureau of Reclamation under the authority of the Colorado River Storage Project (CRSP) Act initiated the development of the waters of the Upper Colorado River Basin. The passage of the CRSP Act allowed for the construction of many large mainstem impoundments on the Colorado River and various tributaries including Navajo Dam on the San Juan, Flaming Gorge on the Green River, and the Aspinall Unit on the Gunnison River.

Endangered Species Act

The Colorado pikeminnow (*Ptychocheilus lucius*) and the humpback chub (*Gila cypha*) were listed in 1967 as endangered. Since the passage of the Endangered Species Act of 1973 (ESA), two other species of Colorado River fishes have been listed as endangered: the bonytail chub (*Gila elegans*) (1980) and the razorback sucker (*Xyrauchen texanus*) (1991). As required under section 7 of the ESA, all actions of Federal agencies that may affect these listed species must undergo consultation with the U.S. Fish and Wildlife Service (Service). This is to ensure that actions undertaken by a Federal agency are not likely to jeopardize the continued existence of listed species. Since 1977, section 7 consultations and biological opinions have been conducted between the Service and various Federal agencies.

Since the early 1980s, two major projects have undergone section 7 consultation with the Service. They are the Animas-La Plata Project (ALP) and the Navajo Indian Irrigation Project (NIIP). During the section 7 process for the ALP, the importance of the San Juan River population of endangered fish species was re-evaluated in the biological opinion. The resulting reasonable and prudent alternative for the project was based on the premise that current and cumulative adverse conditions of the San Juan River jeopardized the continued existence of the species.

It was recognized that while the impacts associated with water development such as water depletion, water quality degradation, contaminants from irrigation return flows, increased sediment, and temperature changes may be exacerbated by continued development of the waters of the San Juan River, a program or plan was needed whereby all entities that have a potential or opportunity to recover or protect the river environment are involved. This led to the formation of the San Juan River Basin Recovery Implementation Program.

San Juan River Basin Recovery Implementation Program

The purpose of the San Juan River Basin Recovery Implementation Program (SJRBRIP) is to protect and recover endangered fishes in the San Juan River Basin while water development proceeds in compliance with all applicable Federal and state laws. Endangered species include the Colorado pikeminnow and the razorback sucker. It is anticipated that actions taken under this Program would also provide benefits to other native fishes in the Basin and prevent them from becoming endangered in the future. Currently a minimum of 500 cubic feet per second of flow is desirable above the river gage at Mexican Hat for maintaining fish population in the river. The San Juan River Basin Recovery Implementation Program recommends a target base flow of between 500 cfs and 1,000 cfs through the critical habitat area below Farmington, New Mexico. The target base flow is calculated as the weekly average of gaged flows throughout the critical habitat area. Withdrawal for the project would likely be downstream of the gage at Mexican Hat.

The specific goals of the Program are (SJRBRIP, 1999):

- To conserve populations of the Colorado pikeminnow and razorback sucker in the Basin consistent with recovery goals established under the Endangered Species Act, 16 U.S.C. 1531 et seq.
- To proceed with water development in the Basin in compliance with Federal and State laws, interstate compacts, Supreme Court decrees, and Federal trust responsibilities to the Southern Utes, Ute Mountain Utes, Jicarillas, and the Navajos.

As a participant in the Program, the Navajo Nation is aware of the ESA consultation process and has indicated that it would initiate that process if a decision is made to pursue implementation of the proposed pipeline project.

3.3 Cultural Resources

This section describes the known cultural resources in or near the project area and the potential effects of the proposed project on cultural resources.

The San Juan - Mexican Hat to Kayenta Regional Water Supply Study is still in its preliminary stages. The exact proposed pipeline alignment and locations of associated project components have not yet been determined. In turn, a definitive area of potential effect (APE) for the proposed project is also unclear.

Previous Cultural Resource Inventories

A Class I literature search was conducted at the Navajo Nation Historic Preservation Department (NNHPD) office in Window Rock, Arizona, by Brian Joseph, archeologist for the Bureau of Reclamation, Provo Area Office on July 28, 2008. Several cultural resource inventories have been conducted near the proposed pipeline alignment. No historic properties, however, were identified within the alignment corridor or in possible associated project component areas. Although no historic properties have been previously identified within the area covered under the SJRPS, changes made to the location of the proposed pipeline alignment or other associated project components may lead to unforeseen cultural resource impacts.

Cultural Resource Field Study

A preliminary cultural resources field study was conducted by Brian Joseph on July 29, 2008, under Class B Permit # B08184, issued July 22, 2008 by the NNHPD. The purpose of the field study was to identify any immediate cultural resource concerns within the current SJRPS area. With the information collected during the field study, Reclamation aimed to examine the feasibility of the proposed project under its current design.

Field Study Results

Two sites and four isolates were discovered during the preliminary cultural resources field study. The four isolates were located in the approximate location of the proposed intake system on the San Juan River near Mexican Hat, Utah. The isolates included one reddish-brown chert tertiary flake, two grey chert secondary flakes, and one white, semi-translucent chert tertiary flake. Dates and cultural affiliations of the isolates are unknown.

The first site consisted of what appeared to be the remnants of a historic period Hogan structure and associated objects. Consultation with the NNHPD would be needed to gather more specific information regarding the site. Although the current project design involves placing a pipeline along a dirt road next to the site, the proposed pipeline alignment could be adjusted in order to avoid impacts to the site.

The second site is a prehistoric lithic and ceramic scatter and appears to date to the Late Pueblo II period (A.D. 1100-1150) based on pottery styles present on the surface. No formal lithic tools were identified on the ground surface. The site is located in the Mystery Valley Quad along an abandoned alternative route for the proposed pipeline. The site would not be impacted by the proposed project under its current design.

Cultural Resource Recommendations

Under the current project design, there should be no adverse effects to cultural resources. This report, however, is only a preliminary study and the cultural resource field study does not fulfill Section 106 obligations under the National Historic Preservation Act of 1966 (NHPA) or those required by the NNHPD for cultural resource compliance. Before construction on the proposed project could begin, a complete and updated Class I literature search at both the Utah and Arizona State Historic Preservation Offices (SHPO) as well as the NNHPD would need to be completed. A Class III cultural resources inventory would then have to be done by a qualified, permitted archeologist for the entire project APE and cultural resource compliance with Section 106 of the NHPA; as well as all of the laws, regulations, and directives mandated by the NNHPD, would have to be adhered to.

3.4 Conclusions

Based upon this preliminary assessment, no significant environmental or cultural resource issues would prevent a feasibility study and ultimately the proposed project from moving forward have been identified. As the proposed project moves further along in design and planning, additional analyses can be undertaken. If this project evolves to a level of a Federal action requiring compliance with the National Environmental Policy Act (NEPA), an environmental assessment (EA) should be initiated.

4.0 Plan Formulation and Alternative Analysis

The alternatives evaluated in this appraisal study are:

Alternative A:	No Action
Alternative B:	Rain water harvesting and water recycling project
Alternative C:	Surface water from the San Juan River
Alternative D:	Treatment at River and Trucking

These potential sources were arrayed against the identified demand in the study area. Only one alternative was found to be viable for the area due to limited available resources. The alternatives are discussed in further detail below.

4.1 Alternative A: No Action

The no action alternative would leave the areas water supply to the only source they currently have in Kayenta and Monument Valley, which is ground water. Population projections have shown that the current water supply would not supply the required water to sustain the growing population. The current supply from the groundwater system would be depleted if necessary measures are not in place within the next few years.

The no action alternative is dependent upon groundwater availability from the N aquifer to service the Kayenta area. According to a recent study prepared by Brown and Caldwell titled *DRAFT-Water Plan for Kayenta Chapter and Township, January 31, 2013,* for Kayenta Chapter and Township and Navajo Nation Department of Water Resources, it states that based on the recorded drawdown in the N aquifer, historical withdrawals from the aquifer are unsustainable. Therefore future withdrawals from the N aquifer are also unsustainable. Based on its location at the edge of the aquifer, Kayenta's ability to withdraw well water could be impacted by further drops in the N-Aquifer levels. This and previous studies of the N aquifer and groundwater in the study area concludes that it will not be sufficient to sustain the projected population growth in the area, therefore the groundwater alternative was deemed nonviable. Groundwater withdrawals in the monument valley area are reaching the limits of sustainable yield for the aquifer in the Monument Valley area, due to the shallow aquifer, and during periods of drought they are further limited.

4.2 Alternative B: Rain Water Harvesting and Water Recycling Project

Many communities around the world are making rain harvesting part of their local water supply. This ancient method of collecting water has been used for thousands of years to develop local water resources. Community wide systems can be an integral part of providing water for irrigation and livestock and if treated for potable water purposes. It can also help with conservation in the community if they participate with rainwater harvesting.

The study area drains directly to the San Juan River over 20 miles to the north (Figure 4-1). It would be economical to look at ways to utilize the rainwater in the local area before it drains to the San Juan and would need to be pumped back under the proposed Alternative C.

Rainwater harvesting in the local area would help supplement some of the costs of bringing water back from the San Juan River. It would not be sufficient to replace the existing groundwater system or satisfy future water demands but it would be a viable option to pursue if resources are available. The region around Kayenta and Monument Valley averages 7-inchs of rain per year.

Figure 4-1. Study Area Drains to San Juan River.

Surface Water

Surface water can be developed from the drainages that feed Laguna Wash. Large scale projects such as dams may raise compact concerns, as well as environmental and economic challenges and may not be feasible with evaporation losses, but smaller check dams may be used to slow the flow and help recharge the local groundwater supply.

Surface water in Laguna Creek or other drainages could be retained by small check rock or gabion dams to improve water quality and help recharge local groundwater that has seen depleted levels over the years. Areas of higher recharge could be located to determine which areas along the drainages would be the most effective.

Small Drainage - Check Dams

A check dam is a small either temporary or permanent dam constructed across a drainage ditch, swale, or channel to lower the speed of concentrated flow for certain design range of storm events. Check dams installed at proper locations would assist in allowing higher groundwater recharge in the area.

Small check dams can be built from wood logs, stone, pea gravel-filled sandbags or bricks and cements are on the order of less than 10 feet in length. From an EPA website, "the cost of check dams varies according to the material they are made of and the width of the channel to be dammed. EPA (1992) estimated that check dams constructed of rock cost about $100 per dam, although Brown and Schueler (CWP, 1997) estimated that rock check dams cost approximately $62 per installation, including the cost for filter fabric bedding. Logs and sandbags may be less expensive alternatives to install, but their use may result in higher maintenance costs." Larger dams would costs considerable more if this were determined to be a viable alternative for helping recharge the local groundwater.

Review of the area using Google Earth shows that many of the existing washes around Kayenta have already been developed to capture water as can be seen in Figure 4-2. With the development of the majority of the drainages already using check dams for short and long term storage, this option does not seem to be a viable alternative to generate additional surface and groundwater for the area unless more studies can be done to see if additional infiltration areas can be found to help recharge the groundwater aquifer.

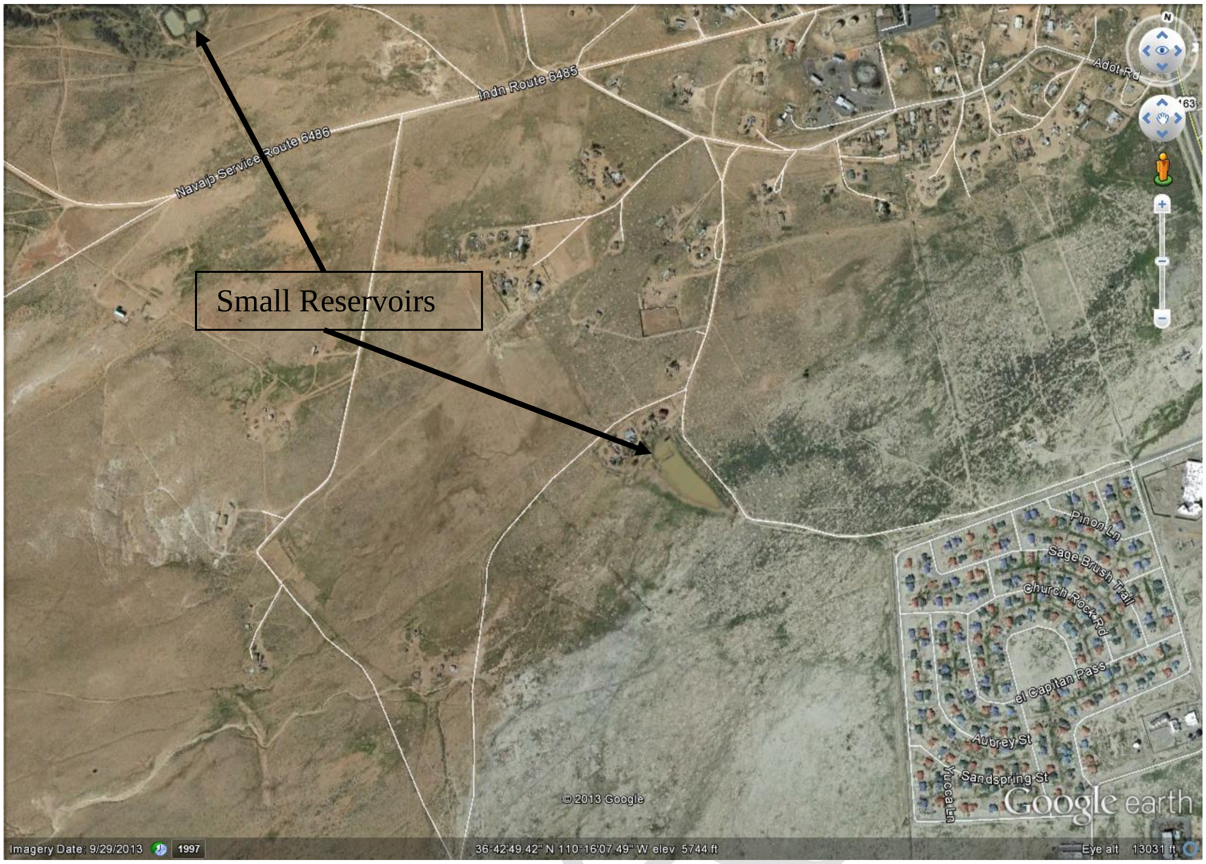


Figure 4-2. View of Small Dams built on secondary drainage adjacent to Kayenta, Arizona.

Storm Water Storage

If designed correctly onsite storm water collection can help improve downstream water quality. In many parts of the world storm water from roadways is collected and stored for irrigation. Roadways in the area could be used to collect runoff to supplement other sources. The highway leading to the school areas would be one example.

With proper administration, water could be retained for short term storage for landscaping and livestock uses and to help recharge the areas groundwater supply. Underground storage systems can be used in parking areas and along roadways to help eliminate evaporation. The EPIC Storm Water Management system is widely used for these applications and has proven to be very economical and eco-friendly. Figure 4-3 shows a cross section view of the EPIC system utilizing runoff from the street for landscaping.

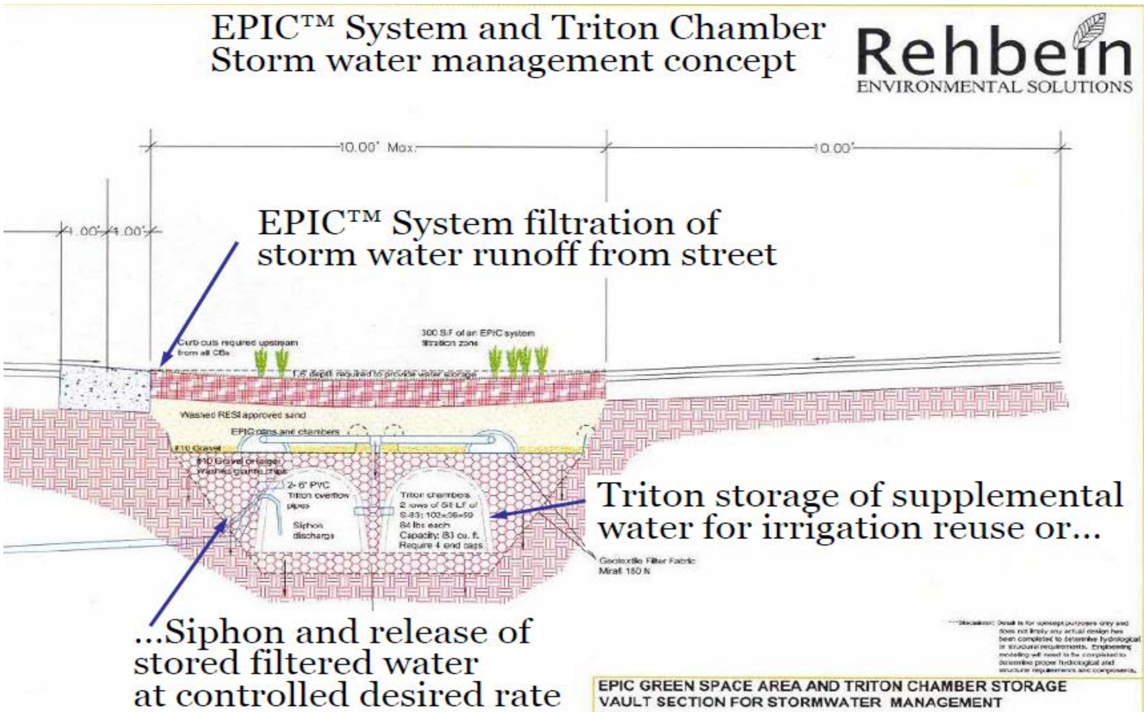


Figure 4-3. EPIC Storm Water Management Concept

This potential option does not seem to present a large amount of water for development due to the limited amount of rain in the area and limited number of paved streets and parking lots in the area but could be used as part of an area water management plan.

Rain Water Storage

The region around Kayenta and Monument Valley averages 7-inchs of rain per year. Although not a lot when compared to other areas of the region, this is a potential source that can be developed and used without treatment cost for landscaping and livestock.

Some of the larger water uses in the regions are the schools, public buildings and motels that maintain landscaping. Athletic fields use water in the region, but provide a great benefit to the local community and can be an area of pride if the fields are kept in good condition. Rain harvesting could be used to store water during larger rain events in the summer and winter, to help reduce the water demand currently provided by groundwater and other supplies in the future. Rain harvesting could also help establish more landscaping and gardening if desired at individual homes and businesses.

Subsurface Irrigation System

Figure 4-4 is an example of a subsurface irrigation system that could be potentially used to irrigate athletic filed at the local schools and businesses.

Figure 4-4. Efficient Subsurface Irrigation and Greywater Utilization.

Dr. Bernd Leinauer of New Mexico State University's Plant Science Department conducted a study of the EPIC system and found its subsurface irrigation approaches 80 percent efficiency of use of water vs. methods of sprinkling and flood irrigation which are more in the 30 to 50 percent range. Figure 4-4 shows an efficient subsurface irrigation and greywater utilization on a football field. Similar systems can be installed in school football and baseball fields.

The roof and parking lot of the local schools can become part of rain collection system. Reuse of treated waste water from the water treatment plant located next to the schools could be used to irrigate the landscape when rain water storage amounts have become depleted between storms.

Although growing sod grass may not be the desired objective for business, growing drought tolerate tall grasses and plants may be desired for attractive zero-scaped landscapes.

Kayenta previously used treated waste water to irrigate sports fields at the nearby schools, but the practice has been discontinued.

The cost to furnish and install a greywater EPIC system on a typical football field would run from as little as $4 per square foot to as much as $10 per square foot depending on the particulars of each project [Firestone/EPIC Cost on Previous Projects]. A typical high school football field (360ft long by 200 ft wide) would cost anywhere from $288,000 to $720,000 for a complete greywater EPIC system.

A football field of this size needs approximately 6 ac-ft of water per year to keep it looking good. The EPIC system saves 30-50% of water in comparison to above ground sprinkler systems waste while watering. This translates to a water savings of approximately 1.8-3 ac-ft/year. The current cost of water for commercial use in the Kayenta area is $8.67 per thousand gallons [NTUA Water Usage Statistics 2010]. The conversion of 1.8 and 3 ac-ft of water is equivalent to 586k and 977k gallons respectively. This would result in a cost savings of approximately $5,100-$8,500 per year. Assuming the installation of the EPIC system resulted in a 50% savings on water use, it would take approximately 34 years for the system to pay the capital cost of the project if we assume the low end [$288,000 / $8,500 = 34 yrs] and 85 years on the high end [$720,000 / $8,500 = 85 years]. Use of grey water or treated waste water instead of pumped groundwater could pay back the system faster and lessen groundwater withdrawals.

Total water use of all the athletic fields in the area (1 in Monument Valley & 3 in Kayenta) is estimated to be 30 ac-ft/year, which is approximately 4.0 percent of the total current water use for the region [NTUA Water Usage Statistics 2010]. If the EPIC system is installed in all four fields it would result in a cost savings of $25,400 on the low end and $42,400 on the high end per year.

Total demand for the San Juan Pipeline project is 2,255 ac-ft/year, the athletic fields water usage of 30 ac-ft/year is a small fraction of the total water use for the project. The capital cost for the San Juan Project is $117M with an OM&R cost per year of $2.6M at full build out.

To use both the San Juan water and existing water system would cost a total of $5,318 per ac-ft per year to water the four athletic fields in the area. If the EPIC system is installed in all four fields providing a 50% cost savings verses a standard above ground sprinkler system, it would save the community and average of $2,659 per ac-ft of water annually [$5,318 x 0.5 = $2,659]. The total cost savings for one athletic field is $15,954 per year [$2,659 x 6 = $15,954]. It would take approximately 18 years for the system to pay the capital cost of one field on the low end [$288,000 / $15,954 = 18 yrs] and 45 years on the high end [$720,000 / $15,954 = 45 years].

Artificial Turf System

Artificial turf is a fairly new technology that is now widely used by big cities and schools for football fields. Artificial turf requires a base to provide moisture to keep it cool during the hot months. The EPIC system is also the most efficient system available for artificial fields as well. A study in Phoenix, AZ showed that the artificial surface with the EPIC system was as much as 50 degrees cooler than an adjacent artificial turf over a gravel base. With the EPIC base in place, the system can be switched from artificial to grass or vice versa at any time without reinventing the foundation.

This system would cost more to implement than if tall grass was used. Dr. Bernd Leinauer of New Mexico State University does not recommend using artificial turf especially in the area of interest. He suggests that regular turf be used even if an EPIC system is to be installed. It would be simpler to maintain and more cost effective than artificial turf. Artificial turf has a life expectancy of less than 20 years with UV exposure and replacement costs can be high over time.

Nonetheless, several local residents already have artificial turf systems in the area and most are very pleased with them. Local authorities should consider this as part of a long term water management plan.

Waste Water Reuse

The following article was recently published by the New York Times on February 9, 2012 about the state of water reuse in communities in the United States and can be used as a guide to determine if waste water reuse would be a viable option for the study area:

"Funneling reclaimed water into water supplies is being considered in a variety of communities like Miami and Denver (which has experimented with the technology), as well as in drought-ravaged municipalities in Texas like Big Spring. The tiny mountain resort town of Cloudcroft, N.M., mingles reclaimed water with local well water. In Northern Virginia, reclaimed water has flowed into the Occoquan Reservoir for three decades.

Still, just one-tenth of 1 percent of municipal wastewater nationally was recycled into local supplies in 2010. Only a handful of systems replenish their reservoirs or groundwater basins with treated wastewater.

The largest is in Orange County, Calif., about 100 miles north of San Diego, where a four-year-old system replenishes the groundwater basin with 70 million gallons of treated effluent daily — about 20 percent of the content of the aquifer. Other sites include El Paso and some areas around Los Angeles.

Edmund Archuleta, the president of El Paso Water Utilities, said in an interview that his city recycled all of its wastewater. Most is used for things like cooling industrial plants or watering playing fields, he said, but "it's been accepted that we're recharging some of that water into the aquifer" and into the Rio Grande.

Globally, the largest population center to adopt the technology is Singapore, home to five million people. Officials say about 15 percent of its water originates from treated effluent, marketed as "NEWater." Most is used for irrigation or manufacturing; some for drinking.

The original technology for recycling wastewater was developed in the 1950s — involving chemical disinfection, carbon-filtration treatment or both — and is in use on the International Space Station. The bulk of recycled water is used on lawns or golf courses, in factories or as an underground barrier against seawater intrusion.

The newest iteration, in use in Orange County, is a three-step process involving fewer chemicals and more filtering.

First, wastewater is filtered through string-like microfibers with holes smaller than bacteria and protozoa. Then it goes through reverse osmosis, an energy-intensive process forcing the water through plastic membranes that remove most molecules that are not water. Finally, it is dosed with hydrogen peroxide and exposed to ultraviolet light, a double-disinfectant process. The result is roughly equivalent to distilled water, Orange County officials say.

After touring the $481 million plant in Orange County, visitors are offered a glass of the water. Is it safe? The new National Academy analysis suggests that the risk from potable reuse “does not appear to be any higher, and may be orders of magnitude lower” than any risk from conventional treatment. There are currently no national standards for water reuse processes, only for drinking-water quality.

Of course, the treatment process is much more expensive than tapping local groundwater — in Southern California, about 60 percent more, and in El Paso about four times more. But to remain sustainable, groundwater must be used sparingly. Orange County’s reclaimed water costs $1.80 per thousand gallons when regional water subsidies are factored in. This is similar to what it pays to import either Colorado River water or water from Northern California. Without the benefit of subsidies, reclaimed water’s cost was just 14 percent less than desalinated water’s, which experts say requires 3 to 10 times the energy output.

The bigger hurdle to public acceptance may be psychological. Carol Nemeroff, a psychologist at the University of Southern Maine, said the notion of treated sewage “hooks into the intuitive concept of contagion” and contamination. To overcome this, she said, a city must “unhook the current water from its history.” That proved to be the case in 1998 in San Diego when the water department’s initiative was derided as “toilet to tap” during a bruising City Council campaign. Council members refused to allow further discussion of it.

A 2004 poll commissioned by the San Diego County Water Authority found that 63 percent of respondents opposed reuse. Then the water department began reaching out to customers with discussion groups and public meetings. Members of the Surfrider Foundation, an environmental group, reminded residents that almost every municipal wastewater plant practices water reuse anyway, since discharged treated wastewater is reused downstream.

“It isn’t toilet to tap. It’s toilet to treatment to treatment to treatment to tap,” said Belinda Smith, a Surfrider volunteer.

Water shortages and rationing, however, did the most to change attitudes. San Diego’s annual rainfall meets about 15 percent of its needs, and the city’s water managers grew worried that as California reeled from droughts, they could have trouble importing water.

In 2009, the third year of a severe drought, Mayor Jerry Sanders met with biotechnology industry executives who told him that water shortages posed a threat to their businesses. “They were talking about moving away from San Diego,” he said.

So the mayor quietly switched sides, and the City Council fell into line. “If science is behind you and you can prove that, I think people are willing to listen,” Mr. Sanders said in an interview. “The public is worried about scarcity.”

Marsi Steirer, the deputy director of San Diego’s public utility agency, said it now estimated that by 2020 or so, recycled wastewater could account for 7 percent of the total in the city’s main reservoir.

Some people are still put off. Virginia Soderberg, 91, president of the Convair Garden Club in San Diego, called reclaimed water “the end of the world. I wouldn’t even want my cat to drink it.”

But a 2011 poll by the utility showed that local opposition to reuse had dropped to 25 percent.”

Using the lessons learned in San Diego, El Paso and other cities, water reuse may be a viable way to reduce the need for bringing water from the San Juan River and it may make sense for future water use, but as pointed out in the article the costs of reusing water is comparable to the cost of importing water, due to the high costs of the treatment processes involves using microfiltration and reverse osmosis, and it does not seem to be a lower cost alternative to bringing water from the San Juan River. Reuse of water seems to make sense for larger communities where there can be centralized collection of waste water which Kayenta may fall into this model, but it does not seem to be a viable option for dispersed population in the remote areas outside the waste water collection systems. Treatment of water could be used to infiltrate into the groundwater to help replenish the N-Aquifer but studies would need to determine if the rate of return was viable after treatment.

Current Wastewater System in Kayenta:

The NTUA Kayenta wastewater treatment facility is located in Kayenta, approximately 3 miles Northwest of Junction US 160 and 163 in Navajo County, Arizona, within the north central portion of the Navajo Nation. The facility serves a population of approximately 3,600, receiving only domestic sewage with a design flow capacity of 0.9 million gallon per day (MGD). According to NTUA's 2012 permit application, the average daily flow rates were 0.25 MGD in 2010, 0.40 MGD in 2011 and 0.32 MGD in 2012. And the maximum daily flow rates were 0.45 MGD, 0.55 MGD and 0.32 MGD for 2010, 2011 and 2012, respectively. The design flow capacity basis of 0.9 MGD was used in determining the permit limits in the previous permit and is being used in the proposed permit.

In operation since the early 1970's, the facility includes a barscreen with a 2-inch opening, six (6) facultative cells operating in series, an ultra sonic flow meter to measure the influent and effluent flows, a lift station, and a chlorination contact chamber for disinfection. Cells #1 and #2 undergo aeration process, Cells #3 and #4 are used for sedimentation, while Cells #5 and #6 are used as polishing ponds. A portion of the treated effluent is pumped to a holding pond at the Monument Valley Unified School District, located southwest of the treatment plant to be used for irrigation of the school grounds. The remaining treated effluent is discharged from Outfall No. 001 to Laguna Creek, a tributary to Chinle Wash, a tributary to the San Juan River. Any sampling and monitoring under the proposed permit shall be performed at Outfall No. 001.

The Navajo Nation EPA ("NNEPA") conducted a compliance evaluation inspection on January 24, 2012, and noted "that the first four cells (Cells #1 to #4) had approximately 4 feet of freeboard and no objectionable odor, while Cells #5 and #6 were not being utilized due to concern of long retention time. NNEPA found several deficiencies. The influent flow meter was not working due to wiring trouble. A manhole between Cell #6 and the chlorine contact chamber was cracked with a hole, and NTUA representatives reported that sedimentation was found present in the contact chamber at times. A large hole was found on the fence along the northeast side of the treatment plant. On the day of inspection, the NTUA operator indicated that treated wastewater was no longer pumped to the school for irrigation purposes".

Summary

This alternative can only assist but is not sufficient to meet the demands of the growing community and water needed to augment or replace the existing depleted water system or provide the 2,255 ac-ft of water per year projected for the area. The highest average daily inflow into the water treatment ponds at Kayenta was 0.40 MGD in 2011 based on NTUA records and as reported the NNEPA, which is approximately 450 acre-feet per year. This volume is consistent with the groundwater volume used in the area. This amount of waste stream if treated would provide approximately slightly more than half the water needed by the community, however, the treatment process would reject a large portion of the water volume, potentially 30 to 40 percent, during treatment of the water using reverse osmosis and other treatment methods to bring the water quality to acceptable level to drink. Dealing with the concentrated waste produced would also be a cost associated with treatment of the waste water for drinking or aquifer recharge. There is currently not a large demand in the area for irrigation in the area, therefore, recharging of ground water would be the most likely use that would need to studied further at the feasibility level to determine if it is a viable option. The use of waste water treatment to provide drinking water or ground water recharge should not be discounted all together, but should be looked at more closely at the feasibility level.

4.3 Alternative C: Surface Water from the San Juan River

This action alternative would generate sufficient water (2,255 ac-ft/yr) to meet projected demands for the area well into 2060. As part of Alternative C, the following facilities would be constructed:

- San Juan River Intake Structure
- A 40-mile-long pipeline to deliver water to the communities
- Central Water Treatment Plant at San Juan River and secondary treatment facilities for each area
- Pumping/Chlorination Booster Plants
- Water Distribution System from Storage Tanks to existing distribution systems.

4.4 Alternative D: Trucking Water from the San Juan River

In areas where neither ground nor surface water are sufficient to support life, water may be hauled in with trucks and trailers for distribution to the local population. Northern Arizona, along with other desert regions, has many such areas where water hauling is a way of existence.

In this alternative, water could be pumped from the San Juan River into a treatment plant and storage facility near Mexican Hat, Utah. Peterbilt 388 semi trucks with trailers capable of carrying 7,310 gallons would be used to haul the water through Monument Valley to Kayenta, Arizona along Highway 163. Water would be deposited in storage tanks at these locations which would hold the water for distribution to the local communities.

Initial capital expenditures would be needed to purchase the trucks and trailers as well as to construct the intake, treatment, and storage facility at the San Juan River, with storage facilities in Monument Valley, Oljato, and Kayenta. Each truck would make the 86 mile round-trip 6 times per day and would be replaced about every 2.65 years at 500,000 miles.

Assuming a population increase of 1.3% per year, and 160 gallons delivered per capita daily, startup costs would be approximately $19,400,000 with the annual operating costs equaling $6,800,000. This includes operation, maintenance, and replacement costs such as depreciation of the vehicles and trailers, diesel fuel, tires, oil, insurance, and compensation for the drivers. The net present value over 50 years to truck the water is approximately $426,080,873 compared to the net present value of $171,370,000 for the pipeline proposed in Alternative C. See Appendix F for a breakdown of cost used to develop the estimate.

4.5 Other Alternatives Considered

These four alternatives were the only alternatives considered during this study. Alternative A is dependent upon groundwater to sustain future growth and development and as presented in Section 4.1 is deemed nonviable due to its limited supply. Alternative B, rainwater harvesting and waste water reuse, was also considered and the findings determined that this would only provide a fraction of the needed water required to sustain population growth at a very high cost. Alternative D, hauling water by truck from the San Juan River was deemed too expensive to operate and in the long run would cost more than Alternative C. These three alternatives were determined to be nonviable for future development and growth of the area. Therefore the preferred alternative is Alternative C and the least cost alternative.

4.6 The Preferred Alternative

Alternative C-Surface water from the San Juan River is the preferred option to provide a sustainable water supply to meet the future needs of the region. The details of this alternative are presented in the remainder of this report.

5.0 San Juan River Intake Structure

An existing treatment plant and river intake is located across from Mexican Hat along the south bank of the San Juan River. The plant consists of a river intake pump, pre-sedimentation tank, chemical contact tank, sand filter, chlorine injection and clearwell. Maximum capacity of the plant is only 140 gpm and due to wearing out of the sump pump at the river current operation is only 100 gpm. Considering the projected demand of nearly 1820 gpm, a new river intake structure would need to be constructed as part of the proposed project.

The existing intake structure should be reevaluated during the final design for possible upgrades to accommodate the proposed water demand and to determine if it may be more economical to upgrade the existing intake structure versus building a new one. Possible expansion of the existing tower or an enlarged replacement could be used to lessen the requirement of a new diversion location.

5.1 Location

The proposed San Juan River intake structure would be generally located on the south bank of the river across from Mexican Hat, Utah. It would be located adjacent to the existing intake and water treatment plant as shown in Figures 5-3 and 5-4. The process of selecting this location was fairly straightforward. Potential intake structure sites both upstream and downstream of Mexican Hat were limited due to the steep canyon bedrock conditions and limited access. Power availability was another concern. In the vicinity of Mexican Hat it was preferable to stay on Navajo Nation land, which meant the south side of the river. Given the fact that the land adjacent to the existing structure was already disturbed and there was an existing alignment heading south from the river, this location made sense from an environmental standpoint. Also, a power supply is readily available and access is not a problem. As an added benefit, the USGS gage is located close by for coordinated water measurement.

In order to pinpoint the exact location of the intake, it is first necessary to select the type of structure. In addition, accurate cross sections and profiles of the river channel should be obtained and evaluated for the selected type of intake structure. Considerations should include river depth, water velocity, potential sediment deposition and bank steepness.

The floor elevation of the existing water intake structure is 4039.8. The original design drawings for the existing structure show low water at elevation 4042.3 and high water at elevation 4057.0. It is assumed that the floor of the structure at or near the bottom of the river channel.

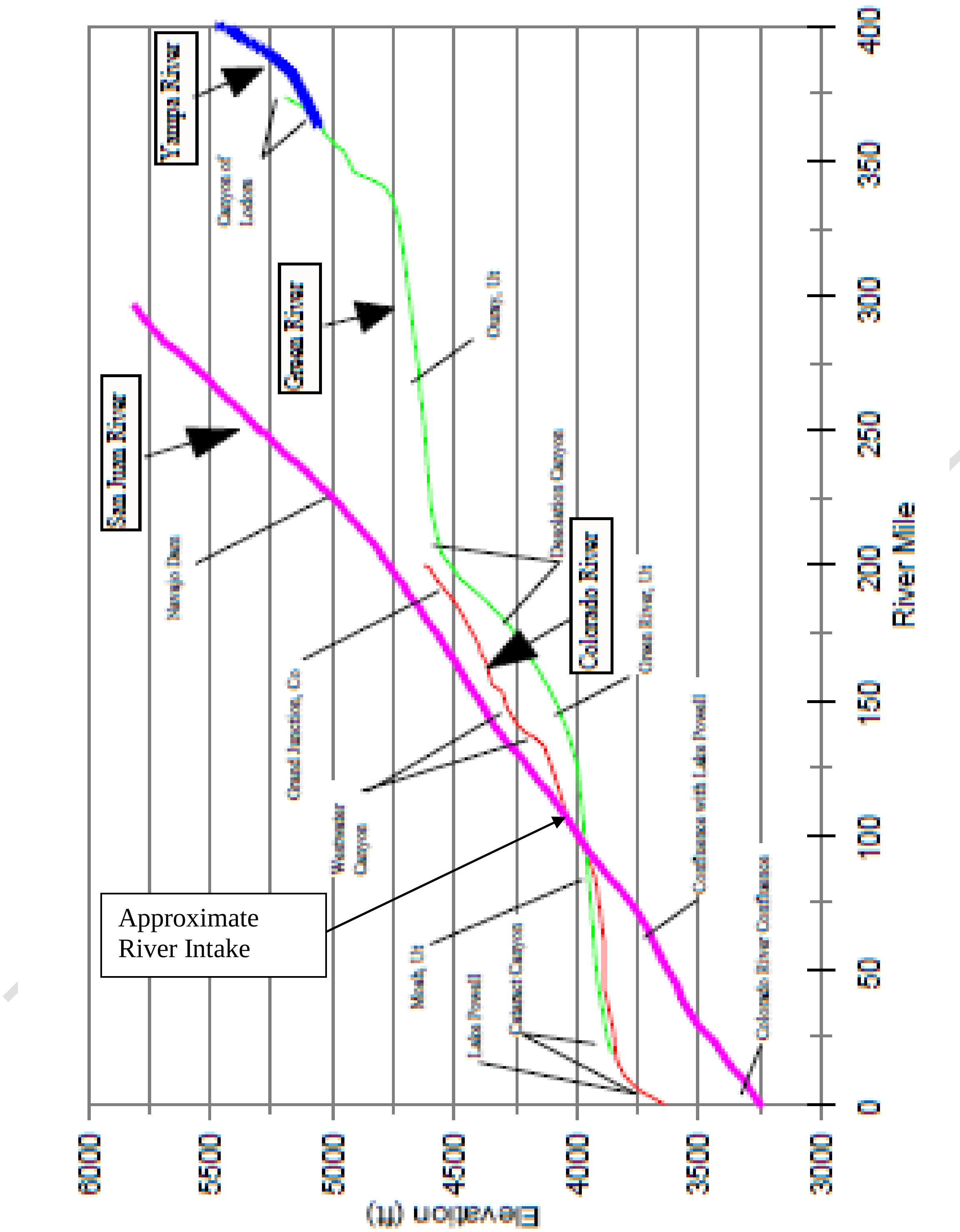


Figure 5-1. Generalize bed profiles for San Juan, Green, Yampa and Colorado Rivers.

In the area of the current and proposed intake the river has a steep profile compared to other river systems in the area that flow into Lake Powell as shown in Figure 5-1.

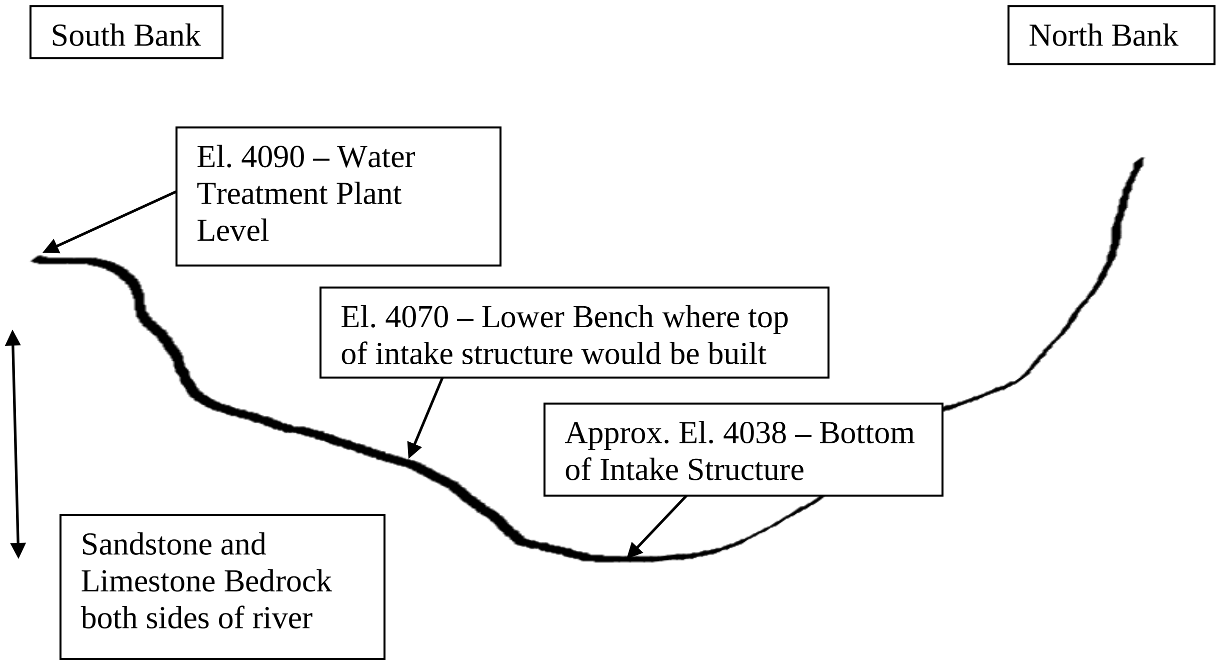


Figure 5-2. Generalize San Juan River Cross Section at Proposed Intake Location.(NTS)

Figure 5-3. View looking upstream at the existing water treatment plant intake structure(Photo December 2013).

Figure 5-4. View looking across the river channel to the existing intake structure (Photo December 2013).

Figure 5-5. Proposed Project Intake Structure Location.

5.2 Site Conditions

The rocks exposed in the Mexican Hat area and at the Highway 163 San Juan River crossing consist of the Halgaito Formation. The Halgaito Formation is the basal tongue and oldest member of the late Pennsylvanian to early Permian age Cutler Group. Overlying the Halgaito Formation is Cedar Mesa Sandstone, which is the resistant cliff forming member of the group. The Organ Rock Formation and the DeChelly Sandstone overlie the Cedar Mesa Sandstone. Both are upper members of the Cutler Group and compose the monuments and lower slopes in Monument Valley. Underlying the Halgaito Formation and downstream of the highway crossing is the Honaker Trail Formation, the youngest member of the Pennsylvanian age Hermosa Group. It constitutes the limestone rocks with interbedded shales exposed at the Goose Neck Overlook of the San Juan River.

The Halgaito Formation consists of thin to medium beds of predominately siltstone, however, shale, fine-grained sandstone and limestone lenses are also present but less common in the formation. The formation is approximately 80 to 215 feet thick in Halchita at the Mexican Hat Uranium Mill Tailings Disposal Cell and is divided into upper and lower units. Most of the upper unit is unsaturated but has some scattered ground water in fractures and as perched water overlying finer-grained zones. The lower unit is classified as the uppermost aquifer at the Mexican Hat site. Ground water in the lower unit is under artesian pressure and is isolated from ground water in the upper unit by limestone beds that limit vertical water movement (U.S. Department of Energy, 2007, p. 2).

Regional joint sets, fracturing, bedding, and general rock characteristics are exposed in outcrops and road cuts in and around the area of the proposed intake system. Brief observations of the bedding planes, jointing, and fracturing of the formation exposed in these road cuts and outcrops indicated a range of moderate to very wide spacing of the features. Future studies of the exposed surface rock and subsurface materials should be performed in the area of the proposed intake for a more detailed understanding of the soil and rock characteristics.

5.3 San Juan River Flows

The San Juan River drainage comprises nearly sixteen million acres of the Four Corners region. It begins at an elevation of about 14,000 feet in the San Juan Mountains of southwest Colorado and drops to about 3,600 feet when it flows into Lake Powell (McPherson, 2004). Today, the flow of the river is largely controlled by Navajo Dam in New Mexico, constructed in 1963.

Figure 5-6 (USGS, 2008) shows the monthly mean discharges for the San Juan River at Mexican Hat based on available USGS data. As expected, peak flows occur during the spring runoff period in May and June. A comparison is made between the 1914 – 1977 monthly mean and the 30-year monthly mean discharges. The peak flow decreases evident during the spring runoff is likely due to the construction of Navajo and other dams upstream.

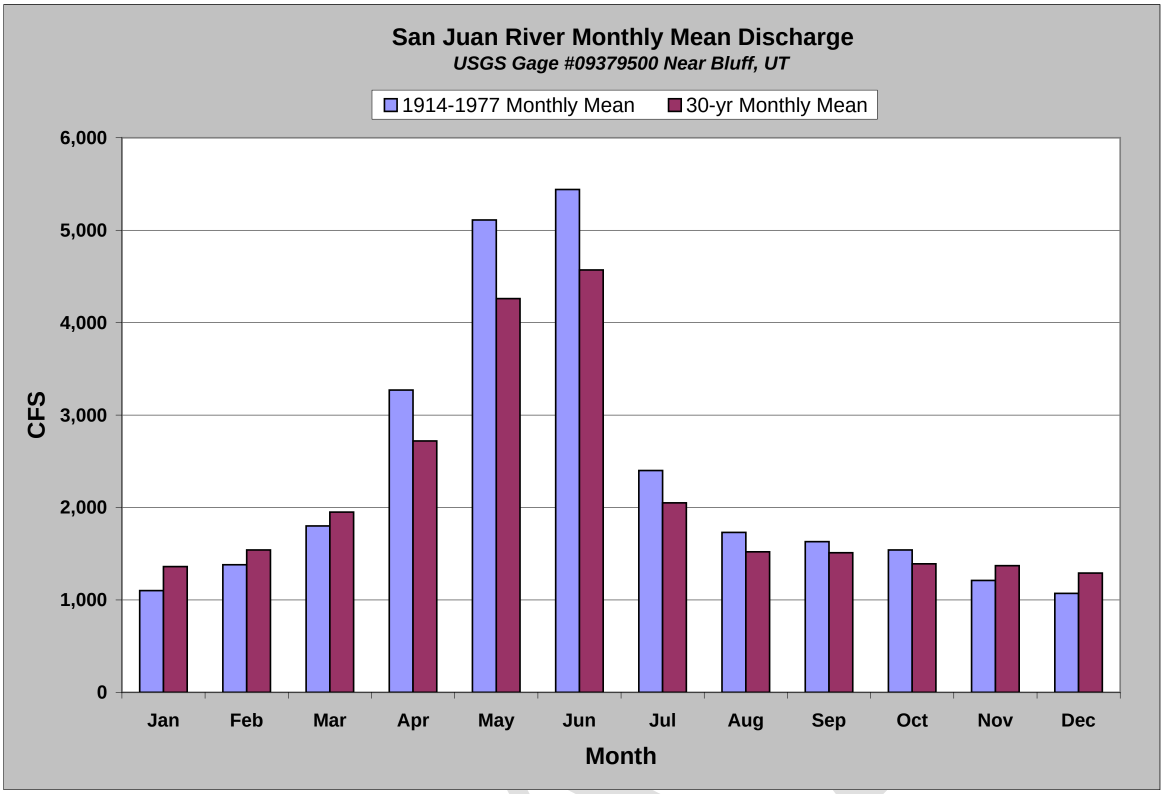


Figure 5-6. San Juan River monthly mean discharges.

In order to design an effective intake structure, the fluctuations and range of river levels, or river stage, needed to be evaluated. The USGS Utah Water Science Center was contacted regarding the most recent stage-discharge relationship for the San Juan River gage near Bluff, UT. Forty seven data points were subsequently provided from which a relationship was determined by plotting the values in Microsoft® Excel and fitting a 2^{nd} order polynomial trendline (C Burden, 2008, pers. comm. 12 Sep). For comparison purposes, 113 historical instantaneous gage height and discharge data points from the USGS gage were retrieved. Similarly, a stage-discharge relationship was determined using this second set of data points. The resulting stage-discharge relationships, or rating curves, are shown in Figure 5-3.

The information from the Utah Water Science Center was provided with the understanding that the rating curve is provisional and that stage-discharge relationships change over time as the channel features at the site change. Additionally, only general conclusions were drawn from the relationships of Figure 5-7. Prior to final design, more in-depth statistical analysis and river channel modeling should be performed.

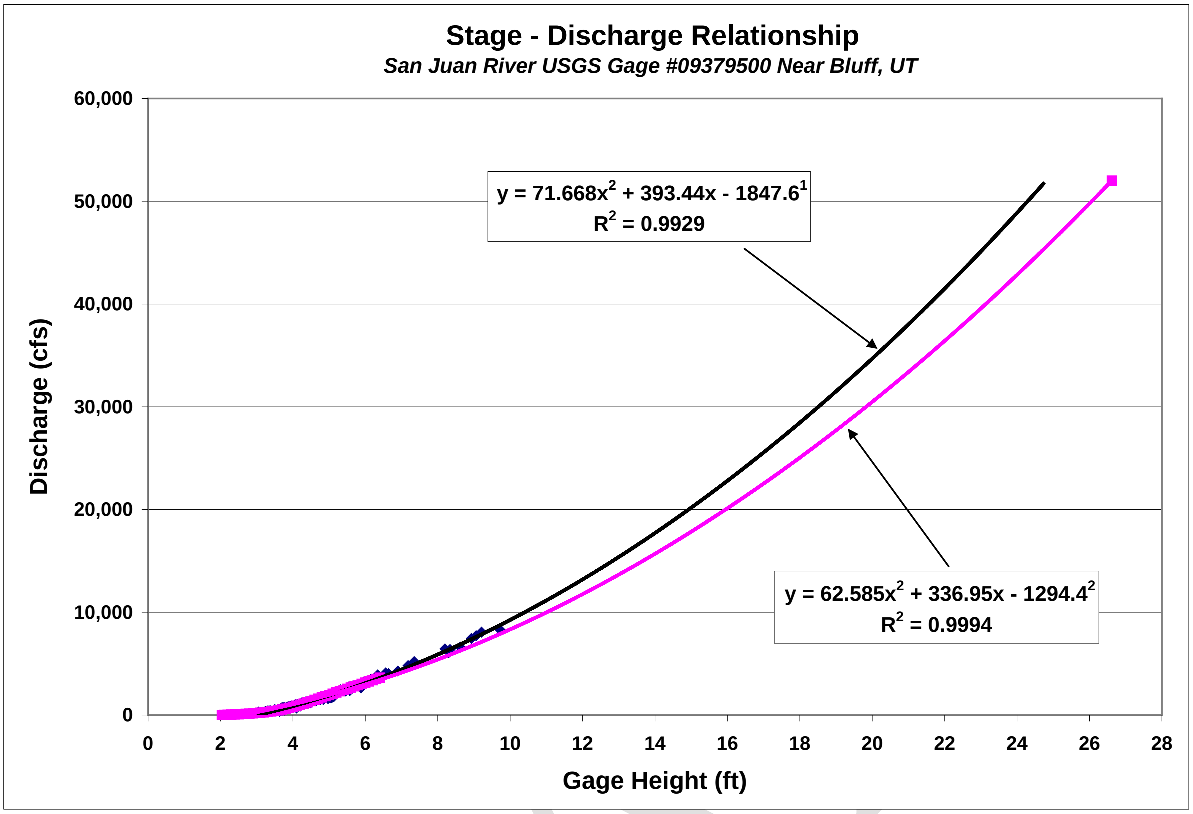


Figure 5-7. Stage-Discharge Relationship for the San Juan River Gage near Bluff, UT.

[1]Stage-Discharge relationship determined from 113 data points retrieved from gage #09379500.
[2]Stage-Discharge relationship obtained from USGS Utah Water Science Center.

In the design of the intake structure, the stage-discharge relationship provided by the USGS Utah Water Science Center would be used because it is the official one provided by USGS and it is also more conservative. In other words, for a given discharge it corresponds with a higher gage height, or river stage.

As can be seen in Figure 5-8 (USGS, 2008), numerous extreme flood events have occurred in the San Juan River near Mexican Hat during the last 90 years. However, since about the early 1970's, the magnitude of peak flows has been significantly decreased, likely the result of the construction of Navajo Dam upstream. The magnitude of flood event to design for would depend somewhat on the type of intake structure selected. For maximum daily mean values obtained from USGS gage #09379500, the 90th percentile is 21,500 cfs. This corresponds to a gage height of nearly 17 feet.

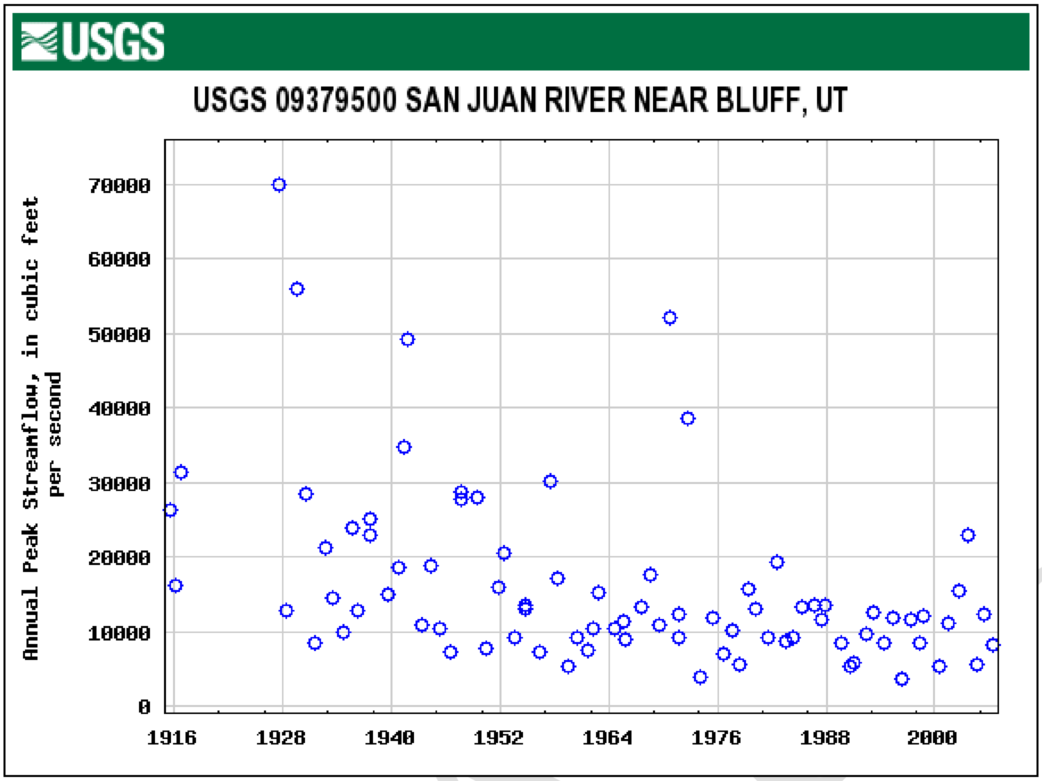


Figure 5-8. Annual Peak Streamflow for San Juan River near Bluff, UT.

Due to the historic river peaks at the intake area, the river depth will fluctuate between 3.5 feet and approximately 14 feet during the operation of the intake system.

5.4 General Considerations

The following general considerations would be discussed for each intake design option:

- **Effectiveness –** The main determination of effectiveness would be the ability of each structure to consistently deliver the required water supply, particularly during extremely low river levels. Another aspect of intake structure effectiveness is constructability. Some options may ultimately be deemed not feasible simply because construction would be too difficult for the given site conditions.
- **Sediment Intake –** Different designs would take in varying amounts of sediment in different ways and during different river flow conditions. Because of the large amount of sediment in the San Juan River and the cost associated with sediment removal, this is an important consideration.
- **Pump Units –** The type, number, size, power requirements and capacity of pump units would be affected by the type of structure. Selection of proper pumping equipment for the particular design is critical; however, specific pump units would not be determined in this phase of the design. Only general considerations are discussed.

- **Maintenance –** The amount of maintenance required would vary considerably depending on the type of structure. It is important to evaluate maintenance requirements for the intake system as a whole and not focus on one single component. Sediment removal from the settling ponds would be required periodically. A suitable location to dispose of the removed sediment needs to be determined.
- **Cost –** The cost of the intake structure would likely be a significant portion of the overall cost of the project. Both the initial cost as well as O&M costs should be considered in selecting an intake option. Costs associated with the settling basin, clearwell, and pumping from the clearwell are assumed to be consistent among the various options.
- **Safety –** Safety to operating personnel as well as the public in general is an important consideration. Items such as railing, electrical equipment, lighting, etc. need to be addressed.
- **Trashracks/Fish Screens –** Trashracks and fish screens may be combined or separate. These components should be designed to minimize plugging, damage to equipment, or the creation of undesirable intake velocities which could affect endangered fish in the river.
- **Environmental –** The smaller the footprint left by the new structure the better. Also, it is desirable to locate the structure as close as possible to the existing intake and treatment plant because this area is already disturbed. Regardless of the type and exact location of the intake structure, a detailed environmental survey of the area would be required prior to implementation of the project. The design of the fish screen would most likely need to meet certain ESA requirements. Most of the environmental impact for each type of structure would result from the settling basin and disposal of accumulated sediment.
- **Aesthetics –** Considering the fact that an intake structure and treatment plant already exist along the river in the area, physical appearance and visibility of the new structure is not as big of an issue. Nevertheless, the new intake should not be an eyesore and should blend in with the surroundings as much as possible, especially considering that this is a popular tourist area.
- **Recreation (River Running) –** This section of the San Juan River is a popular spot for river running. This needs to be taken into account in the design of the intake. Issues such as safety of the river runners as well as vandalism and damage to equipment need to be addressed.
- **Flooding –** Large flood events would be expected during the design life of the structure. The intake needs to be designed to withstand both the water forces as well as impacts from boulders and debris.

Quagga Mussels

The concern regarding Quagga Mussels (as well as Zebra Mussels) is relatively recent in the Western U.S. Considering the potential damage and cost that they can cause to a water intake and delivery system, it is important to take this threat into consideration in the design of the intake structure. The presence of either species has not been confirmed within the San Juan River Basin at this time and significant effort is being put forth to prevent their spread from contaminated water bodies. Even still, it is a definite possibility that the mussels would someday become established and therefore reasonable measures should be taken during the design stage of this project to minimize their impacts.

Power Supply

A 3-phase Rocky Mountain Power transmission line extends from Blanding, Utah south to Halchita. It is assumed that this line which currently supplies the Halchita intake and treatment plant can be utilized to supply the proposed pumping plant at the San Juan River. Further study of the powerline would be need during Feasibility Design.

Flow Measurement

In order to most effectively utilize the water resources from the San Juan River, capabilities for flow measurement in the system should be provided. An appropriately sized and located ultra-sonic flowmeter would be installed as part of the water treatment plant.

5.5 Riverbank Infiltration System

Because of the large quantities of sediment in the San Juan River, eliminating sediment using some type of riverbank infiltration system would be preferable. This type of system essentially collects water through lateral well screens located beneath or adjacent to the water source. The water then enters a vertical shaft or "wet well" located on the river bank. From there, the water is subsequently pumped out. Sediment is filtered out as the water enters the horizontal intake collection lines, thus reducing the need for treatment. Riverbank infiltration systems can provide water with more consistent temperature and water quality than a direct intake (Ranney Collector Wells, 2008) and it would be better to provide a consistent water supply for membrane water treatment. Another added benefit is the elimination of Quagga Mussels, which can wreak havoc on a water distribution system and significantly increase maintenance costs. Although there is no evidence of Quagga Mussels in the San Juan River basin at the present time, it appears likely that they would become established in the future as they have been reported in more water bodies in the western United States.

The San Juan River channel in the area around Mexican Hat consists primarily of exposed bedrock. These rocky conditions present a major challenge to the design of an effective riverbank infiltration system. Generally, a sufficient depth of alluvial material is required for this type of system. Ranney® Collector Wells out of Columbus, Ohio, who specializes in design and construction of these systems, was contacted regarding this project. Given the rock conditions at the site, Ranney representatives felt that it would be unlikely that an effective infiltration system could be designed which would provide the required water demand.

Another option that was considered involved utilizing vertical fractures which were evident in the exposed bedrock. Essentially, horizontal intake lines would be located beneath the river bed at an angle perpendicular to the vertical fractures. If enough lines intercepted enough of the vertical fractures, the required amount of water could potentially be collected. Some degree of filtration could be achieved as the water traveled down through the bedrock joint sets. Again, after discussion with Ranney representatives, it was determined that this option would not likely provide the required water supply and would be a very costly option.

The subsurface hydrogeologic conditions at the site are not well known at this point and, as a result, assessments of the preceding options were made with limited information. It is possible that with enough subsurface investigations and well testing it could be determined that an adequate, consistent, and reliable supply of water could be obtained. Subsequently, one of the preceding options (or variation of either one) could be used. However, this would require a significant up-front cost with no guarantee that the desired outcome could be obtained.

Another possibility of relocating the intake structure to a location with conditions more suited to an infiltration system was evaluated. General site conditions both upstream and downstream of Mexican Hat were investigated using Google Earth™. This technology provided a easy way to get an idea of general conditions along the river. The conclusion was that no obvious location was observed that would provide better conditions than those around Mexican Hat. In addition, access and power availability was nearly nonexistent for any reasonable distance both upstream and downstream of Mexican Hat. In other words, even if a suitable location were found, the cost of developing the site would likely prove to be more costly in the long run.

For these reasons, it was determined that the option of using a direct intake from the river would need to be investigated. The possibility of using a river infiltration system should not be completely abandoned at this point however if designs could be made to design a covered engineered gallery overlaying the bedrock at the site. Any infiltration system that could be designed would need a backwashing system to keep the system from silting in. Operation of the backwash system would need to be performed on a regular basis to prevent loss of flow through the system.

The only other option that could possibly be used similar to infiltration gallery would be the use of multiple bedrock wells installed along the river.

5.6 Bed Rock Wells Along River

- **Effectiveness –** Gage heights in the river at this location typically range from four to six feet during normal flows and can get as low as three feet. Three feet does not leave much room for a submerged intake structure. This means that a channel would need to be excavated into the bed of the river for the placement of the intake. Bedrock wells drilled next to the river may be a way of collecting water during periods of low river levels and ice formation along the edges of the river. Periods of low flow may affect other options to the point they may not affectively withdraw water from the river. Periods of high sediment would also not affect bedrock wells, due to the filtering that would occur as the water is pulled through the in-filled bedrock joints. Assuming each well would be capable of producing 50 gallons per minute under the influence of the river it would take approximately 36 wells to produce the 1820 gpm needed at maximum build out. These flow rates are what are seen in the bedrock wells that are currently being used by Mexican Hat across the river. Mexican Hat's current two wells produce 40 and 70 gallons per minute.

- **Sediment Intake –** Bedrock wells would be best alternative when it comes to eliminating sediment intake from the river due to some filtering of the water through the joints in the bedrock.
- **Pump Units –** Each well would have a submersible pump, electrical supply and piping to each well. The wells would be manifolded together to create the needed volume of water.
- **Maintenance –** Maintenance of the well screens would have to be done on a regular basis to keep deposits of iron bacteria from reducing the water flow into the well and pipeline. The wells would need to be run to prevent inducing air into the system to prevent buildup of the bacteria which can be extensive if not managed.
- **Cost –** This option does not take a major structure to install and only access for the drill rigs to install. This option would not require building a cofferdam in the river for construction of the intake structure**.**
- **Safety –** This structure would likely be safer than the other options since access to the river would be eliminated.   Mobile lighting should be provided for nighttime emergency maintenance to the wells.
- **Trashracks / Fish Screens –**There would be no impact to the river system in regards to river runners and fish. There would be no impact from Quagga Mussels if they were to migrate to the area in the future.
- **Environmental –** Of other options considered, this option may have the lowest impact to the river, but well locations, electrical conduits and pipelines would need to be run along the river to collect the water from the well locations and would need to be installed in an environmentally compatible way.
- **Aesthetics –** This option would have a minimal impact on the area, due to the small exposure of the well casing. Access roads to the well locations could be planned to limit their effects on the landscape.
- **Recreation (River Running) –**There would be not impact on river running operation from the wells.
- **Flooding –** This design is not susceptible to damage from flooding due to the well not being directly in contact with the river flood plain**.**

5.7 Direct Intake – Overview

A direct intake structure would necessitate the design of some type of initial sediment removal system. Ideally, the intake should be designed and located in such a way that sediment pick-up is minimized. Four different designs of direct intake structures would be evaluated and compared in this study. None of the options would be eliminated at this point, thus allowing for further evaluations when more accurate data becomes available, as well as input from the Navajo Nation.

5.8 Option 1 – Suspended Pumps

This option involves the construction of a steel derrick type structure which cantilevers out over the river (Figure5-9). From the end of the derrick, floating pump(s) are suspended down to the surface of the river. Discharge lines would connect to a manifold system and from there discharge into a settling basin through a single line. From the settling basin the water would enter a clearwell from which separate pump units would convey the raw water to the regional treatment plant. This design allows for the floating pumps to adjust relatively easily with the fluctuating river level. The other benefit is that the pump intake is located on the surface of the river where sediment concentrations are generally lower. Given the sediment challenges present in the San Juan River this is an important consideration.

Figure 5-9. Example of a suspended pump intake structure.

- **Effectiveness –** In order to obtain the required supply of water, especially during low flows, the structure needs to extend far enough out into the river channel so that the suspended, floating pumps are always in contact with the water. In addition, there needs to be an adequate depth of water below the pumps so that they operate properly. An accurate channel cross-section at the proposed intake location is required to achieve this. Generally, the south bank of the river in this area is relatively steep so a lot of lateral fluctuation of the water surface would not be expected with changing flows. The exposed bedrock along the bank of the river would provide a good foundation for the structure.
- **Sediment Intake –** As stated above, by floating on the surface where concentrations are generally lower, sediment intake is minimized. Even still, an adequately sized settling basin would be required to remove the remaining fine sediment prior to piping the raw water.

- **Pump Units –** The floating pump units would only be pumping from the river surface to the settling basin so a lot of head is not required, and subsequently low-head pumps can be used. Floating pumps generally have relatively small capacities which means that more units would likely be required compared to the other options. From the settling pond the water would enter a clearwell. From here, additional pump units would convey it into the pipeline.
- **Maintenance –** Backwashing the pump filters/screens would be required, likely at relatively frequent intervals. At least one, preferably more, spare pump units should be provided for maintenance, emergency shut down, and pump cycling. The steel structure needs to be adequately coated to eliminate rusting and corrosion. A location particularly susceptible to corrosion is at the river level or "splash zone" where salts tend to accumulate.
- **Cost –** Minimal excavation into the bedrock is required for this option resulting in some cost savings. The floating pump units may see increased wear because of the sediment. The majority of the cost for this option would be the steel structure.
- **Safety –** Sufficient railing needs to be placed around the platform perimeter as well as along the walkway and any stairs. Pump units can be raised onto the steel deck where maintenance and repairs can be performed more easily. Lighting should be provided for nighttime operations. Adequate fencing would be required to prevent kids from accessing and playing on the structure.
- **Trashracks / Fish Screens –** Each individual pump unit would be equipped with the necessary trashracks and fish screens.
- **Environmental –** Environmental considerations are considered similar to the other intake options.
- **Aesthetics –** Because this structure sticks out into the river channel it would be more noticeable to the public.
- **Recreation (River Running) –** Consideration in the design of this structure needs to be given to recreation, particularly river running which is popular in this stretch of the San Juan River. The structure would preferably be located along an outside bend of the river where the channel is deeper and flows are swifter. This is also the likely route that river runners would take. Warning signs or even a buoy line may be needed to prevent potential collisions with the pump units.
- **Flooding –** Because this structure actually sticks out into the river channel, it is particularly susceptible to flood damage. During large storm and flood events the structure needs to be secure and strong enough to withstand the force of the water and any debris. This includes the pump units and any piping. Ideally, the intake should be designed so that the pump units can be quickly raised during adverse conditions to minimize damage. Again, a buoy line would likely be required for this option.

5.9 Option 2 – Concrete Intake Bay

With this option, a concrete bay would be constructed into the bank of the river (Figure5–10). The required number of vertical pumps would be located towards back of the structure, supported by a concrete platform. The pump motors would also be supported by this platform. The structure would be excavated down into the bank so that the floor and pump intakes are sufficiently submerged, even during low river flows. The entrance to the bay would be controlled by an adjustable weir. This weir would move up and down with the fluctuating river level to only allow the very top water surface to flow over and into the bay. As a result, sediment intake would be minimized.

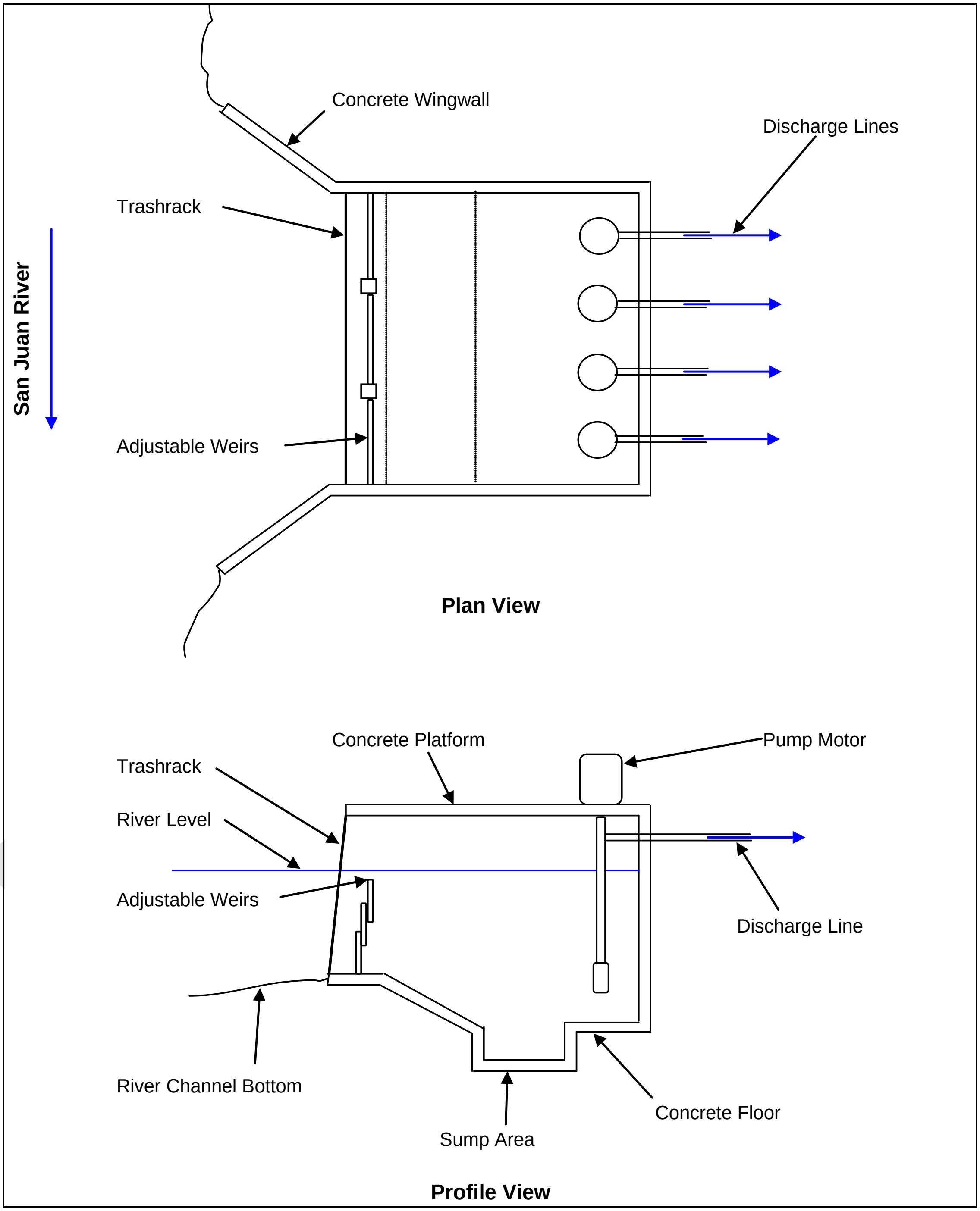


Figure 5-10. General Diagram of Option 2 – Concrete Intake Bay Structure.

- **Effectiveness** – Because the floor of this structure would actually be lower than the river bed, this option should perform well at ensuring an adequate water supply, even during low flows. There are two challenges associated with this option. The first would be the adjustable weir. The San Juan River at Mexican Hat has a wide range in discharges and associated river levels, or stage. It is not feasible to design the weir to have the same range in height as the maximum river stages. It is expected that during large flows the weir would be overtopped by flood waters with an associated increase in sediment intake. A 15-foot weir height would be used for this option. This corresponds to a river discharge of nearly 18,000 cfs or the 80th percentile of historical maximum daily discharges. The second challenge would be excavating a sufficient distance into the rock bank to create the inlet bay. The most suitable location would need to be determined in order to do this as effectively as possible.

- **Sediment Intake –** By using the adjustable weir, only the water at the top surface of the river is allowed into the bay, which theoretically allows less sediment. The idea is essentially the same as that for the floating pump units in Option 1. The weir should be automated so that it would quickly adjust with the fluctuating river level. Once inside the bay where velocities are lower, some of the sediment which makes it over the weir with the water would be settled out onto the floor. From here it would need to be periodically removed. More frequent removal would be required after large storm events when more flood waters and sediment overtop the weir. The amount and size of sediment settled out in the bay would be a function of how big the structure is. Remaining fine sediment with the water would then be pumped into a settling basin(s) for final removal. During large storm events with heavy sediment loads, it is desirable to have the ability to completely shut down the pumps and temporarily rely on storage.
- **Pump Units –** The initial pumping from the bay to the settling pond can be achieved with low head, vertical turbine pumps. From the settling pond the water would enter a clearwell. From the clearwell additional pump units would convey the water into the pipeline and up to the next booster station.
- **Maintenance –** Backwashing the vertical turbine pumps would probably be required, although less frequently than with the floating pump units. Settled sediment within the bay would need to be removed periodically. In order to do this, the weir would be raised sufficiently to stop inflow. A sump pump would be required to dewater the bay. Sediment removal could then likely be achieved by means of a vacuum truck. This means that an access road needs to be provided next to the structure. Sediment removal should preferably be performed during low river flows when the weir does not need to be fully extended to dewater the bay. Otherwise, the weir would experience a large amount of force due to the unbalanced hydrostatic head from the river side of the structure. During normal operations the weir would be in the balanced condition. At least one spare pump unit should be provided for maintenance, emergency shut down, and pump cycling.
- **Cost –** This option would require a large amount of excavation through rock resulting in considerable expense. Concrete would also make up a large part of the cost.
- **Safety –** Sufficient railing needs to be placed around the concrete platform perimeter as well as along the walkway and any stairs. Lighting should be provided for nighttime operations. Adequate fencing would likely be required to prevent kids from accessing and playing on the structure.

- **Trashracks / Fish Screens –** A trashrack would be placed at the entrance to the bay, outside of the adjustable weir. The trashrack should be equipped with a hydro-rake to facilitate debris removal.
- **Environmental –** Environmental considerations are considered similar to the other intake options.
- **Aesthetics –** Considering that this structure is excavated into the river bank it may tend to blend in more and be less noticeable.
- **Recreation (River Running) –** Because this Option is set back into the bank of the river, it would cause less disruption for river runners. Even still, warning signs should be provided. Also, water velocities entering the trashrack should be kept well below unsafe limits.
- **Flooding –** Unlike Option 1, this structure sits back in the bank of the river and is therefore less susceptible to damage from flooding and debris. The intake and trashrack should be located so that debris would be swept downstream and not directed towards the structure. The primary concern with this structure during flood events is damage to the adjustable weir.

5.10 Option 3 – Side Channel Inlet

This structure is based off of the proposed intake structure for the Navajo-Gallup Water Supply Project, which is similar to a side channel wasteway structure as shown in Bureau of Reclamation Design Standards 3, Chapter 7, Figure 5. The structure would have a side intake with a trash rack and fish screen, as well as an adjustable weir. The flow was assumed to be 0.5 feet per second through the trash rack. There would be a ramp at a 10:1 slope down which equipment would be driven to the pumping plant sump from which silt buildup would be removed. A pump would also be provided to remove sediment from the sump. The required number of vertical turbine pumps would be located towards the back of the structure. At the top of the ramp would be a square parking/loading area. The entire site would be fenced with a 7-foot high chain link fence. The pumping units would pump from the sump to settling basins. Unlike the Navajo-Gallup Project, there is no existing diversion dam at the Mexican Hat location. A large amount of bedrock excavation would be required for the construction of the side channel inlet which may make it cost prohibited.

- **Effectiveness –** The concept of this structure is similar to Option 2, except that it uses different geometry. Instead of using a rectangular bay, it utilizes a long, narrow side channel with a ramp. The ramp allows access of maintenance equipment to remove accumulated sediment. This option would also use an adjustable weir to only allow intake of the river surface water. Concerns similar to Option 2 for the adjustable weir apply to this option as well.
- **Sediment Intake –** Sediment intake considerations for this structure are similar to Option 2. However, the size of the structure would likely be larger than Option 2 which would result in slower water velocities and more settling.
- **Pump Units –** Pump unit considerations are similar to Option 2.

- **Maintenance –** Maintenance considerations are similar to Option 2. The exception to this is that the ramp would be utilized for maintenance equipment access to remove accumulated sediment.
- **Cost –** This option would require a large amount of excavation through rock, even more so than Option 2, resulting in considerable expense. Concrete quantities would also be higher than for Option 2.
- **Safety –** Safety considerations are similar to Options 1 & 2, although more fencing would likely be required.
- **Trashracks / Fish Screens –** Trashrack / Fish Screen considerations are similar to Option 2.
- **Environmental –** This design would leave a larger footprint along the river bank than the others and is therefore less attractive from an environmental standpoint.
- **Aesthetics –** Aesthetic considerations are similar to Option 3.
- **Recreation (River Running) –** Recreation considerations are similar to Option 2.
- **Flooding –** Flooding considerations for this structure are similar to Option 2.

5.11 Option 4 – Submerged Intake

This type of structure is used in both lake and river applications. A vertical shaft of sufficient diameter is drilled on the bank a short distance from the river. From near the bottom of the shaft, a horizontal line would extend out into the river (Figure 5-11, Ranney, 2008). The horizontal line and associated intake would need to extend out to the deepest part of the channel. The shaft would be concrete lined and a concrete floor constructed at the bottom, creating a "wet well". Submerged pumps would extend down from a platform at the top near the surface. Pump motors would be placed in a pump house constructed at the top of the shaft.

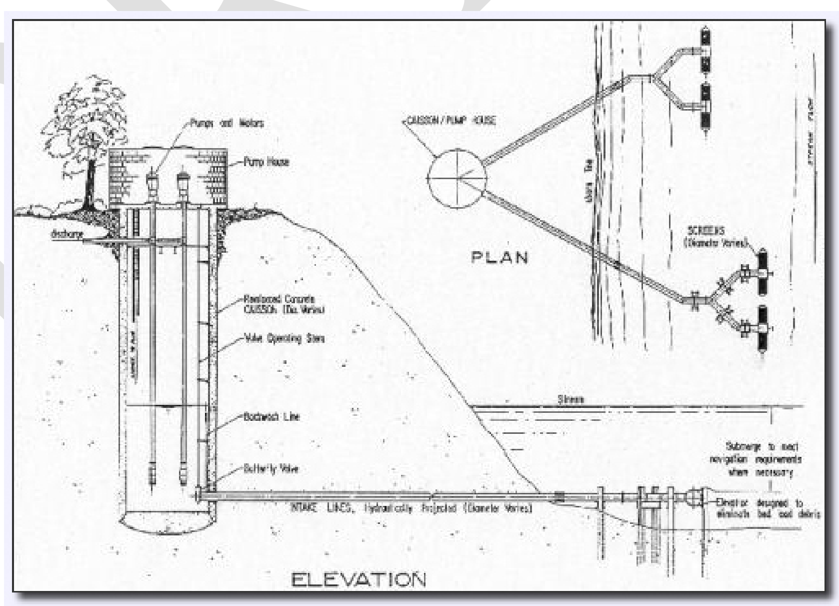


Figure 5-11. Surface water intake representative diagram.

- **Effectiveness –** Gage heights in the river at this location typically range from four to six feet during normal flows and can get as low as three feet. Three feet does not leave much room for a submerged intake structure. This means that a channel would need to be excavated into the bed of the river for the placement of the intake. This would ensure that the required amount of water can always flow into the "wet well" through the horizontal line. The vertical pumps in the wet well would need to be sufficiently submerged so that they operate properly. Accurate channel cross-sections at the intake site would be needed to effectively design this structure and prove it's effectiveness.
- **Sediment Intake –** This design does little to minimize sediment intake through the initial pumping units. The submerged intake would be located at the lowest point in the channel where sediment concentrations would be the highest. Also, some sediment deposition is expected within the "wet well," where removal would be difficult.
- **Pump Units –** The initial pumping from the "wet well" to the settling pond can be achieved with low head, vertical turbine pumps. From the settling pond the water would enter a clearwell. From here, additional pump units would convey it into the pipeline and up to the next booster station.
- **Maintenance –** Backwashing the vertical turbine pumps would probably be required, although less frequently than with the floating pump units. Settled sediment within the "wet well" would need to be removed periodically with some type of sump pump. Depending on the depth of the "wet well" this could possibly be achieved by means of a vacuum truck or sump pump. This means that an access road needs to be provided next to the structure. At least one spare pump unit should be provided for maintenance, emergency shutdown, and pump cycling.
- **Cost –** This option would require a large amount of drilling through rock resulting in considerable expense. Also, the cost of the concrete-lined caisson structure would be significant.
- **Safety –** This structure would likely be safer than the other three options. The one exception to this would be when maintenance personnel need to enter the "wet well." Air quality would need to be tested for unsafe conditions. In addition, the submerged intake would need to be designed so that entrance velocities would not create unsafe conditions for swimmers and river runners. Lighting should be provided for nighttime operations.
- **Trashracks / Fish Screens –** A sturdy and well-designed trash rack is critical for this design. The intake would be place in the bottom of the channel where large boulders and debris would impact it during large floods.
- **Environmental –** Of the four options, this structure leaves the smallest footprint, which is basically the diameter of the vertical shaft.
- **Aesthetics –** This option would have the least visual impact on the river bank. The only exposed portion of the structure would be the pump house.
- **Recreation (River Running) –** Because the intake to this structure is submerged, impacts to recreation and river running are nearly eliminated. The exception to this would be during extremely low flows when submergence of the inlet is minimal.
- **Flooding –** This design is extremely susceptible to damage from flooding. The intake is on the bottom of the channel where large boulders and debris can impact it.

5.12 Option 4 – Rotating Self-Cleaning Screens, Sand Separator and Filtering

This type of structure is used in both lake and river applications.

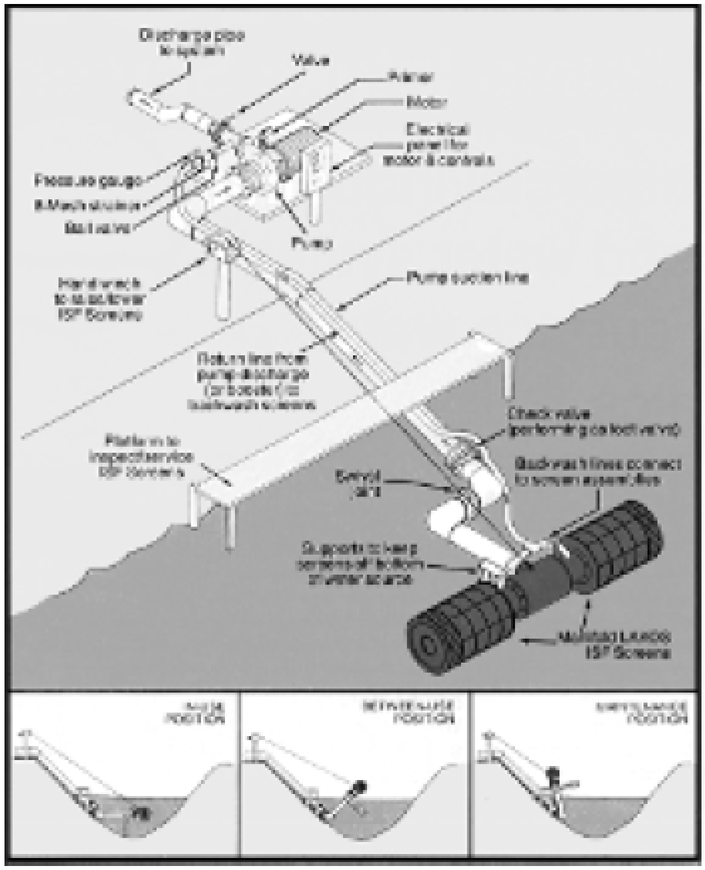


Figure 5-12. Self cleaning screens diagram.

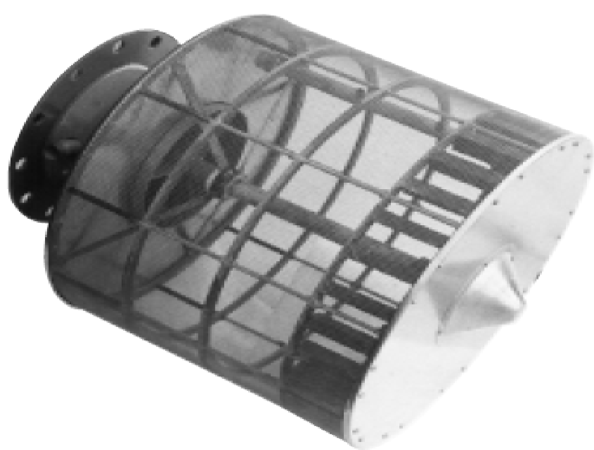


Figure 5-13. Self Cleaning Screen.

- **Effectiveness –** Gage heights in the river at this location typically range from four to six feet during normal flows and can get as low as three feet. Three feet does not leave much room for a submerged intake structure. This means that a channel would need to be excavated into the bed of the river for the placement of the intake. This would ensure that the required amount of water can always flow into the “screen area”. The rotating screens would prevent debris and fish from being trapped against the screen. Standard screen size is a 10 mesh, but other screen types could also be designed. This type of system would be similar to the suspended pump system that would allow removal of the screens for maintenance and removal. Accurate channel cross-sections at the intake site would be needed to effectively design this structure.
- **Sediment Intake –** This design does little to minimize sediment intake through the initial pumping units. The submerged intake could be positioned at the midpoint in the river depth to have a good water supply but minimize sediment concentrations. This system does have about the lease amount of impact from the sediment in the river since it is removal and is not stationary. Water jetting of the screen provides constant cleaning which is an advantage to other options. This technology has been used for many years so it has a proven track record for industrial and municipal use. Several companies currently make these types of systems.
- **Pump Units –** The initial pumping from the “self-cleaning screens” to the pumps mounted on the platform would be by suction through the screens and piping. Flexible joints that swivel could be installed to raise and lower the screens to allow the best with drawl of water from the river.
- **Maintenance –** Maintenance of the screens and piping could be done by raising them from the river to perform maintenance screens and piping exposed to the water would be made from stainless steel to eliminate the need to perform coating repair. The water flushing hose would need to be replaced periodically to maintain pressure and potential leaks. These system have been run in Alaska and Canada so they can be run in cold temperatures.
- **Cost –** This option appears to be the least cost alternative of the various options, due to lower construction cost for the supporting infrastructure, however, it would be slightly higher costs compared to the other options due to the need for wash water to keep the screens clean of debris. The added cost of the water may offset the maintenance when compared to other systems, since they may need constant removal of sediment, which this option does not have at the intake.
- **Safety –** This structure would likely be safer than the other four options. Maintenance personnel would not need to enter a wet well and could perform maintenance from platforms next to the river. A walkway would be needed similar to the existing walkway that would allow access from the high level. The walkway could be enclosed to prevent ice from forming. Once option to lower costs would be enclose the existing walkway and provide lighting within the enclosure. In addition, the submerged intake would need to be designed so that entrance velocities would not create unsafe conditions for swimmers and river runners. Lighting should be provided for nighttime operations.
- **Trashracks / Fish Screens –**The screens for these systems rotate and range in size from 15 to 24-inches in diameter. Standard screen size is a 10 mesh screen, but other screen openings have been designed for areas with endangered fish species. Entry

velocity at the screen could be designed to prevent impingement of fish fry to the rotating screens.

- **Environmental –** Of the five options, this structure leaves a small footprint next to the river for the platform structure and pipes would enter the river to submerge the screens. The intake screen would be suspended next to the river bank and would not impact the bottom of the river channel.
- **Aesthetics –** This option would have a minimal impact on the area, due to the existing intake structure in the area. The pipe and pumps could be design in smaller units to keep the size of the facility down and provide flexibility for the operation of the system.
- **Recreation (River Running) –** Because the intake to this structure is submerged, impacts to recreation and river running are nearly eliminated. The exception to this would be during extremely low flows when submergence of the inlet is minimal. A angled concrete deflector wall could be build upstream of the submerged screen to protect the screen from debris and people running the river. Since the intake will be next to the river bank, there would not be any impact to the center of the river. Entrance velocity at the intakes could be designed to prevent large suction forces at the intake.
- **Flooding –** This design is not susceptible to damage from flooding. The intake can be raised to allow flood depths to pass. Floating debris would need to be deflected.

Table 5-1. Intake Selection Matrix.

Option	Effectiveness	Sediment	Cost	Environmental	Aesthestics	Maintenance
Suspended Pumps	3	3	3	4	4	2
Concrete Intake Bay	4	5	4	5	5	6
Side Channel Intake	5	4	6	6	6	5
Wet Well	6	6	5	3	1	4
Self-Cleaning Screens	2	2	1	2	3	1
Bed Rock Wells along River	1	1	2	1	2	3

1 – Highest potential of being selected 6 – Lowest potential of being selected.

Selection of the intake system is a very important component of the overall project. In review of the intake options in a generalized matrix, the self-cleaning screen system appears to have the best qualities in comparison to the other surface options for effectiveness, sediment control, cost, environment and maintenance. In talking with the representatives at

Lakos Filtration and Separation they have used these screens in a variety of situations from Alaska to California.

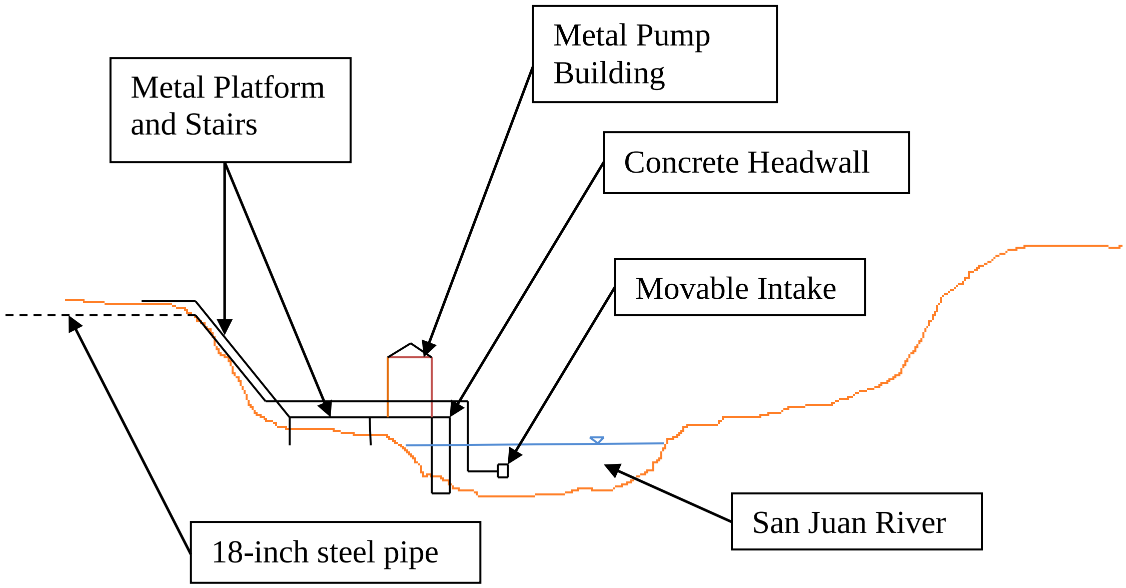


Figure 5-14. Generalized layout of Intake and Support Structures next to River.

Figure 5-15. Typical Self Cleaning Screen Installation.

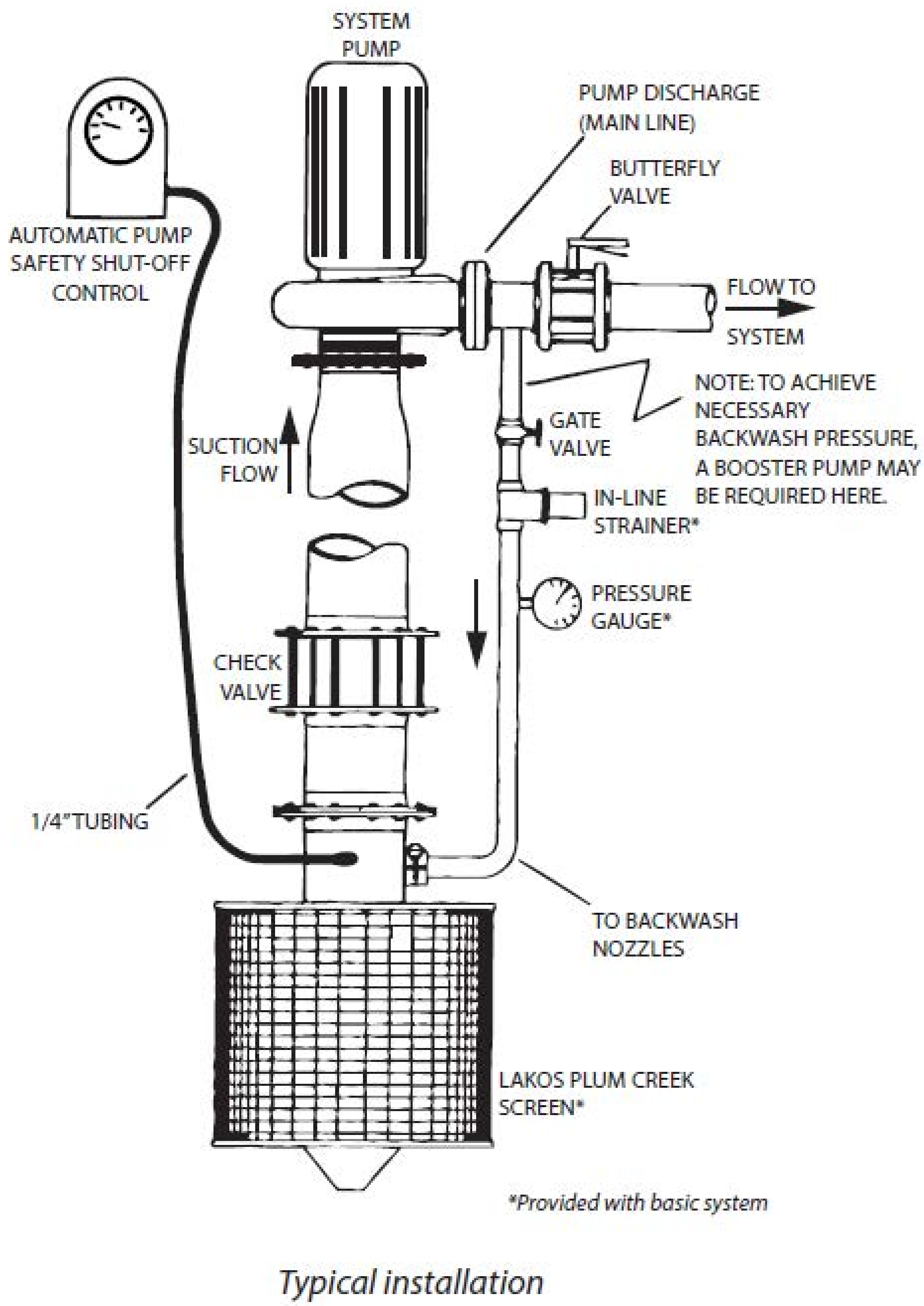


Figure 5-16. Typical Self Cleaning Screen Installation.

If self-cleaning screens were to be used they recommend using a sand separator to remove the sand size particles that would be brought into the pump system based on their specific gravity to help lessen the need for treatment of these particle sizes. They also recommended using sand filters or other pretreatment, such as an inclined plate settler or solid contact clarifier to help eliminate silt and clay size particles prior to being pumped to the treatment plant, to eliminate the wear on the booster pumps in the treatment system. An inclined plate settler would take less of a foot print due to the surface area of the plates. A solid contact clarifier would take more area, but would potentially provide better treatment of the sediment with coagulation and flocculation added. As with all the options the sediment in the river would need to be dealt with prior to treatment and it seems that a self-cleaning screen, sand separator or other pretreatment prior to treatment would bring the size of particles down to an acceptable size for membrane treatment. As an alternative to the sand filters, plate settlers or solid contact clarifiers are also a possible option to look at during final design. The other benefit of this treatment at the river would be reduced sediment load on the water treatment plant. At the gage above the proposed intake location, river depths have been less than 4 feet during low flows. During periods of low river flow and ice, bedrock wells may be the best alternative due to the limited depth that would cover an intake such as the self-cleaning screen. If a direct intake system is used this low flow period and shallow depths would need to be accounted for.

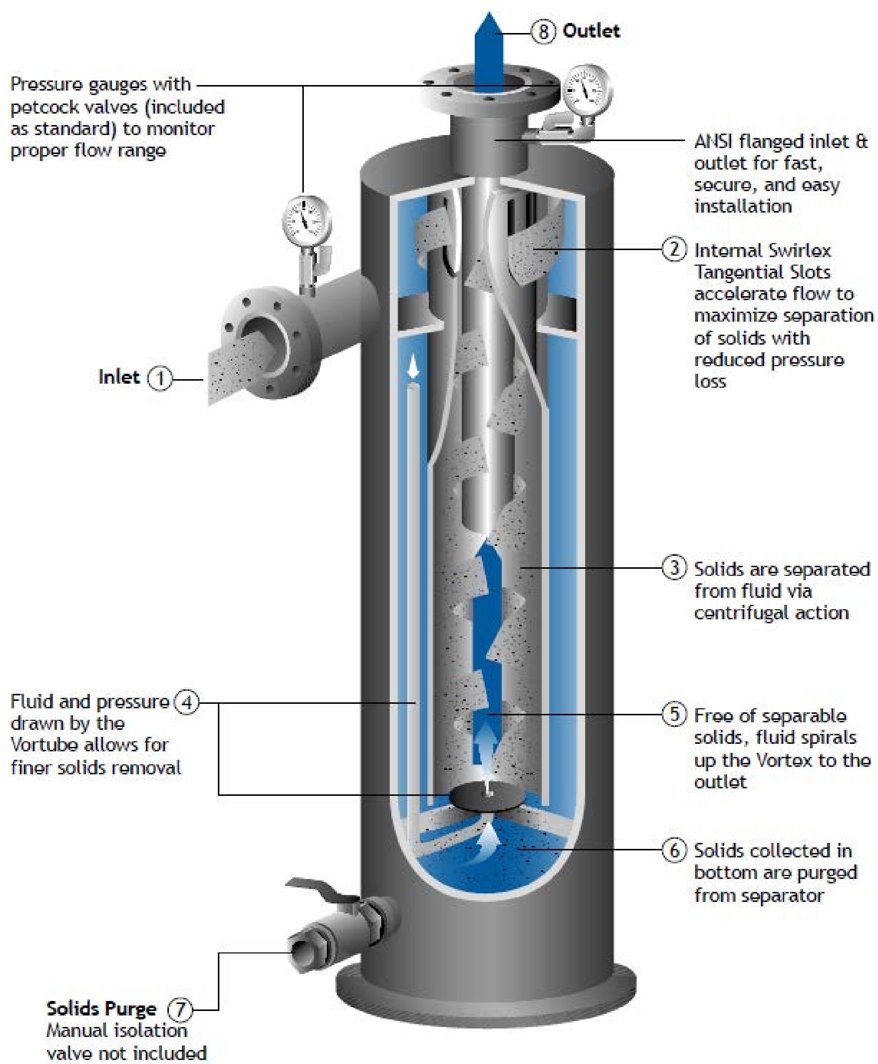
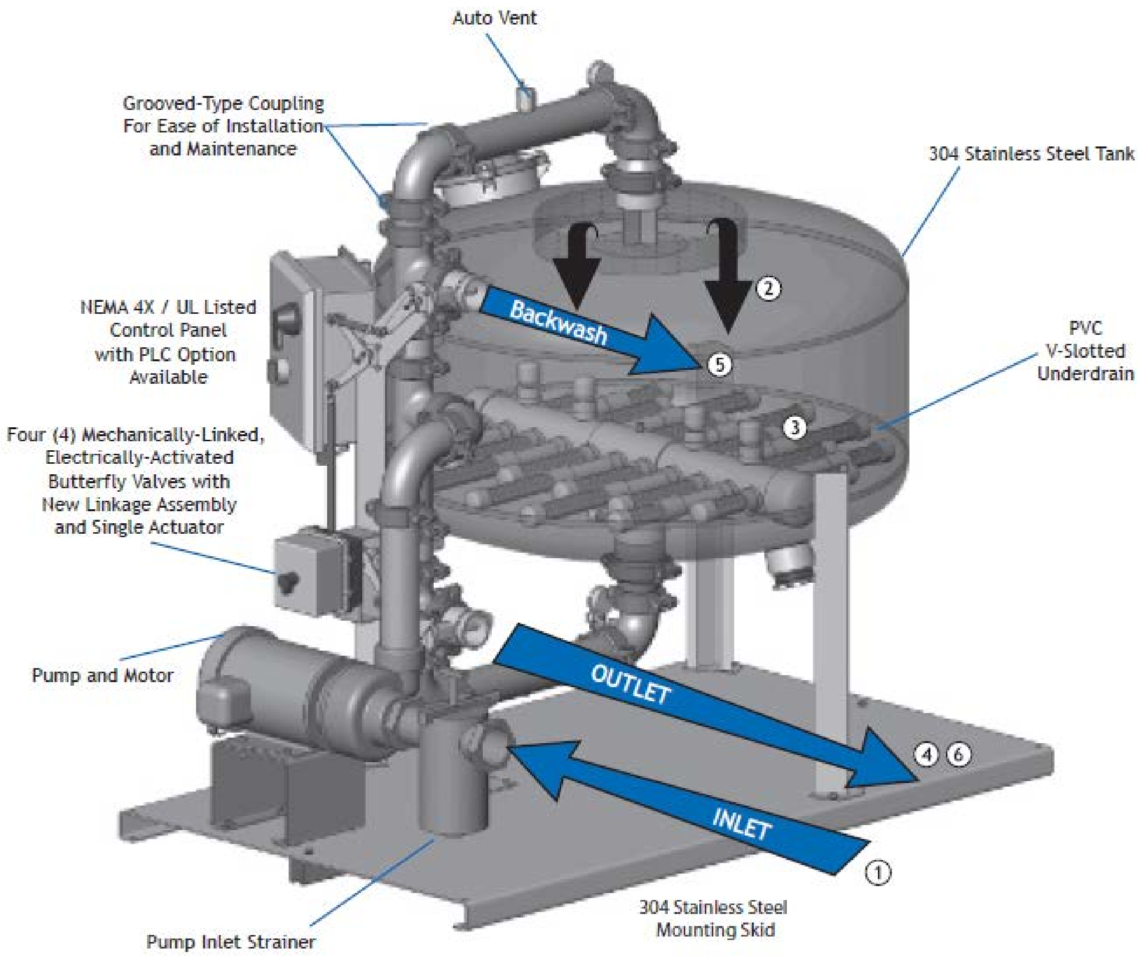


Figure 5-17. Typical Sand Separator.



The Basic Steps of Media Filtration Operation

① Unfiltered system water enters pump suction INLET.

② Water is pumped to top and is uniformly dispersed over the media bed.

③ Water passes through the media bed, leaving debris behind.

④ Filtered water exits the OUTLET.

⑤ The media bed is cleaned through a backwash cycle at specified intervals or differential pressure. The backwash cycleruns for 3 minutes.

⑥ System returns to normal filter mode.

Figure 5-18. Typical Sand Filter.

Figure 5-19. Multiple Sand Filter Installation(Lakos).

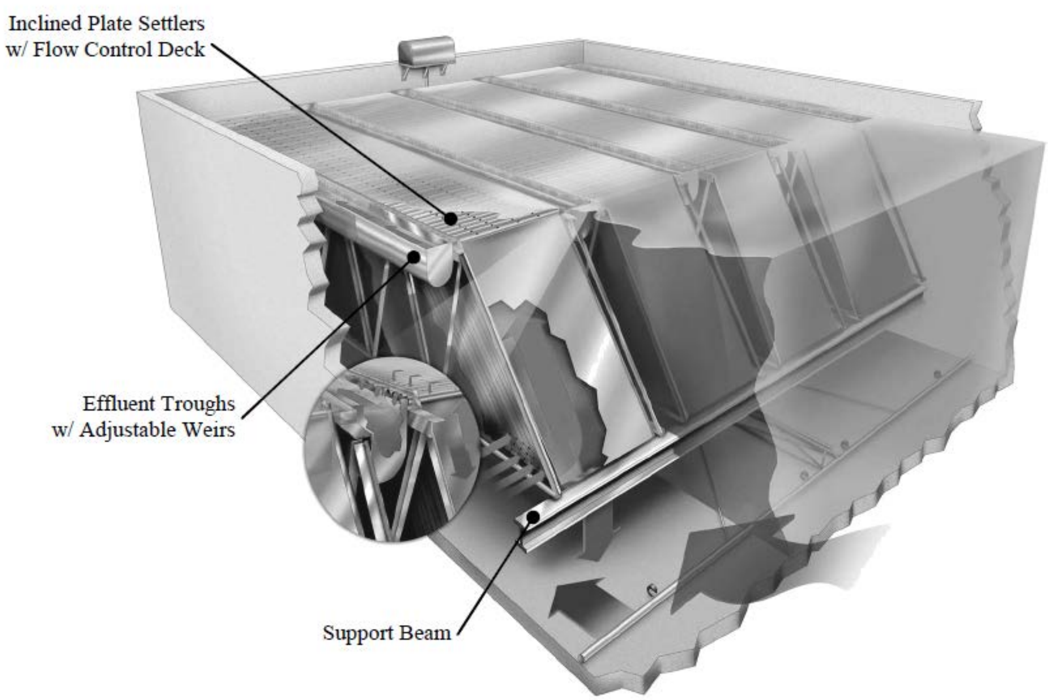


Figure 5-20. Inclined Plate Settler(MRI).

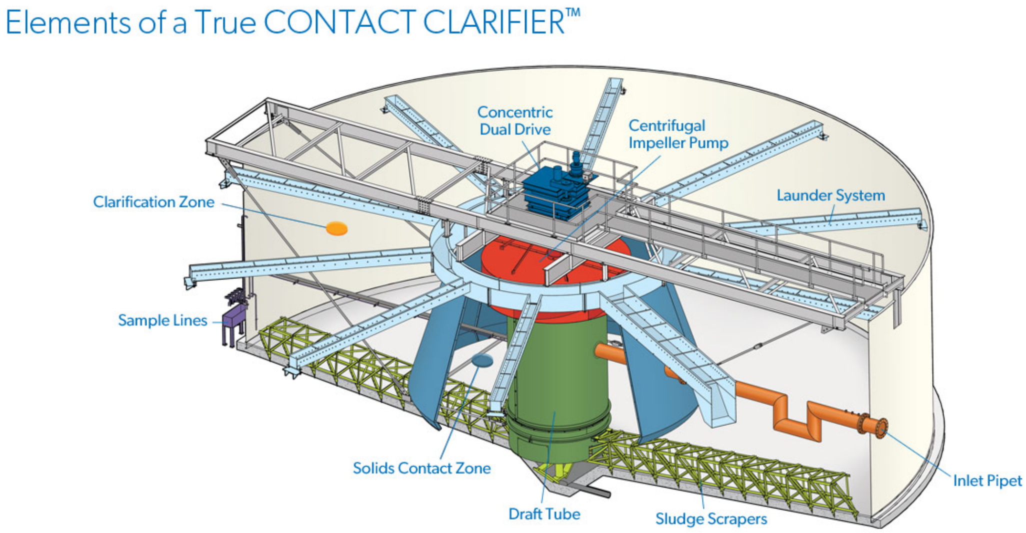


Figure 5-21. Solid Contact Clarifier(Westech).

5.13 Forebay and Surge Tanks

A surge tank or multiple smaller surge tanks would be manifold together would be required at the beginning of the system to protect the pipeline and pumping plant from damaging surges that could potentially develop, particularly during power outages. Sizing of the tank would need to be completed after a surge analysis has been performed during final design. Tanks would also be needed at the high points along the alignment to prevent negative pressures from developing in the pipeline system. The sizing of the tank would need to be determined from a more in depth analysis of the pipeline system.

A large storage/forebay tank would be needed to provide a constant supply of water to the initial pumping station adjacent to the water treatment plant at the river.

6.0 Water Pipeline

6.1 Alignment Overview

Selecting the route for the proposed regional water supply system raw water pipeline was fairly straightforward. Wherever possible, it was desirable to have the alignment follow existing roadways in order to minimize environmental impacts. With the preferred alternative, approximately 26.8 of the 39.1 total miles (68.5%) follow Highway 163. Of the remaining 12.3 miles, the vast majority of the alignment runs along several dirt roads for 8.6 miles and the remaining portion of 3.7 miles would follow along E Halgiotah Wash Road. There is a very small portion of the alignment between the intake and Halchita which runs overland, and most of this follows an existing pipeline alignment.

The proposed pipeline alignment runs as follows: From the intake structure on the San Juan River generally south along the existing pipeline alignment to the east side of Halchita below the two water storage tanks (1.9 mi); southwest overland around Halchita (0.9 mi); generally south/southwest along the Gypsum Creek Road (2.9 mi); southwest along an unnamed dirt road (3.0 mi); west along Indian Route 6480 (3.7 mi); southwest along HW-163 to the Monument Valley and Kayenta approximate final water treatment facilities (Figure 6-1).

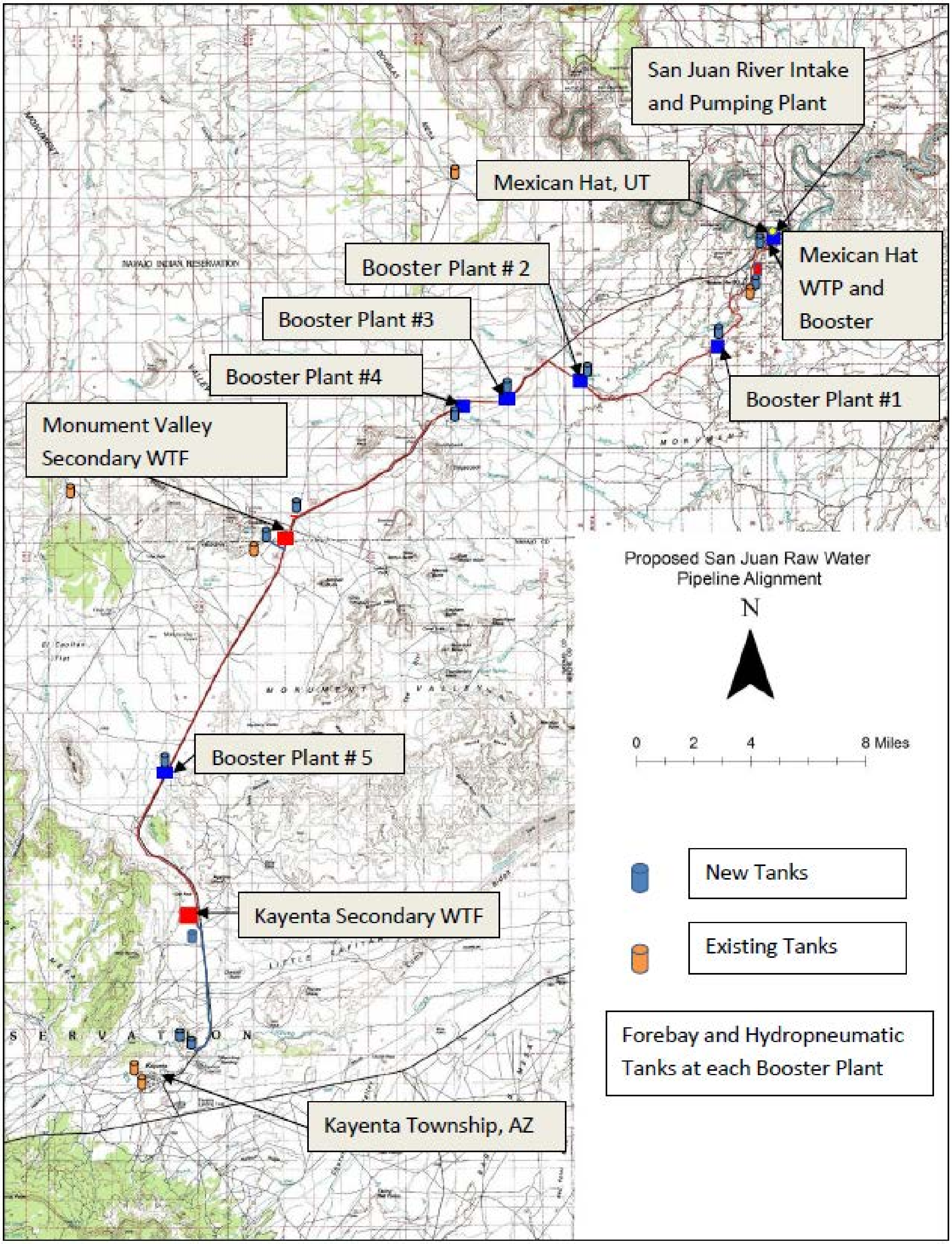


Figure 6-1. Proposed San Juan Pipeline Alignment.

The technical memorandum, *Utah Navajo Municipal Water Projects, April 2007,* estimates that for a San Juan River – Monument Valley Water Project, the proposed alignment consists of 30% rock and 70% common excavation between the San Juan River and Monument Valley. Based on general observations made during a July 29, 2008 and December 2013 site visits to the proposed alignment for the current pipeline study, this estimate appeared to be fairly accurate for the entire 40 mile alignment. Most of the rocky conditions were observed between the river and Monument Pass area along HW-163, with area of sand dunes also along the alignment. An alternate alignment bypassing the Monument Pass area was considered in order to minimize the rock excavation necessary. The alternate alignment deviated from HW-163 at a location approximately in the middle of Section 7 T43S R17E (SLB&M). From here it generally runs west and then back to the south, essentially around Eagle Mesa, where it eventually comes back to HW-163 approximately 0.4 mi north of the Goulding's and Oljato turnoff.

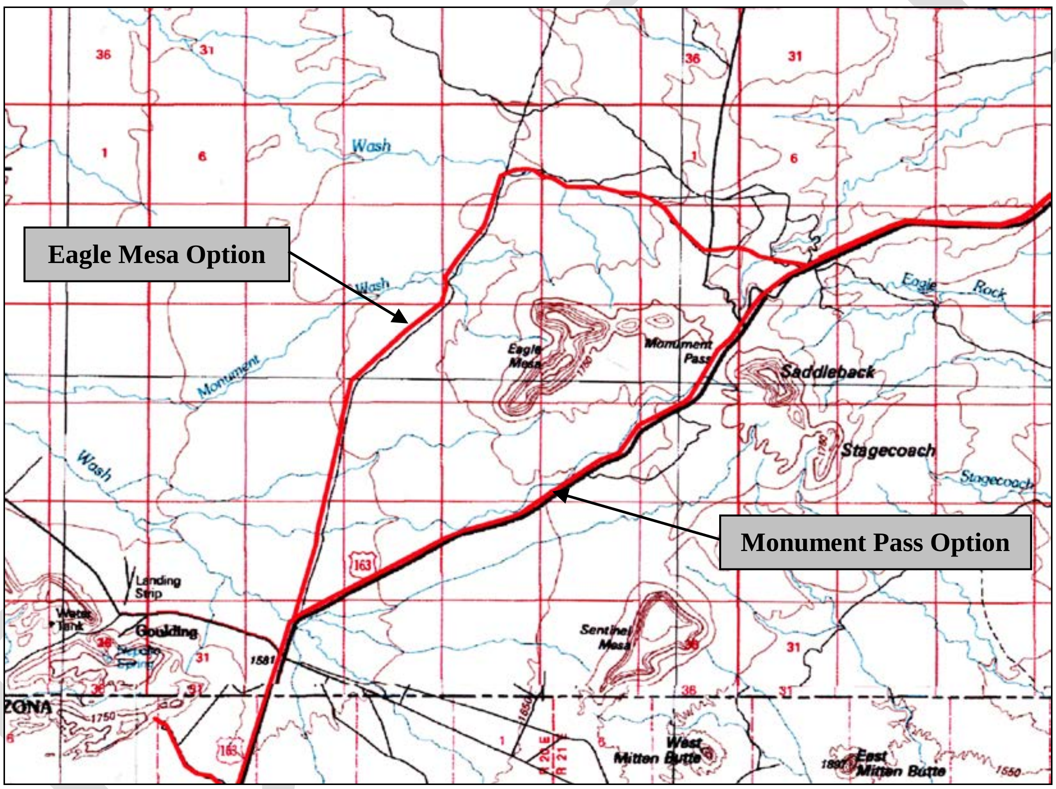


Figure 6-2. Eagle Mesa Alternative Alignment.

While the alternate alignment would likely require less rock excavation for the pipeline, it would increase the total length from 39.1 miles to 41.2. For about ¾ of a mile at the northeast end of Eagle Mesa, the alternate alignment would travel overland across a drainage which would likely present some construction challenges. Also, a significant portion of the dirt road at the north end of Eagle Mesa is rough and would require improvements in order to gain access with construction equipment. For these reasons, it does not appear that the alternate alignment would provide any significant economic advantage. Deviating from the highway would likely be less desirable from an environmental standpoint as well. The preceding assessments were based on general comparisons and a more thorough evaluation of the alternate alignment may be beneficial for the final design.

The other alternative that needs to be reviewed further is following the highway from Mexican Hat to Monument Pass. This alignment would require placement of the pipeline away from the roadway in areas due to several steep road way fills, but in comparison to the preferred route, this alternative alignment would have about the same amount of bedrock excavation to contend with. The route along the highway would cut some distance off of the alignment, but siting of pumping plants and air/vac structures along the highway may be more difficult and would need to be studied further.

Land Ownership

Based on land status maps, it appears that there are limited allotments of individual property along the proposed alignment. If this is indeed the case, the right-of-way process would be simplified. Although this process is relatively straightforward, it can take some time to work with allotments. For example, the right-of-way process for the Farmington to Shiprock Pipeline took about two years. Eventually, each of the land use permitees along the pipeline corridor need to sign off on the right-of-way request and an appraisal needs to be done on it. Finally, the Navajo Nation Land Department needs to review the entire package before it can be approved by the Resources Committee and BIA (J. Leeper, 2008, pers. comm. 29 Sep). Sufficient time should be provided to complete this process.

Pumping station locations could be adjusted to minimize the impact of the allotment residence.

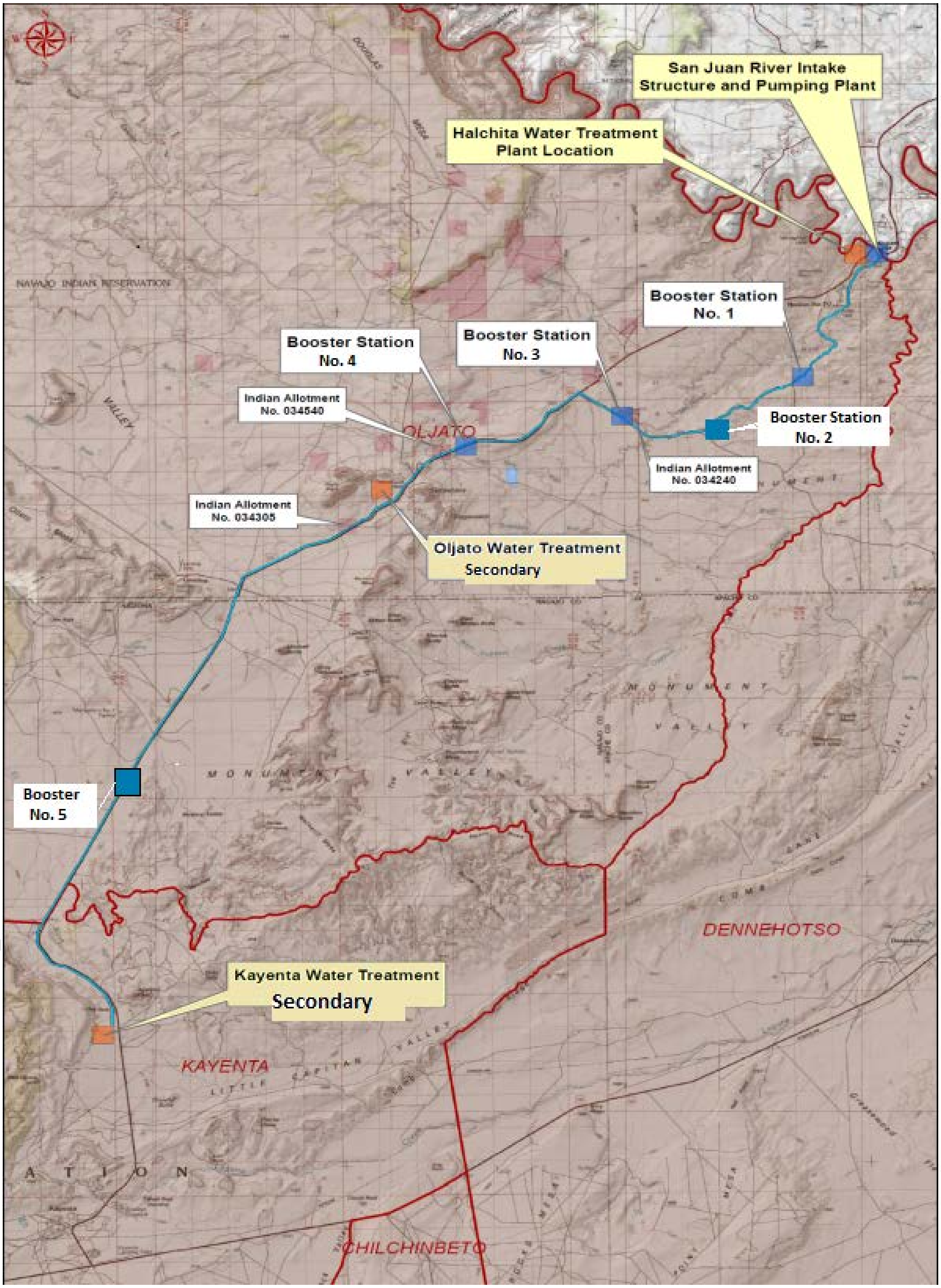


Figure 6-3. Land Ownership Allotment Map

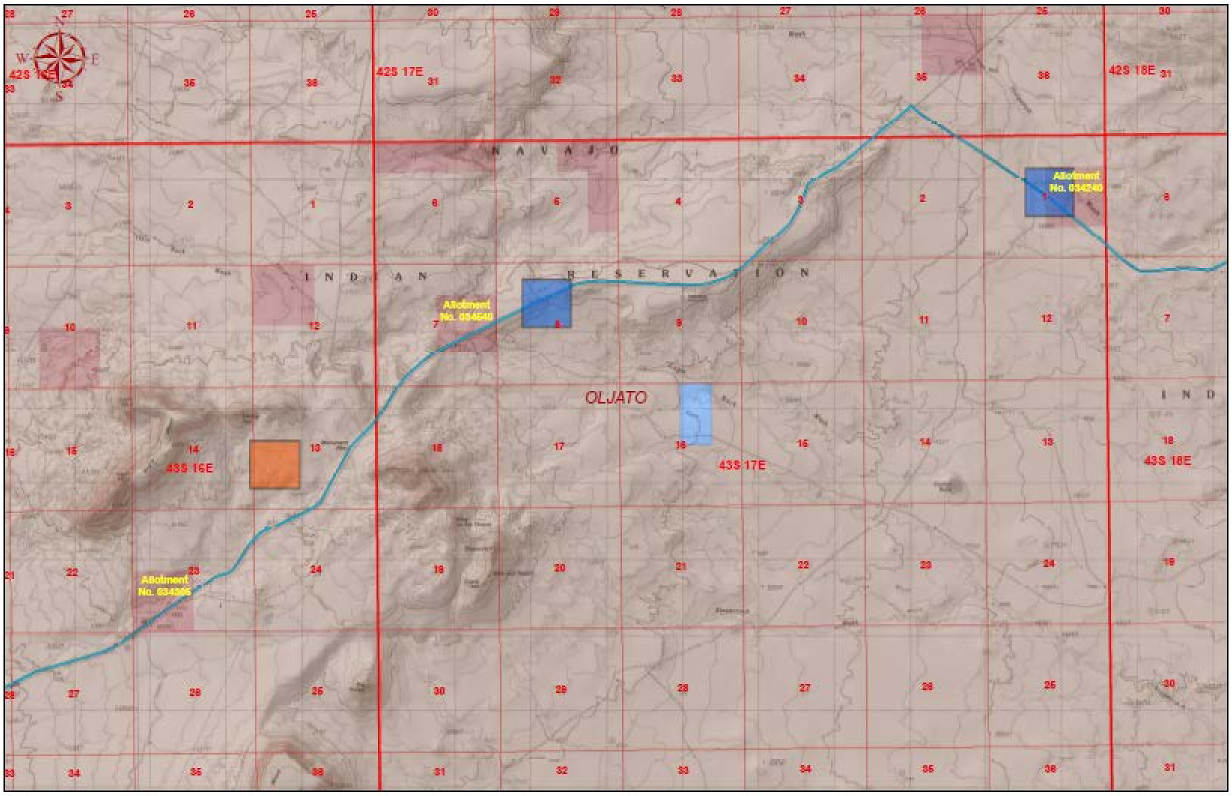


Figure 6-4 .Land Allotment Numbers along proposed pipeline shown in Figure 6-3.

6.2 Pipe Profile

Figure 6-3 shows a basic profile of the proposed raw water pipeline alignment up to the Kayenta water treatment facility. Monument Pass is the high point along the alignment at approximate elevation 5,730 feet. The Monument Valley water treatment facility should be located approximately in the area of the existing water distribution lines and tank locations as possible, for distribution reason, but would need to be built in an environmentally pleasing manner related to the vicinity of the monuments. The location of the treatment plant would need to be made during final design to service residents of both Douglas Mesa and the Oljato area. From Monument Pass it is about 70 feet higher than the proposed Kayenta water treatment facility and associated storage tank elevation of 5,660 feet. The elevation gain from the San Juan River (4,040 feet) to Monument Pass is 1,680 feet to an elevation of 5,730.

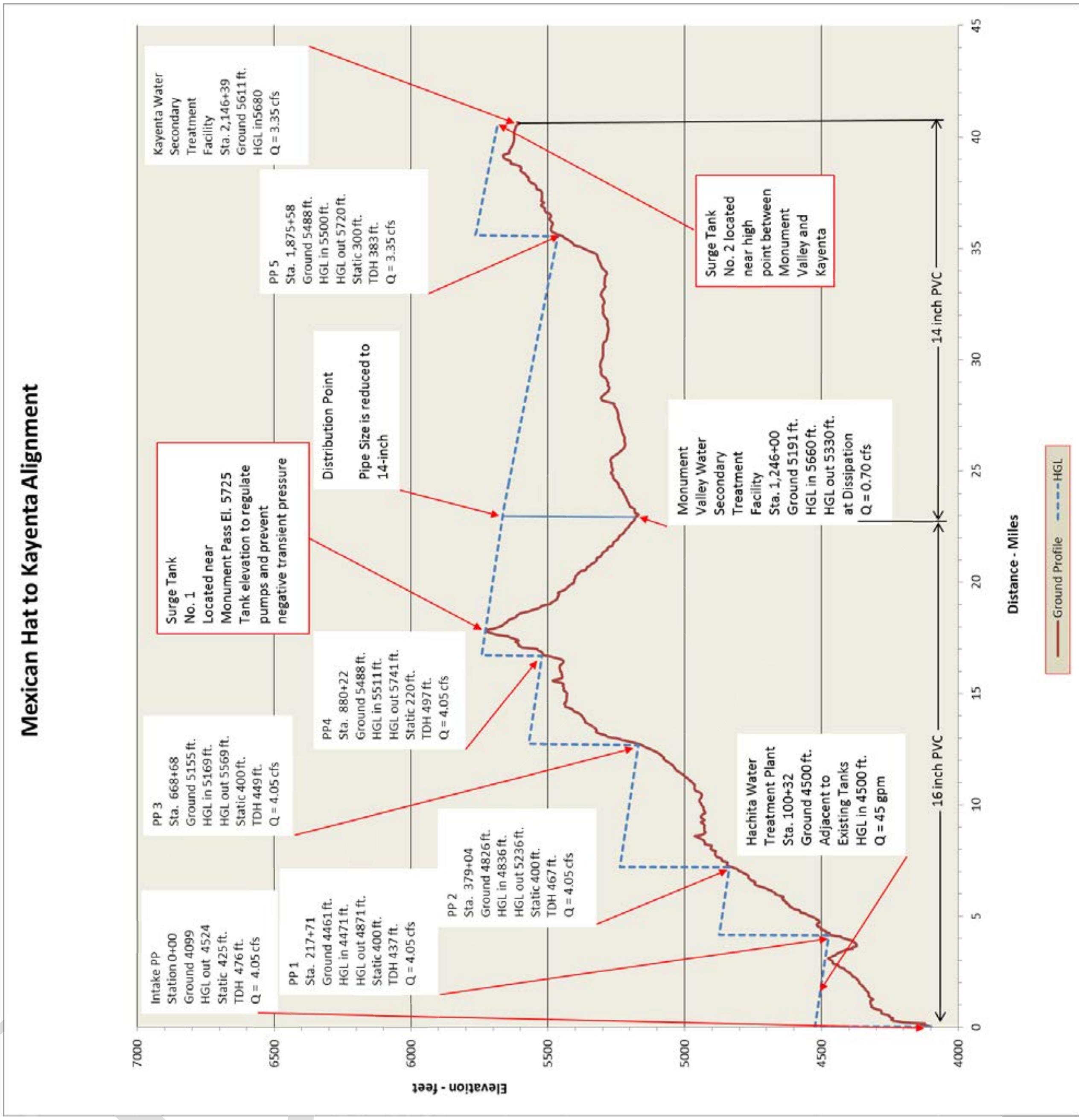


Figure 6-5. San Juan Raw Water Pipeline Profile.

6.3 Pipe Hydraulics

An extensive hydraulic analysis of the pipeline system was not performed as part of this study. Instead, general hydraulic considerations were considered.

One hydraulic concern in particular is during initial operation of the pipeline system when demands are significantly less than the design flow. This situation can present problems with cavitation, sedimentation, air removal, and the possibility of open-channel flow. Control valves can be placed in the pipe to help maintain positive pressures which in turn minimizes the risk of open-channel flow which tends to occur on steep grades. Control valves also help with cavitation concerns by regulating flow and pressure. In order to facilitate biofilm and air removal during periods of low flow, periodic flushing at higher velocities may be required (Tullis, 1989, p. 34). Further hydraulic analysis is required during the next stage of design to determine to what extend the preceding concerns apply to the pipeline system and to remedy them.

6.4 Pipe Type

Factors such as pipe size, hydraulic roughness, pressure requirements, ease of handling and installing, resistance to internal and external corrosion, useful life, and economics all affect the selection of a pipe material. The ability to withstand the maximum internal pressure is the most basic requirement for a pipe material (Tullis, 1989, p. 41). Because of the relatively large pressures anticipated in this system required to lift the water to the Monument Valley area, the three pipe materials considered are PVC, ductile iron and steel. HDPE pipe material was considered but is limited to 267 psi pressure rating for HDPE and would not meet some of the higher pressure requirements. Plastic pipe material recommended maximum operation velocity is 5 feet per second. This maximum velocity is lower than the velocities recommended for steel and ductile iron pipe. As shown in Figure 6-5 the comparison of plastic pipe would require larger diameter pipe to keep the velocities within the recommended velocity range.

In a recent study completed in April 2012 by Steven Folkman, Ph.D., P.E. of the Utah State University Buried Structures Laboratory, he published the following failure rates for various types of pipe material. A major finding of the study is that PVC pipe has the lowest overall failure rate when compared to cast iron, ductile iron, concrete, steel and asbestos cement pipes. Another major finding is that corrosion is a major cause of water main breaks. The study did also make another key finding that PVC pipe did have a high failure rate during the first 20 years of service, but that has been linked to poor installation practices and if installed correctly the failure rate is very low. As the study points out proper installation of the pipeline material is important in relationship to the failure rate of the pipeline material.

Some of the finding are as followed and have been reference the Figure 6-6 that was included in the report:

“The results in Figure 6-6 are related to when a pipe material was introduced or removed from the market. Asbestos Cement pipe has not been installed in the USA and Canada in the past 20 years, and, thus, all AC pipe failures exceed 20 years of age. Widespread DI and PVC pipe production in the USA did not start until about 1970, so we should expect to see a small failure percentage for both DI and PVC in the 41 to 60 year age group and none for the 61 to 80 and 80+ age groups. PVC follows that trend in Figure 6-6. Figure 6-6 shows the majority of DI pipe failures occur at an age between 21 and 40 years. The DI results in Figure 6-6 for the 61 to 80 and the 80+ age groups are possibly caused by incorrect records on the age of those failed pipes. It is of interest that Figure 6-6 shows a greater percentage of PVC pipes fail in the first 20 years of use than in the next 20 years. This was investigated in a previous survey funded by Water Research Foundation (formerly AWWARF) (Moser, 1994). Figure 6-6 illustrates the percent of failures as a function of time for AWWA rated PVC pipe. As shown below, over 40% of the reported failures occurred in the first year. Often the cause of these failures in PVC pipe is related to improper installation practices and not a defect in the pipe. The city of Calgary has been able to achieve remarkably small PVC failure rates due to enforced construction standards (Brander, 2004). In addition, Calgary requires new subdivision infrastructure to remain the property of the private developer for a period of two years. During this two year period, most construction related problems will occur. An AWWARF study (Burn, 2006) estimates the design life of PVC to be in excess of 110 years."

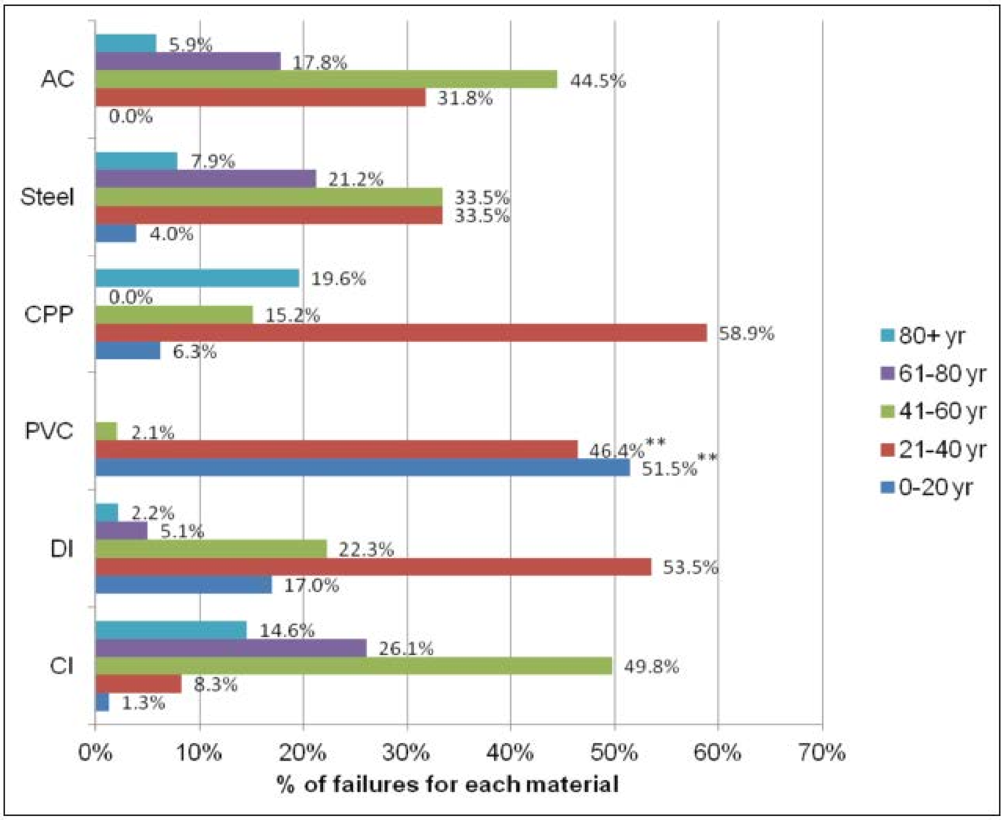


Figure 6-6. 2012 Utah State University Pipe Material Failure Rate Comparison as a function of age and pipe material.

For the purposes of this study, PVC was selected as the preferred material type. This is principally due to its better resistance to corrosion in alkali soils and its reputation of having a long service life as highlighted in the recent Utah State University study. It is assumed that steel pipe would require extensive corrosion monitoring and cathodic protection, particularly in a buried application so that is why it was not considered as the preferred material for the size of pipe being considered in 6 to 16-inch sizes. Final design information would be used to make the final selection between materials available. In the pipeline system, annual pumping costs for steel pipe were calculated to be nearly 8% higher than for DIP, so steel does not seem to the most favorable material to use when compared to ductile iron or PVC. Reclamation has published concerns against the use of Ductile Iron pipe in highly corrosive soil, but from available data at the time of this report, the soil where the pipeline would be placed is not considered highly corrosive for the majority of the pipeline, however, some soil deposits between Monument Valley and the Kayenta treatment facilities are from shale bedrock which may contain higher level of alkalinity However, soil alkali levels would need to be tested to determine in final design if Ductile Iron pipe meets current design considerations for corrosion or if other alternatives should be considered.

Head Loss Comparison for Piping Materials - 14-inch Nominal Diameter					
Pipe Material	C Factor	Flow Rate (gpm)	Actual Inside Diameter (in)	Velocity in Flow (fps)	Head Loss (ft.)
Ductile Iron	140	2,500	14.55	4.82	4.72
PCCP	140	2,500	14.00	5.21	5.69
Steel	140	2,500	14.00	5.21	5.69
PVC	150	2,500	13.50	5.60	5.98
HDPE	155	2,500	12.35	6.70	8.68

Note: Assumed 1000 feet long pipe flowing full. Used Hazen-Williams Eq. for Head Loss.

Figure 6-7. Head loss comparison for various piping materials.

The selection of PVC as the preferred pipeline material for this study was based on general information and comparisons. All things considered, the costs of the materials are quite similar and steel or ductile iron should not be completely eliminated at this point. During the next stage of design when more accurate information is known, a more in-depth comparison should be performed between the other materials.

6.5 Pipe Sizes

Required pipe inside diameters were calculated based on the continuity equation (Q = V*A), with an assumed maximum velocity of 5 ft/sec. As shown in Table 6-1, the total year 2060 demand requires a 16-inch pipeline to transport the water to Monument Valley and then the line would be reduced to a 14-inch line to continue on to the Kayenta water treatment facility.

6.6 Pipe Length

Pipe length in this section applies only to the water pipeline from the San Juan River. Lengths for the distribution pipelines from the water treatment facilities would be discussed in Section 10. The total length for the preferred alignment (Monument Pass option) is 39.1 miles. Nearly 70% of this length follows Highway 163.

6.7 Pipe Pressures

Pressure classes of PVC pipe vary due to the increased elevation climb from the river to Monument Pass. Higher pressure class pipe rated 305 psi is needed at the higher hydraulic grade line locations next to the booster/relift station location and the pressure class will reduce as the difference between the ground surface and the hydraulic grade line decreases to a pressure rating of 125 psi at the pipeline approached the booster/relift stations. These findings may need to be adjusted after a more in-depth hydraulic analysis is conducted during final design.

Although a surge allowance of the PVC pipe is considered adequate for most applications, a surge-analysis of this pipe system should be conducted during final design to determine if any larger surge pressures are anticipated.

Plastic pipe could be used for the distribution lines from the water treatment plants with pressure rating from 125 to 200 psi.

6.8 Pipe Trench

To protect the pipe from freezing in the winter the pipe will have a minimum of 3 feet of cover. The frost depth in the area is 18 to 24 inches and providing an additional 1 foot below the frost depth will protect the pipe during the winter. The trench depth will vary along the alignment due to the terrain along the alignment and will need to be studied further in final design.

Rock Excavation:

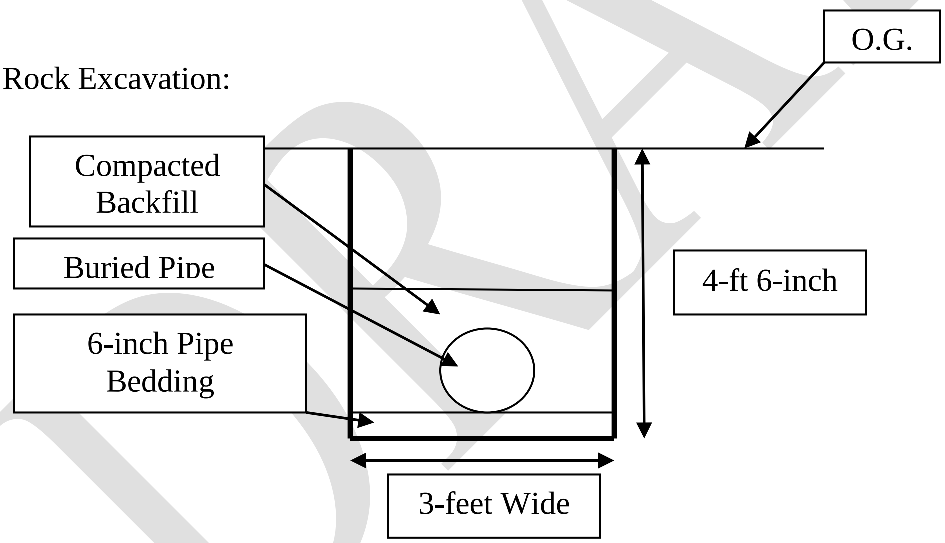


Figure 6-8. Rock Trench Approximate Dimensions(NTS).

Common Excavation:

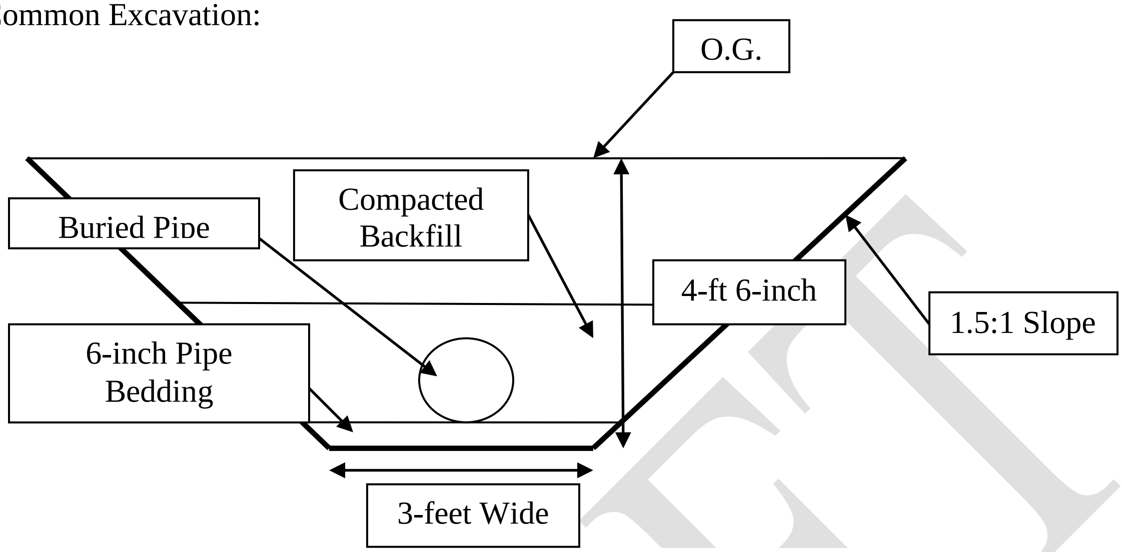


Figure 6-9. Common Excavation Trench Approximate Dimensions(NTS).

The pipeline alignment from Halchita to the intersection with Halgaitoh Wash Road consists mainly of shallow bedrock of sandstone and limestone, with some areas of sand dunes along some portions of the alignment. The bedrock is considered massive and it would take a full depth cut to create the trench for the pipeline in areas where the rock is exposed at the surface. Determining the extent of the rock excavation is a large component of the costs associated with the project. Core samples and testing of the sandstone and limestone samples along the alignment between Halchita and Halgaitoh Road show unconfined compressive strengths of 12,000(83Mpa) to 17,000 psi(117 Mpa) for the sandstone and 15,000 psi (103Mpa)for the limestone. Further examination of the rock will need to be made to determine the wear of the chain trencher teeth and if the equipment is suitable to cut the harder rock type over the long distances needed of up to 9 miles along the alignment consistently the full depth of the trench and up to 3 miles more intermittently in depth. The rock excavation unit costs in Means indicate that the chain cutter teeth would be changed out every 100 feet with 280 feet of trench excavated in the rock each day. This production rate is consistent with the summary published by Pipeline International in Figure 6-10 which summaries production rates for various rock types. Figure 6-9 and 6-10 are from an article published by PipelinesInternation.com. Wearing of the teeth may be more severe for this rock type than is reflected in the Means cost guide. In a conversation with Danny Morris, of Custom Trench Inc. who have a fleet of chain trenchers working around the western states, indicated that the compressive strengths determined so far could result in a slower rate when compared to those published in Means, however, all rock is different and more information is needed before making that determination. One property that Danny recommended that would help determine the tooth wear and production rate would be the silica factor of the rock, which needs to be determined by further testing under the Feasibility Design. In comparison Danny explained that they were trenching rock with approximately 18,000 psi compressive strength in Colorado that had high silica content and they were able to only reach approximately 20 feet per day and went through 200 to 300 teeth per day in a slightly larger width and depth trench. In talking with Bill Gaines of Monument Resources in Bluff, Utah, a local material supplier, rock trenching has been previously performed in the Mexican Hat area associated with their gravel pit operation. The trenching did not go well with teeth being ripped off the trencher and they were not able to advance the trench at a productive rate. Bill mentioned that blasting the rock types in the area has produced blocky fragments and is somewhat slow drilling of the holes. Bill said that ripping the rock in the area produces large blocks of up to 20 feet in width that they have needed to break down to be able to process in their crushing operation. Bill said the limestone in the area is just very hard and will be a challenge to construct the pipeline with blasting or with a rock trencher. Bill mentioned that there may be newer trenching teeth designs currently available that may be improved for trenching the rock material in the area in comparison to the older teeth designs. Further investigation would need to be made with manufacturers to determine if the rate of production in Means is an achievable rate with the corresponding rock strength and abrasiveness. It is recommended during feasibility design to actually bring a trenching machine out to the proposed alignment in several areas along the alignment to determine if a reasonable rate can be produced to verify the assumptions used in the cost estimates and are valid. If rock trench machines cannot be used to excavate the pipeline trench the unit price to drill and blast per linear of pipeline would affect the overall cost of the project in the 8 to 10 dollar range per linear foot above the Mean rate for rock trenching.

The reddish colored sandstone in the area adjacent to Halchita shows more joints that could be chipped and broken with a blow from a geology type hammer, but the limestone appears to be a more massive harder cap rock and could not be chipped or broken with repeated blows of a geology type hammer. Abrasion to the equipment from both rock type materials needs to be examined further. Both of these rock types are seen following the proposed alignment and along Highway 163 and appear to cover the region from Mexican Hat to the area north of Monument Valley, therefore any alignment selected would deal with similar rock qualities during trenching. As figure 6-10 indicates the spoil material is good to fair for reuse as bedding for the pipe, however, further investigation is needed to verify this assumption. The spoils would need to be processed by the mobile crushing/screen plant or equipment mounted buckets that specialize in processing spoil material to produce the 1-1/2 inch minus material. If it is found that a trenching machine will not be able to excavate the rock in a productive manner, this would also affect the production of bedding material from the trench and additional bedding would need to be imported or processed from the blasted rock for the rock trench section of the alignment.

Trenching Method	Application	Excavation Effects	Security Issues
BLASTING	Can be used in very strong, abrasive, massive rock, but not suitable for rock masses composed of small, loose blocks; relatively easy to set up and execute; backhoes and dump trucks required to remove blasted material; particularly useful on steep slopes.	Significant over-excavation with very irregular, possibly unstable trench walls and floor; sidecast spoil causes ecological damage and increases risk of sediment release to watercourses; alternatively, spoil transported to temporary or permanent disposal sites.	Potential restrictions on use of explosives; cannot be used in built-up areas or in proximity to utilities, structures and other pipelines.
HYDRAULIC ROCK BREAKERS AND BACKHOES (+/-RIPPING)	Can be used in rock masses composed of small, loose blocks, but generally not economic in very strong, abrasive, massive rock; easy to set up but can be very time consuming; useful for tight curves, and where the ground changes from soil to rock over short distances.	Moderate over-excavation with irregular trench walls and floor; sidecast spoil may cause ecological damage locally; some spoil may have to be transported to temporary or permanent disposal sites.	Suitable for use in built up areas or in proximity to utilities, structures and other pipelines.
CHAIN TRENCHERS	Efficient in weak to strong rocks; generally not economic in very strong, abrasive, massive rock; unsuitable for rock masses containing loose cobbles and boulders or those containing pockets of wet clay; larger machines require considerable lateral working space and operate most efficiently over long distances in relatively homogeneous rock.	Minimal over-excavation with regular trench walls and floor; provided that there is sufficient operating space, spoil is deposited in a continuous windrow alongside the trench; where space is limited, spoil must be discharged to dump trucks and transported to temporary sites for processing; no sidecast spoil.	Smaller machines suitable for use in built-up areas or in proximity to utilities, structures and other pipelines.

Table 1. Some important factors to be considered in selecting an appropriate trench excavation method in rock.

Figure 6-10. Rock Excavation Comparison – Source PipelinesInternational.com.

Examples of Rock Types	Typical Rock Material Properties		Trenchability			Production of Intimate Backfill	
	Rock Strength (UCS in MPa)	Mohs' Hardness	Appropriate Trenching Method	Expected Advance Rate (m/day)	Chain Trencher Tooth Wear	Potential Re-use of Spoil	Required Processing of Spoil for Re-use
Mudstone	10	2.5	Bucket wheel or chain trencher	800	Minimal	Good	Self-propelled screener; intimate and general backfill must comply with specified moisture content
Chalky Limestone	25	3.0	Chain trencher	500	Minimal	Good	
Dolomite, sandy limestone	75	3.5-4.0	Chain trencher	250	Moderate	Good to fair	Self-propelled crusher/ screener
Calcareous/ silty sandstone, clayey siltstone	100	4.5-5.5	Chain trencher	150	Moderate-severe	Fair	
Basalt, gneiss, quartz-schist	120	6.0	Chain trencher (may need hydraulic breaker for high spots)	80	Severe	Fair to minimal	Self-propelled crusher/ screener; offline crushing/screening will increase re-use of spoil; imported material may be required
Granite, andesite, orthoquartzite	160	6.5	Chain trencher econ. marginal; hydraulic breaker + backhoe; blasting	20	Extreme		
Chert, rhyolite, metaquartzite	200	7.0	Hydraulic breaker + backhoe; blasting	10	-	Minimal to zero	Offline heavy crushing/ screening will increase re-use of spoil; imported material probably required

Table 2. Summary of trench excavation and backfilling methods appropriate to various rock types.

Figure 6-11. Summary of trench excavation and backfilling method appropriate for various rock types – Source PipelinesInternational.com.

Figure 6-12 – Typical Trenching Machine – Source PipelinesInternational.com

When the Halgaitoh Wash Road is reached more cover is seen for the pipeline which consists mainly of wind-blown sand dunes with vegetation stabilizing the dunes. Bedrock is likely shallow below the dunes, so many areas may be a combination of sand over bedrock which is difficult to quantify at this level of review. In some areas it may make sense to mound the backfill material over the pipe so deeper rock excavation is not required. For trench locations in soil, the sand will not provide stable slopes for the excavation and the excavated slopes may need to be laid back at a 1.5:1 slope for the work since it will most likely be classified OHSA Type C trench material.

6.9 Pipe Air-Vac / Blowoff/Isolation Valves

Blowoff valves would be located at various low points along the alignment to allow for drainage of the pipe, while air-vac valves would be located at all of the highpoints and at regular intervals along the pipeline. Both valves should be designed for buried service. More in depth hydraulic analysis is required to determine the number and locations of these structures. The pipeline alignment does cross several drainages so locating areas where the pipe can be drained to for maintenance should be relatively easy. Due to the length of the pipeline isolation valves will be needed to isolate sections of the pipeline for maintenance purposes.

6.10 Booster Pump/Relift Stations

From the San Juan River to the proposed water delivery locations there is a nearly 1,600 foot increase in elevation. In addition to this static lift there are significant friction losses (over 500 feet at design flow) in the nearly 40 mile length of pipe which need to be overcome. It is not feasible to design the system so that all of the pumping for the system is performed at the San Juan River. Some booster, or, relift pumping stations are required along the pipeline.

It will be more economical to combine the pumping and chlorination booster in one building along the pipeline. The buildings would be approximately 30 feet wide and 80 feet long with associated fenced in utility yards of 100 by 200 feet. The fenced area would also enclose the forebay tank and hydro pneumatic tanks.

The pumps for the pumping plant have been preliminary sized for 300 horsepower vertical turbine motors and pumps located within vertical cans buried in the ground.

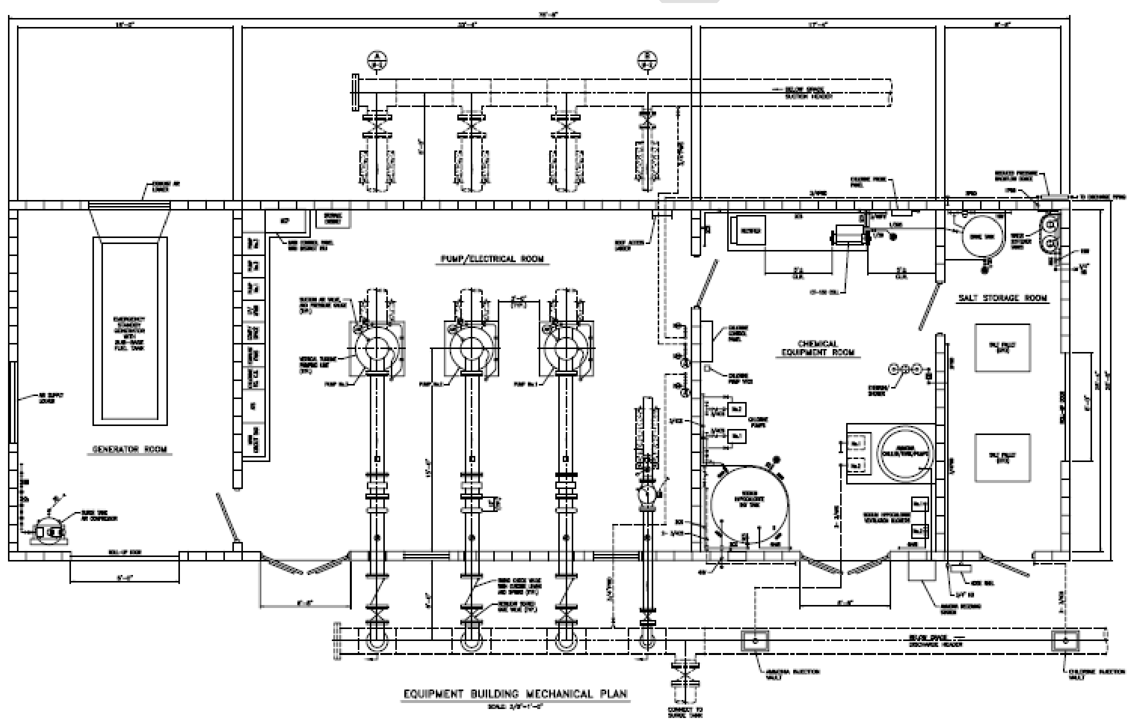


Figure 6-13 - Typical Pumping/Chlorine Booster Building Layout.

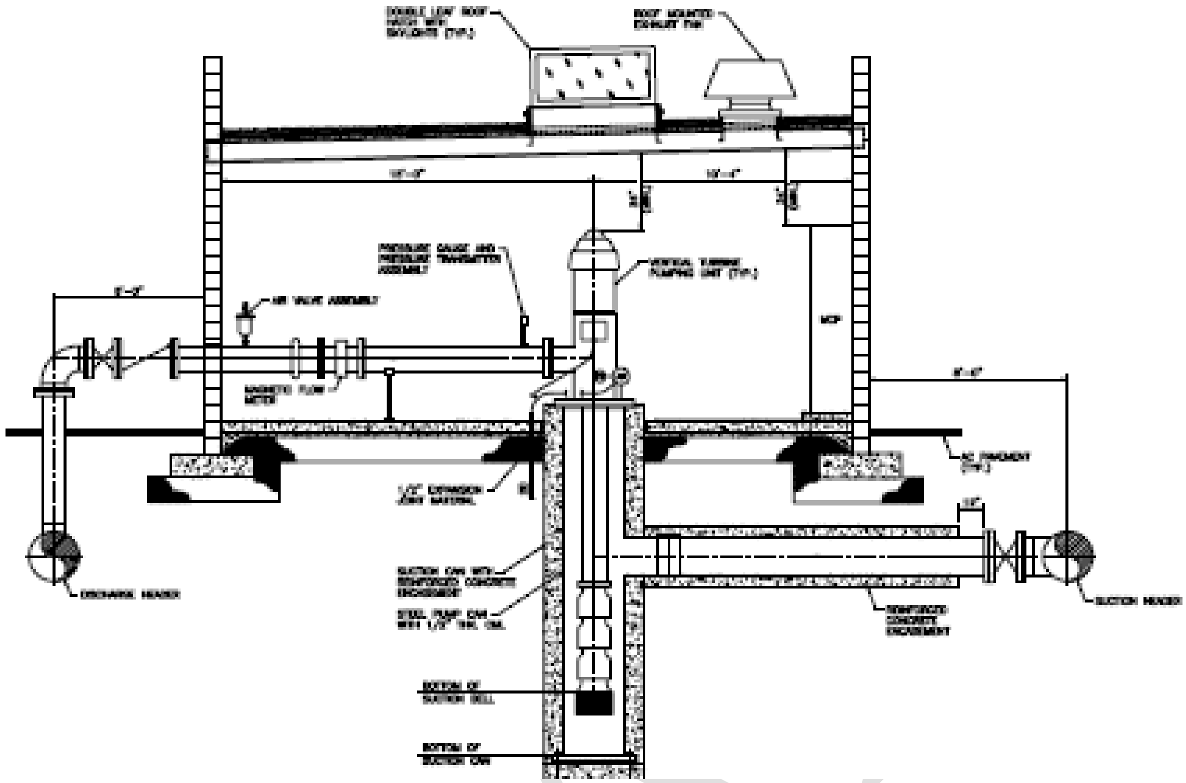


Figure 6-14 - Typical Pumping Plant Cross Section.

General Description

It is important to recognize the relationship between the number of booster pump/relift stations and the required pipe pressure class. Theoretically, as the number of booster pump stations increases the required total dynamic head (TDH) at each station and associated pipe pressures decrease. Similarly, with less booster pump stations, more head is required at each one to obtain the required lift, and subsequently, a higher pipe pressure class is required. Normally it is best to keep the TDH below 250 psi to use readily available valves and fittings. Naturally, this leaves room for cost optimization for a given system. As part of this study only general hydraulic calculations were performed and, therefore, further analysis and cost comparisons should be done in the next stage of design.

For the purposes of this appraisal level design it was determined that four booster pumping stations along the water pipeline are sufficient to lift the water nearly 1,600 feet to the water treatment facilities at Monument Valley and an additional plant is required the remaining distance to Kayenta and offset friction losses. Each booster station would have a TDH of between 440 and 490 feet. This is in addition to the pumping plant located at the San Juan River with a TDH of approximately 480 feet. With four booster stations, 16-inch pipe pressure classes PR 305, PR 235, PR 200, PR 160 and PR 125 polyvinyl chloride pipe (PVC) would be required.

Each booster pumping station would consist of a forebay tank, pumping plant, hyrdropneumatic tanks, and an electrical system and would occupy approximately one acre of land (Reclamation, 2007, p. F-11). Each forebay tank is assumed to be a concrete structure 10-foot in diameter and 20-feet high with a nearly 12,000 gallon capacity. The average size air chamber is assumed to be a multiple hydropneumatic tanks totaling 30,000 gallons. Each booster plant would have a minimum of three pumps to allow the pumps to be cycled to minimize overuse of the pumps and to allow maintenace. During final design an analysis could be made to determine if a jockey pump would be beneficial during periods of lower flow to maintain the pressure range in the hydropneumatic tanks. Hydropneumatic tanks could be added in phases as the flow demand increases and then manifolded together for final build out of the system.

Table 6-1. Hydraulic Analysis

Descriptions	Ground Elevations	Water Elevation In	Water Elevation Out	Station	Static Head	TDH
San Juan River	4,040					
River Treatment Plant	4,099	4,100	4,524	0+00	425	476
Pumping Plant 1	4,461	4,471	4,871	217+71	400	437
Pumping Plant 2	4,826	4,836	5,236	379+04	400	467
Pumping Plant 3	5,155	5,169	5,569	668+68	400	449
Pumping Plant 4	5,488	5,513	5,741	880+22	220	492
Pumping Plant 5	5,488	5,500	5,720	1,875+58	300	383

Location(s)

Essentially, all of the elevation gain along the pipeline alignment occurs in the first 18 miles up to Monument Pass (Figure 6-5). As a result, the initial one at the river and four booster pump stations would be located in this initial portion of the alignment. From the San Juan River they would be spaced approximately at five mile intervals and provide up to approximately 490 feet of total head (The initial pumping plant at the San Juan River would provide approximately 480 feet of total head). After the pass, the terrain drops down into the Monument Valley area to a low point of about 5,200 feet. When the pipeline is extended to Arizona, the elevation would gradually increase to the water treatment facility location at elevation 5,600 and another booster plant would be needed which is shown as Pumping Plant 5 in Table 6-1.

Power Supply

At the present time, there is no available 3-phase power supply between Halchita and Monument Pass, which is where the four booster stations would be located. This means that power transmission lines would need to be extended from Halchita south a distance of about 15 miles along the proposed alignment to the fourth booster station. Currently, Halchita receives its power from the Mexican Hat substation which is supplied by Rocky Mountain Power and it is assumed that power would be available for the initial pumping plant at the river. The power is metered on the south side of the San Juan River, where it becomes part of the NTUA system. It is also assumed that adequate power from the existing 3-phase power line for the fifth pumping plant to be located between Monument Valley and Kayenta.

According to NTUA, plans are in the works to extend various transmission lines in this area. Phases I (overhead) and II (underground) would extend from the Halchita line. Phases IV (overhead) and V (underground) would extend from the Kayenta line in the south. Presently, these transmission line extensions are planned to provide single-phase power. With proper planning and sufficient lead time, it may be possible to incorporate the required 3-phase transmission line extensions for the booster stations into the planned upgrades of NTUA's power lines. This would likely result in cost savings for the proposed project. The details of this possible option would need to be worked out during the next stage of design with involvement from the appropriate tribal entities. Running powerlines along the preferred alignment in Utah would also help bring power to families that are not currently being served between Halchita and Monument Valley.

For the purposes of this study, costs would be estimated assuming new 3-phase transmission lines would need to be extended to the southernmost booster station from Halchita.

Another option that really needs to be looked at during feasibility design is the use of wind and solar power tied to the grid to help offset the power use of this system. Solar panels and wind turbines could be incorporated at each pumping plant location to provide power for each plant along with power provided from the grid.

6.11 Pigging Stations

Pigging is a maintenance tool used to help protect the considerable investment in a pipeline. Essentially, a pig is a device that is inserted into the pipeline and while traveling through it performs a specific task. It is anticipated that the primary function of pigging in the San Juan Pipeline would be for cleaning, particularly sediment and biological buildup. Inline inspection of the pipeline for potential problems such as corrosion or leaks is another important function that can be performed by pigging (PPSA, 2008). Pigging stations (for insertion and removal of the pigs) should be provided in the pipeline to assist in maintenance. The number and locations of these stations would be determined in the next stage of design.

Depending on the selection of the treatment options, if the river water is treated at the river to nanofiltration levels to remove bacteria and organics from the water and chlorinated along the pipeline alignment, buildup of bacterial material inside the pipe would be reduced but it is assumed that cleaning of the line would be required by a pigging operation on a regular basis to keep the biofilm from affecting the pumping of the water.

7.0 Water Treatment

7.1 Location

In evaluation the water treatment for the system, three main alternatives were considered. The first was to construct three separate treatment plants for each area, one in Halchita, a second one at Monument Pass to supply the Oljato areas, and a third one close to Kayenta for the Kayenta population. From each location, treated water would be pumped to the various communities through a system of existing and new pipelines of various sizes.

The second alternative was to construct one treatment plant at the high point near Kayenta to treat the raw water from the river then reroute the treated water through smaller water lines back from this main facility to service the Oljato, Cane Valley, and Halchita areas. This option was considered since the water treatment plant operators are stationed in Kayenta.

The third option would be to build a main water treatment plant next to the river at Mexican Hat where the level of treatment would be performed through the Nanofiltration and chlorination process. The treated water then would be transported to the end user where it would be filtered for biological build up in the pipe and chlorinated prior to being stored in tanks. The first two options would require that additional water be pumped from the river to allow for loss of water from Micro and Nano filtration processes that could account for a loss of up to 30 percent of water from the treatment process in the form of filtered concentrate depending on water quality in the river.

Since operation costs for pumping the water from the river is a large annual costs, it does not make economic sense to pump the water 40 miles knowing that a percentage of the water will be stripped away as concentrate in the treatment process that will need to be disposed. Under Options 1 and 2, pumping the additional 30 percent and treating at Monument Valley and Kayenta would add approximately $600,000 more annually based on the 2060 water demand to the O&M cost for operating the system.

Placing the treatment plants in Monument Valley and Kayenta would make more sense from the aspect of being a closer proximity to Kayenta where the treatment operators are stationed, however the additional pumping cost may make it necessary that one treatment plant be built at Mexican Hat. There would be some benefits in building one plant in Mexican Hat, water could be delivered at multiple locations after being treated with Nanofiltration and chlorination and would just need to be filtered with secondary strainer and bag filters and treated with chlorine at the end users, provided the Navajo Nation water quality regulators approve of this methodology. In an abstact written in the Journal of Water Supply, Research and Techology-Aqua, titled Nanofiltration and Reverse Osmosis Biostability relative to alternative methods of water treatment.dated Feb2007, Vol. 56 Issue 1, p25-40. 16p. by, Liu Suibing, Michael LePuil, J.S. Taylor and A. A. Randall, they summarize the testing they performed on various biofilm that were produced on pipes downstream of the membrane treatment processes. There studies showed that there would be biofilm created on the surface of the pipes downstream of the treatment plant using the nanofiltration process, but only pilot testing would show to what extent that it would be formed based on the makeup of the treated water. Biofilm consists of living, nonviable, dead microorganisms, EPS, organic and inorganic matter. Although most of the matter and microorganisms should be removed by the Nanofiltration treatment process, however, there may be enough quantity in the water to develop in 20 to 40 miles of pipe to require secondary filtration prior to final chlorination. From a paper by, *M.W. LeChevallier,* "the pipe surface itself can influence the composition and activity of biofilm populations. Studies have shown that biofilms developed more quickly on iron pipe surfaces than on plastic polyvinyl chloride (PVC) pipes, despite the fact that adequate corrosion control was applied, the water was biologically treated to reduce AOC levels and chlorine residuals were consistently maintained (Haas et al. 1983; Camper 1996). This stimulation of microbial communities on iron pipes has been observed by other investigators (Camper 1996). In general, the larger surface to volume ratio in smaller diameter pipes (compared with larger pipes) results in a greater impact of biofilm bacteria on bulk water quality. The greater surface area of small pipes also increases reaction rates that deplete chlorine residuals. In addition to influencing the development of biofilms, the pipe surface has also been shown to affect the composition of the microbial communities present within the biofilm. Iron pipes supported a more diverse microbial population than did PVC pipes (Norton and LeChevallier 2000). The purpose of these studies is not to indicate that certain pipe materials are preferred over others, but to demonstrate the importance of considering the type of materials that come into contact with potable water. Various water contact materials may leach materials that support bacterial growth. For example, pipe gaskets and elastic sealants (containing polyamide and silicone) can be a source of nutrients for bacterial proliferation. Colbourne et al. (1984) reported that Legionella were associated with certain rubber gaskets. Organisms associated with joint-packing materials include populations of Pseudomonas aeruginosa, Chromobacter spp., Enterobacter aerogenes and Klebsiella pneumoniae (Schoenen 1986; Geldreich and LeChevallier 1999). Pump lubricants should be non-nutritive to avoid bacterial growth in treated water (White and LeChevallier 1993). Coating compounds for storage reservoirs and standpipes can contribute organic polymers and solvents that may support regrowth of heterotrophic bacteria (Schoenen 1986; Thofern et al. 1987). Liner materials may contain bitumen, chlorinated rubber, epoxy resin or tar-epoxy resin combinations that can support bacterial regrowth (Schoenen 1986). PVC pipes and coating materials may leach stabilizers that can result in bacterial growth." Due to the long length of the pipeline minimizing these potential growth materials should be considered in the final design.

Treating at the river would give more flexibility in delivering water to remote areas that are from Douglas Mesa out east to Cane Valley that currently are not included in existing water system plans for NTUA and IHS. Another benefit of building one plant at the river is that some of the concentrate could potential be discharged back into the river after obtaining proper permits to meet the total dissolved solids requirements, otherwise it would have to disposed of in evaporation ponds at the water treatment plant or by waste system and belt press. There are approximately 9 acres of undeveloped land to the south and east of the existing water treat plant that could be used to build a water treatment plant and associated facilities. If needed more area is available adjacent to Halchita for finished treated water storage tanks. For the area next to the river, it may be more conducive to use the waste treatment and belt press due to land limitations. Building the plant next to Halchita would allow ample room for evaporation ponds as an alternative to waste treatment and belt press.

Some things that could be used to keep the biofilm in check through the length of the pipeline are as follows:

Operational Factors Inhibiting the Growth of Biofilm

1. Reduce nutrient levels

    Biodegradable fraction of TOC
    Reduce residual free ammonia for chloraminated systems

2. Optimizing disinfectant dose

    Maintain disinfectant residual
    Booster chlorination station

Table 7-1. Methods to Control or Mitigate Biofilms in Main and Distribution Systems.

Control or Mitigation Measure	Author(s)
Main flushing, pigging and cleaning	Costello (1984), Berger et al (1993), USEPA (1992b), Trussell (1999), Van der Kooij et al (1999)
Disinfectant residual	Trussell (1999), Geldreich and LeChevallier (1999)
Main repair and replacement	Costello (1984), USEPA (1992b), Kirmeyer et al., (2001)
Minimization of dead ends/flow management	Costello (1984), Geldreich and LeChevallier (1999)
Corrosion control program	Berger et al (1993), Volk et al (2000), Trussell (1999), Geldreich and LeChevallier (1999)
Proper Storage Tank/Reservoir O&M	USEPA (1992b), Geldreich and LeChevallier (1999)
Control and mitigation of system hydraulic problems	USEPA (1992b), Van der Kooij et al (1999)
Nutrient suppression	Volk et al (2000), Trussell (1999), Van der Kooij et al (1999), Geldreich and LeChevallier (1999)
Cross-connection control	Kirmeyer et al (2001), Van der Kooij et al (1999)

Considering these operation factors, chlorination or other mixed oxidants would be required at the water treatment plant and along the pipeline to inhibit the growth of biofilm in the pipeline. It also recommends periodic flushing and pigging. Due to the long pipeline length and the amount of pumping lift that is required for the system control of the biofilm in the pipeline system would be a major cost savings realizing the additional costs a buildup of material inside the pipe would cause.

Multiple water treatment facilities using secondary filtering and final chlorination prior to going into the storage tanks provides a way of phasing the implementation of the system, with the Oljato and Halchita facilities built first and the Kayenta facilities built as the need surpasses the current groundwater supply. Secondary treatment would consist of stainless steel strainers, bag filters with low head loss, chlorination monitoring and injection. Design of the equipment to be used would be performed during feasibility design. By treating the water at the river the footprint for the water treatment facilities at the various locations would be smaller in comparison to building a full water treatment plant at each location. The same could be said however for phasing the treatment trains for one plant built at the river.

Water quality is another potential difference between the options. With the concept of three treatment plants located at each area, it would require shorter delivery times to the storage tanks and, as a result, a higher likelihood that the required free chlorine residual could be maintained. Having only one plant more centrally located (Kayenta option), it would need to be determined that the required free chlorine residual could be maintained the entire length of the distribution system. With either alternative, it would need to be determined that the required chlorine contact time could be achieved at the nearest point of delivery. Having one plant at the river and treating to the Nanofiltration level with chlorination at the plant, booster chlorination along the pipeline and chlorinating at the end use point would provide the most flexibility in locating chlorination points in the system to keep the level of chlorination at the right level to the end user.

From a practical standpoint, it makes more sense to locate the treatment plant at the river due to the cost of pumping and the flexibility it would provide for future delivery to existing and potential new development. Operators would need to travel to Mexican Hat and to the various chlorination sites to check on the system which would be part of the O&M cost. One option that could be explored is to have the water treatment plant operator for Mexican Hat also operate the new water treatment system since they are familiar with membrane technology or have them train the new operators for future operation. The current operator at Mexican Hat comes from Blanding, so they are driving there anyway.

Further investigations on this issue may be warranted prior to final design.

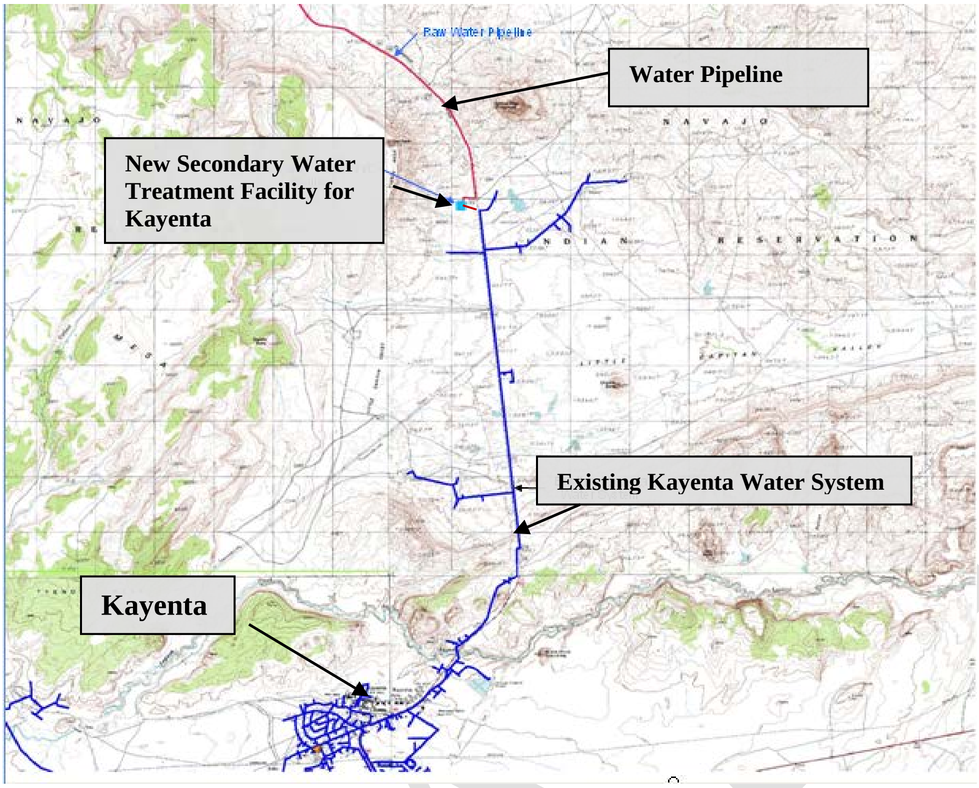


Figure 7-1. New Kayenta Secondary Water Treatment Facility location.

Assuming constructing the treatment plant at Mexican Hat is the best option for providing treated water from an economic standpoint, it becames necessary to determine a more specific location for each secondary treatment facility. For Halchita no secondary water treatment facility would be required due to the close proximity to the water treatment plant by the river. The other two facility locations would be located next to the tank locations that would be built for the project. For the Oljato areas, it was determined that an area adjacent to the existing water tanks near the intersection of the highway may be a suitable location. The high point for the Kayenta plant is at approximate elevation 5,665 ft located near Agathla Peak (El Capitan), about six miles north of Kayenta (Figure 7-1). The Kayenta water treatment facility would be located next to an electrical distribution yard so power availability should not be a problem.

Land Ownership

Similar to the water pipeline corridor, it is assumed that the footprint of the proposed water treatment plants lies entirely on Navajo Nation Trust Land. Typically the right of way process requires the approval of the Department of Fish and Wildlife, the Department of Historic Preservation, the Mineral Departments, and the Division of Natural Resources, the Navajo Nation Environmental Protection Agency, the Navajo Department of Justice, and the Office of the President and the Vice President. After that if the right of way is secured by Reclamation and not NTUA, it would require the approval of the Navajo Nation Resources and Infrastructure Committee. After that it would require the approval of the Bureau of Indian Affairs. Once again, sufficient time needs to be provided to complete the process.

7.2 Design Overview

Assuming the water treatment plant option located at Mexican Hat is the most economical option, the proposed water treatment plant would be designed to meet the projected water demand for each study area. The projected water demand based on a 1.5 peaking factor for 2040 is 2.33 MGD (1,618 gpm or 3.6 cfs). The projected water demand for 2060 with a 1.5 peaking factor is 2.7 MGD(1840 gpm or 4.1 cfs)

While the majority of sediment removal would occur at the intake structure on the San Juan River by the used of media sand filters that would separate the water particles down to 5 microns or by other means of solid contact clarifiers, it is anticipated that some sediment would be transported to the treatment plant. Any source water with a turbidity of over 200 NTU would need to be re-treated (Reclamation, 2007, p. F-14). Use of settling ponds could also be studied further. If, on the other hand, it can be ensured that turbidity would never exceed 200 NTU, a settling pond would not be needed. This issue needs to be further investigated prior to final design by pilot testing.

Due to the high amount of salts, organics and metals in the river water Nanofiltration would be used to treat the water.

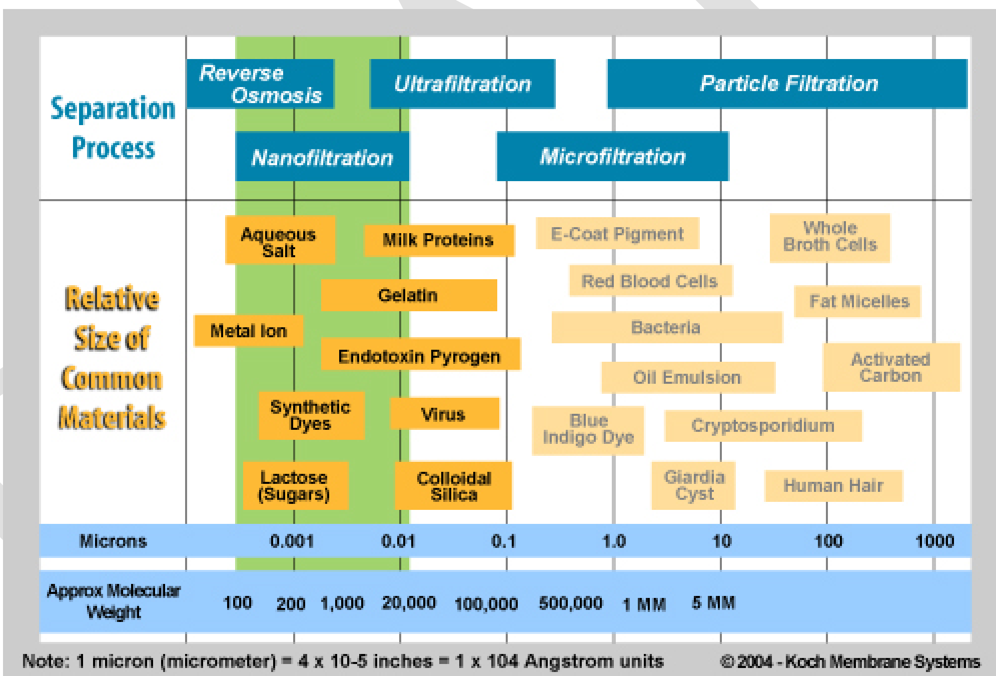


Figure 7-2. Water Treatment Separation Processes. Source Koch Membrane

Nanofiltration is a low- to moderately high-pressure (typically 50 to 450 pounds per square inch [psi]) process in which monovalent ions will pass freely through the membrane but highly charged, multi-valent salts and low molecular weight organic molecules will be rejected to a much greater degree.

NF and RO: Similarities, differences
Comparisons of NF with RO can be generally highlighted as followed:

- Both are RO technology. The NF membrane is just a little “looser” — that is, RO will remove smaller-diameter particles than NF.
- The key difference is the degree of removal of monovalent ions such as chlorides. RO removes monovalent ions at the 98 to 99 percent level at 200 psi. NF removal of monovalent ions varies between 10 and 90 percent, depending on the material and manufacture of the membrane.
- In general, RO has less flow (produces less volume) than NF.
- NF and RO are generally in the spiral-wound configuration.
- RO membranes are characterized by high rejection of TDS (total dissolved solids) in the range of 98 to 99.5 percent.
- NF membranes are characterized by higher water permeability than the RO membranes and lower TDS rejection.
- NF membranes have sufficiently high rejection of selected constituents, i.e., hardness, metals (iron) and organic matter.
- Membrane fouling and scaling: Organic matter fouling of NF and RO membranes is a concern and appropriate pretreatment must be provided along with maintaining sufficient membrane cross flow velocities. Membrane scaling is also a concern. Attention to scaling conditions and use of a chemical scale inhibitor is required to ensure membranes do not scale. Since the RO membranes remove more salts than NF membranes, there is a higher potential for membrane scaling with RO membranes.
- RO permeate has very low hardness and alkalinity, and therefore, it is highly corrosive. The permeate needs to be conditioned (e.g. lime contactor, addition of post treatment stabilizing chemicals) to provide a stable and non-corrosive product water.
- NF and RO membranes can be damaged by disinfectants like chlorine, unlike those for microfiltration and ultrafiltration.
- This is why chlorine and chloramines must be removed in the system prior to the NF and RO membranes.

The system described in the following paragraphs is considered the state-of-the-art in water treatment design. The design is general in nature and once more accurate information is known a more detailed water treatment plant can be designed. Figure 7-3 (Reclamation, 2008) shows a basic schematic diagram of the treatment process.

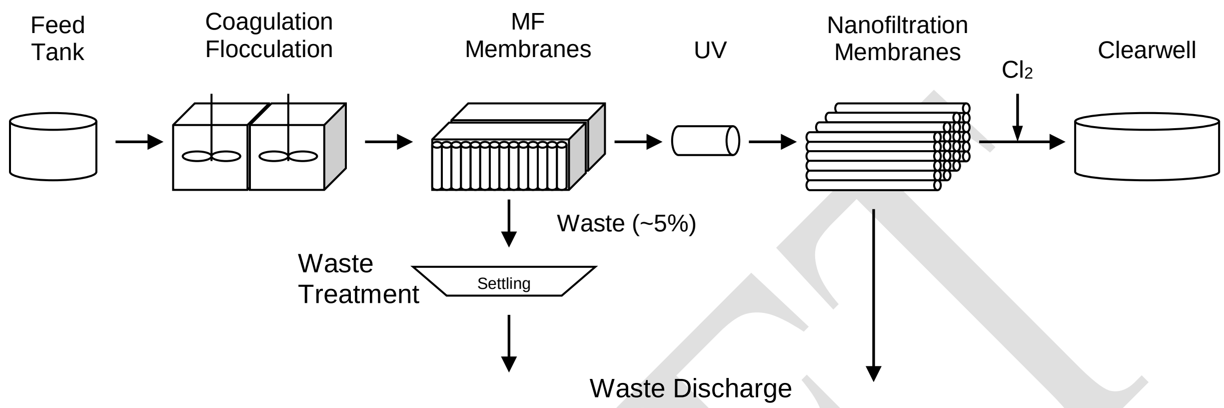


Figure 7-3. Basic schematic diagram of the treatment process.

Pre-sedimentation

A sand separator would be used to separate the sand size particles in the river water as the first process. Sand filters or plate settlers could be used to perform additional sedimentation of the river water. Due to high sediment loads that vary in the river either of these processes are needed to buffer the water quality prior to treatment due to the variation in the sediment load. The use of the plate settlers would provide a simple operation and would allow discharge of waste back to the river.

Another method to settle out the varying amounts of sediment in the river would be by using a solid contact clarifier mechanism. This process has a very good ability to handle fluctuation in the sediment loads in the river throughout the year and will handle the sludge very effectively during period when the filtration systems are off line for backwashing. This process would require more area to locate the tanks, but may be a better option from the standpoint of simple operation. The solid contact clarifier could potential take the place of the equalization tank and coagulation system shown in the process schematic since it provides both coagulation and flocculation and settling of the particles. Two tanks containing the mechanisms would be needed to allow maintenance of the system.

Equalization Tank

Influent from the intake sand separator would initially enter an equalization tank. A solid contact clarifier could also serve as the equalization tank in the system. In order to ensure a constant supply to the WTP the tank is sized to provide for a 30 minute detention time. Also, the equalization tank would be located at the high point in the system to obtain gravity flow through the treatment process. The tank would be operated between a high and a low set point with a constant pressure control valve providing constant gravity flow to the downstream coagulation process. If the water treatment plant was built at Mexican Hat the water tank could be built on the higher bench south of the water treat area to utilize the elevation difference.

Coagulation

Some particles cannot be removed by simple filtration and are too small to settle out in a reasonable time period. Coagulation is a chemical treatment process that causes the particles to adhere to each other and subsequently be removed by sedimentation and filtration (Masters, 1998, p. 275). The type of coagulant and dosages would not be specified at this time but would need to be determined by jar testing or some other method at a future time. The coagulant would be injected into an in-line rapid mixer. From the rapid-mixer the influent would enter two-stage vertical shaft coagulation/flocculation tanks where flocculate is formed. Each tank would be sized to provide for a 30 minute detention time.

Microfiltration

Microfiltration is the next step in the treatment process. The microfilter (MF) membrane can easily remove the flocculate created during the coagulation process. This treatment technology typically achieves 4-log removal of *Cryptosporidium* and *Giardia*, 1.5-log removal of viruses, 6-log removal of bacteria, and turbidity less than 0.02 NTU (Siemens, 2006, p. 6). The MF membranes need to be periodically backwashed. The backwash waste needs to be treated in settling ponds with the sludge periodically removed or it can be processed with tube settlers and belt press to process the waste. If possible, it is preferable to discharge the backwash waste as opposed to treating it in the settling pond. From the MF membranes the filtrate enters break tank with 10 minutes of detention time.

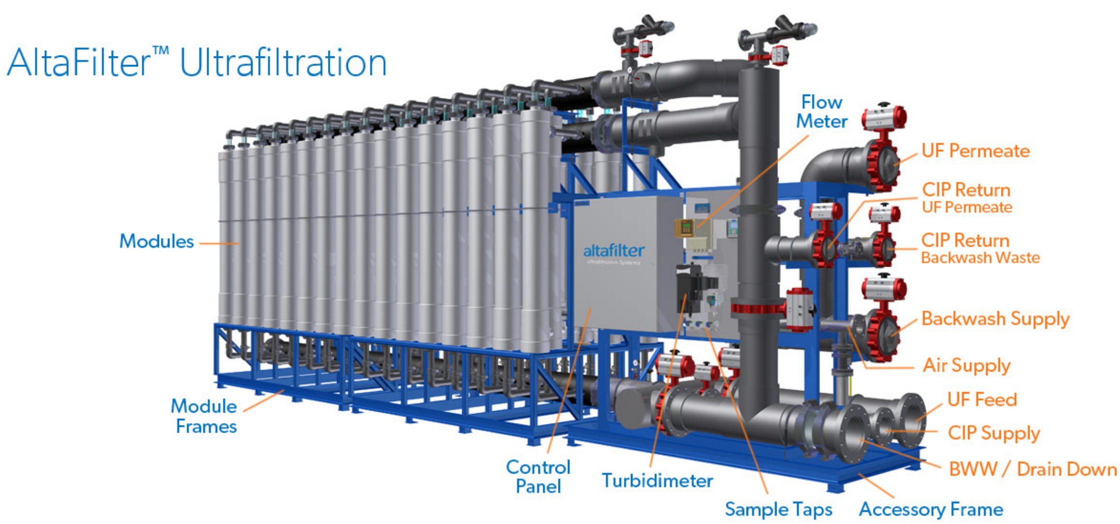


Figure 7-4. Micro/Ultra Filtration Skid(Westech).

UV Disinfection

Ultraviolet (UV) disinfection units are located on the filtered water discharge line following each microfiltration treatment train. UV radiation is increasingly being used as an environmentally friendly addition to chemical disinfectants. Benefits include simple operation and reliable disinfection, no by-products, and no taste or smell (Siemens, 2007, p. 2). It allows for lower chlorine concentrations and subsequently reduces the potential for DBP formation. Microfiltration will meet treatment requirements for Cryptosporidium and Giardia, with the UV providing minimal inactivation of these and other virus when the Microfiltration is working properly. The UV will be provided as a redundancy for deactivation if there was a loss in membrane integrity.

Nanofiltration

From the UV units, three high-pressure pumps (one redundant) supply the nanofiltration membranes. Nanofiltration is similar to reverse osmosis treatment, although it has several benefits, namely, lower operating and energy costs and lower waste discharge (RO Consumables, 2001). Unlike MF membranes, the nanofiltration membranes are not backwashed and produce a waste stream that would normally not be recycled. Whether or not the waste can be discharged directly or recycled needs to be determined in the next stage of design.

Figure 7-5. Nanofiltration Skid(Siemens Water Technologies).

Chlorination

Chemical disinfection with chlorine would follow the nanofiltration process. It is the second step in the disinfection process, with UV being the first. Chlorine provides the disinfectant residual in the distribution system. Because of the relatively long distribution times, the formation of disinfection by-products (DBPs) is a possibility with the used of chlorine. However, because of the level of filtration prior to chlorine disinfection it is anticipated that most of the organic matter would be removed which minimized the risk of DBP formation. One option is to use chloramines for disinfection, which has the advantage of a stable residual and reduced potential of DBP formation. The disadvantage is a less effective disinfectant than chlorine (Reclamation, 2008, p. 20). A more in-depth comparison between the two disinfectants should be performed in the next stage of design.

Clearwell

Typically, after chlorination the treated water would enter a clearwell. In this particular system, however, the proposed storage tank would be located adjacent to the treatment plant. The exception to this would be if the storage tank is located at a higher elevation than the end of the treatment train. If this is the case a clearwell (30-minute detention time) with associated pumping would be needed. The water from the clearwell would be pumped into the pipeline system using vertical turbine pumps drawing water from the clearwell. A minimum of three pumps would be provided to cycle for the delivery the treated water. The booster station building could be built over the concrete clearwell to house the pumps and motors.

Backwash Wastewater Treatment

Backwash wastewater from media filtration is treated with a packaged tube settler unit (**Figure 7.5**). Effluent from the tube settler is recycled back to the front of the water treatment plant. Sludge from the tube settler unit is pumped to the sludge belt press.

Figure 7-6. Packaged Clarifier(Siemens Water Technologies).

Sludge Dewatering System

Sludge from the tube settler is pumped to a sludge dewatering belt press (**Figure 7.6**). The dewatering process occurs between two belts where increasing pressure is applied. Pressure is gradually increased by passing the belt over rollers that successfully decrease in diameter.

Figure 7-7. Sludge Dewatering Belt Press(Siemens Water Technologies).

7.3 Mass Diagram

A preliminary mass diagram has been prepared to show flow rates from the river, recycled flows, delivered flows and waste volume generated.

Waste from the process could be handled in several ways. One way would be discharging into settling ponds, which would require a large amount of area for construction. Another way would be to use a filter press. This method is shown in the mass diagram with the waste stream being recycled back into the process stream.

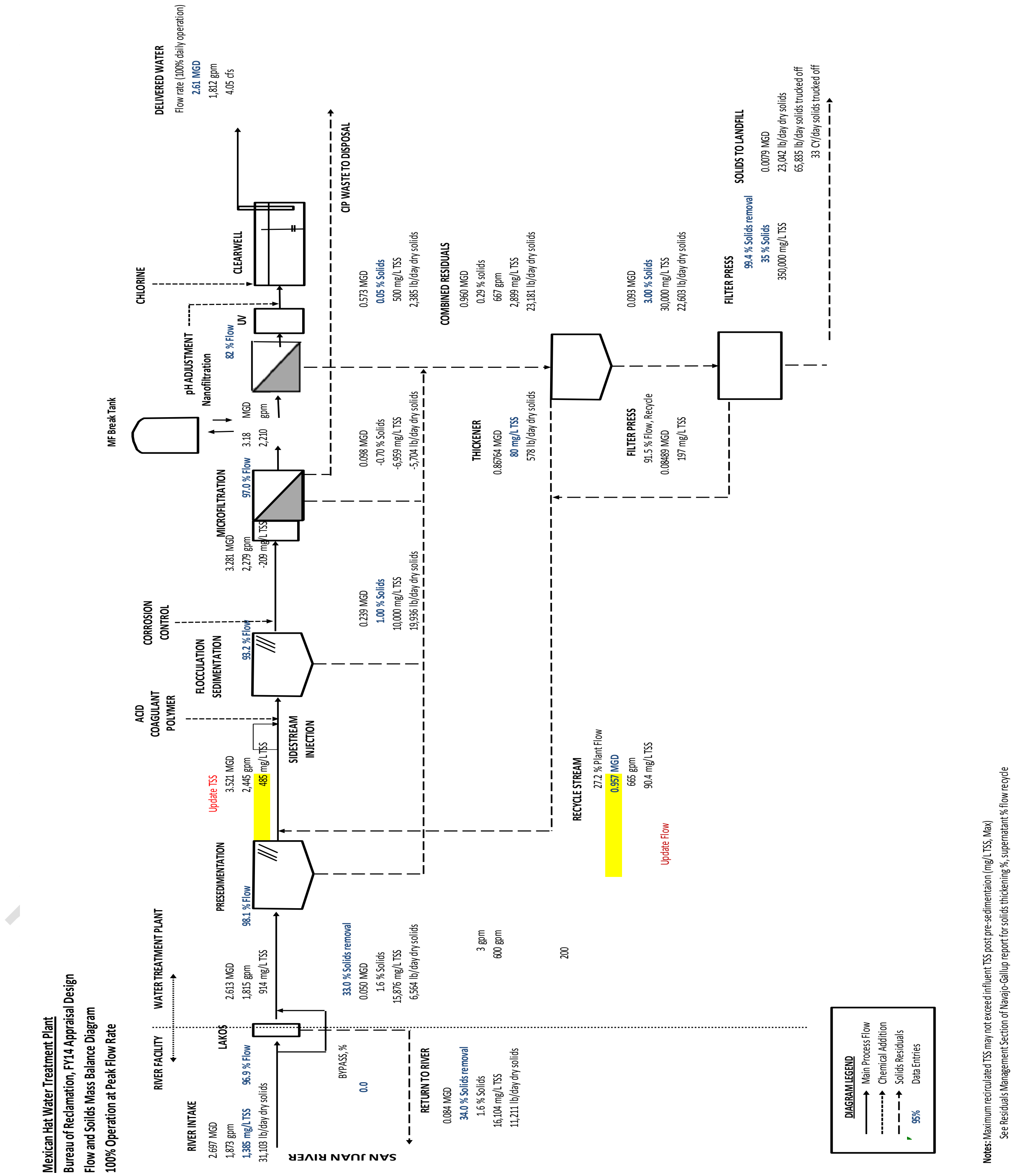


Figure 7-8 - Mexican Hat Water Treatment Mass Diagram.

7.4 Nanofiltration O&M Consideration

The O&M of a treatment system using Micro and Nanofiltration needs to be looked at closely to determine the best system for treatment of the water but also long term O&M. From an abstract on Cost Effective RO and NF Systems the following items were discussed and need to be considered during pilot testing and final design as presented in the abstract: Importance of O&M Considerations in Design, Procurement and Manufacturing written by Julia E. Nemeth, PE, Process Design Manager Harn R/O Systems, Inc., Venice, Florida and Tomas F. Seacord, PE, Senior Project Engineer Carollo Engineers Boise, Idaho

"The amount of engineering effort as well as the project aspects to which this effort is applied significantly impacts the capital and O&M costs of a membrane treatment facility. As with conventional water treatment facilities, the larger the facility, the greater the opportunity to significantly leverage engineering effort into cost savings. For membrane facilities, significant savings through customized designs are often obtainable at facility sizes greater than a few hundred gallons per minute. In addition, focusing the engineering effort on areas most sensitive to site-specific savings is key to optimizing the benefits of engineering. For example, developing an integrated approach to pretreatment, recovery efficiency, and by-product disposal is far more likely to realize significant savings than the same level of effort spent detailing skid assembly procedures. To make the best decision regarding engineering services procurement, Owners must understand and consider the types of services that are available and relative merits of each. Engineering services can be separated into two basic categories:

• Commodity Engineering Approach
• Custom Engineering Approach

Commodity Engineering involves the use of a pre-packaged approach to membrane plant design. Treatment plant design plans and specifications are re-used in a fashion that is sometimes referred to as a "rubber stamp" approach. Potential benefits to this type of approach include:

• Owners often pay less for commodity engineering services,
• Capital costs are well understood,
• For small applications, capital costs are potentially minimized due to a generic application of desalting technologies, and •Engineers may maximize their profits by use of one design for repeated applications.

In contrast, Custom Engineering takes a more holistic approach to each project, recognizing the unique nature of each project and how costs are controlled by accounting for both capital and O&M costs. The most significant component of cost for desalting over the life a project is the O&M component, and as such, protecting the Owner's interest must involve an examination of the O&M component of desalting facility. With the O&M component minimized, capital costs are assessed and life cycle costs can be optimized through an iterative process that involves reevaluating costly capital components that were used to minimize O&M. Benefits of the Custom Engineering approach include:

• Owners’ long-term interests are protected by an accounting for the O&M component of desalting processes,
• The unique nature of each project is recognized and reflected in the design of the desalting process in a manner that controls life cycle costs that include both capital and O&M costs,
• Application of innovative, yet reliable technologies are encouraged to reduce both capital and O&M costs, and
• Engineers experienced in Custom Engineering are better equipped to respond to a variety of project conditions since they are frequently required to re-think desalting processes in terms of each circumstance as an individual case.

Owners often focus on the “sticker” price of the project in terms of the capital cost and cost for engineering services. The benefits of a Custom Engineering approach is the ability to consider the value of supplemental engineering relative to project cost. For both Custom Engineering and life-cycle cost analysis, the owner needs to appreciate that the capital cost may be higher, but over the long-term the impact on rate-payers is lower. Additionally the quality of the end product is superior and the Owner and consumer will be happier with the end result. The “value added” to a project through the Custom Engineering approach is a membrane facility that is more economical over the life of the project.

Raw Water Quality/ Process Design Evaluation: The first step in evaluating the application of membrane technology involves reviewing the raw water quality with relation to the desired finished water quality. At this point there may be two different approaches considered. The first approach would involve trying to tailor the RO permeate quality to match the desired finished water quality. In seawater or high brackish water supply systems this is generally the required approach. All water produced is treated through the membrane system. In a low brackish or softening application there is another alternative. This would involve treating the raw water to a high level of purity, enabling blending of the permeate with raw water to reduce the quantity of water that must be treated by the membrane system. There are advantages and disadvantages to each approach and a cost analysis should be performed to weigh the cost impacts.

Alternative 1: Tailor Membrane Treatment to Finished Water Quality

Advantages	**Disadvantages**
100% treatment through membranes	Typically more costly
Simple, one-process operation	Higher membrane replacement costs
Lower pressure operation	Consumes more raw water
May have lower energy costs	Produces more concentrate
Concentrate is less “concentrated”	May require bigger footprint

Alternative 2: High Level Treatment, Maximum Blending

Advantages	**Disadvantages**
Reduce size of R/O treatment system	Lose 100% membrane barrier

Reduce amount of raw water required	May require by-pass treatment process
Reduce amount of concentrate produced	System less adaptable to future regulations
Reduce amount of chemicals used	May require more post-treatment chemicals
Usually saves money	Concentrate is more “concentrated”

The considerations are many when comparing high level RO treatment with blending versus membrane softening or lower level treatment with no blending. The membrane softening process may or may not use less energy because even though it will operate at a lower pressure more feedwater will have to be pumped. Raw water by-pass may be desired, however, the raw water may contain constituents that make it undesirable for blending, such as iron. In this case it may be cost-effective to treat only the by-pass water with conventional iron removal processes. This may allow the amount of raw water blending permissible to be increased. The treatment of 100% of the produced water through membranes is advantageous for virus and bacteria removal credit, otherwise the by-pass water will still have to meet the requirements as applied to a water characterized as a surface water or a groundwater under the direct influence of a surface water. Planning for 100% membrane treatment will enable the plant to be more flexible in accommodating future regulations. For example, an ion that is currently not regulated may be present in the raw water blend. It may become regulated in the future, negating the ability to blend, then the RO system capacity would have to be increased or additional treatment processes would have to be installed on the by-pass stream. When evaluating blend options, less tangible constituents such as taste, odor and particularly color should also be taken into consideration.

Concentrate disposal requirements may also be important to the evaluation. The high level RO treatment will produce less concentrate volume, however, it will be of worse (more concentrated) quality. Basically the “waste load” of dissolved solids to be disposed of will be the same either way, the engineer must evaluate whether the disposal requirements more easily accommodate higher volume or higher concentrations. The amount of chemicals required can vary site-specifically. Typically a high level RO treatment process will require higher pre-treatment chemical dosages as a result of rejecting more ions and producing a more scale-forming concentrate. However the membrane softening process, while requiring a lower scale inhibitor dosage and possibly no acid feed, will have a higher feedwater flow that the chemicals must be injected into. The post-treatment analysis will demonstrate that although the high level RO permeate will be more pure and will require more post-treatment, blending with raw water is a very effective way to provide alkalinity and buffering and raise the pH to an acceptable level, thus reducing the amount of post-treatment chemicals required. In summary, the evaluation of whether to consider producing the highest quality permeate feasible and blending with raw water, versus producing a custom-tailored, 100% RO permeate finished water is complicated. It is the first step in applying the value-added engineering principles previously discussed. Making this important decision based on thorough evaluation and careful study will pay off through the life of the plant.”

From this abstract a couple of ideas supports the idea of having one water treatment plant located at Mexican Hat. The recommendation that “As with conventional water treatment facilities, the larger the facility, the greater the opportunity to significantly leverage engineering effort into cost savings.” is a good point staying with one plant, verses three separate plants. There would be some economy in having just one building verses three for separate water treatment plants. Only pilot testing would provide the information if blending of water is even an option or 100 percent treatment through the membranes is needed for the water quality out of the river.

7.5 Pilot Study

Performing a pilot study for the best treatment methods of the San Juan River water at Mexican Hat in an important step to providing clean and safe drinking water for the area. Mexican Hat system on the other side of the river uses a Reverse Osmosis system, so information from their plant operation may help determine some of the lessons learned they have encountered over the years running the plant year round. From an abstract on Cost Effective RO and NF Systems on the importance of pilot testing: Importance of O&M Considerations in Design, Procurement and Manufacturing written by Julia E. Nemeth, PE, Process Design Manager Harn R/O Systems, Inc., Venice, Florida and Tomas F. Seacord, PE, Senior Project Engineer Carollo Engineers Boise, Idaho

"Benefits of Pilot Studying: One of the primary decisions that must be made when initially considering a membrane system is whether or not to perform a pilot study on the potential water source. There are several factors to consider:

•1. The cost of the study versus the capacity and expected cost of the plant,
•2. If any existing users have experience with membrane treatment of the source water,
3. If preliminary analysis indicates any particularly troublesome constituents may be present in the raw water,
• 4. If concentrate disposal methods must be evaluated,
• 5. If the end users are not familiar with or skeptical about the process

There is an economy of scale to consider when evaluating pilot studying. A thorough pilot study using a comprehensive, properly-sized pilot, running for an adequate length of time (typically at least 2000 hours on a groundwater – longer on a surface water), will typically cost about $75,000 to $150,000. Obviously this would not be considered for a small system that was only likely to cost about $100,000. On the other hand, this is a small sum of money to invest to obtain invaluable O&M data for optimizing a 40 MGD plant that could cost $160 million. In fact it is common for a full-scale pilot unit to be purchased by an end-user contemplating a large plant. The pilot unit will be continually useful throughout the life of the plant to test different membranes, pre-treatment chemicals, cleaning schemes, etc. An unexpected benefit that has often been realized from a pilot study is a change in attitude toward the technology from negative operators and customers. Operators that may have been resistant to the technology due to opinions that it was difficult or expensive have completely changed their views after running a well-designed pilot study. Also customers can become fans of the technology if a small post treatment system is set up with the pilot permitting the production of actual drinking water from the unit which is made available to the end-user. Several utilities have done this as a successful public relations technique.
The benefit of the full-scale pilot, which incorporates full-length, six or seven element vessels, is in its ability to simulate full-scale design conditions and recoveries without

requiring concentrate recycle. Recycling the concentrate to achieve higher recoveries may affect the projected results by introducing a feedwater that includes already super-saturated fluid and, thus, does not exactly match the design feedwater. Therefore, the most useful data is obtained from a full-scale pilot. Membrane screening can be performed in a single element pilot, but a single element pilot cannot provide accurate design and operational information. It is important that the pilot unit be comprehensively instrumented, durable, and designed for flexibility of operation. A low pressure booster pump should be included, in case the raw water is not under adequate pressure for the cartridge filter pretreatment. A high quality, stainless steel high pressure pump should be supplied to provide the RO feed pressure. A variable frequency drive and a feed control valve are recommended to provide maximum flexibility in controlling feed pressure. Sample locations should be installed on all flow streams. Instrumentation must include flow measurement, pressure measurement, feed pH, and feed and permeate conductivity. The unit should be designed to test any manufacturers' membrane softening or reverse osmosis elements. It is ideal if the unit has a modem and data logger. It also may be desirable for the pilot to have an interstage booster pump with variable frequency drive. An amp meter can be invaluable for predicting energy consumption. There are innumerable benefits to be realized from performing a pilot study that can recoup the cost of the study many times over. Additional benefits will be mentioned throughout this paper.

Raw Water Supply and Transmission:

Once the general treatment process idea is developed the single most important factor in predicting the successful operation of a membrane plant is the condition of the raw water supply. A membrane plant can be superbly designed, perfectly fabricated, and flawlessly operated, however, if the raw water supply is not suitable for membrane treatment due to particulate or biological contamination, the plant will be fraught with problems and operation and maintenance costs will increase exponentially. Therefore, the Owner is encouraged to commit adequate time and resources to developing and designing the raw water supply and membrane pre-treatment systems. The first step is performing thorough hydrogeological studies of the proposed water source if it is a groundwater. For surface water sources the water quality review must cover an entire year as quality and temperature can vary seasonally. Listed below is a summary of the minimum constituents that must be known for membrane treatment evaluation.

Recommended Minimum Water Quality Analysis for Design Parameter:

Calcium
Magnesium
Sodium
Potassium
Ammonia
Strontium
Barium
Iron
Manganese
Carbonate

Bicarbonate Alkalinity
Sulfate
Chloride
Nitrate
Fluoride
Silica
Carbon Dioxide
Hydrogen Sulfide
Total Dissolved Solids
Temperature
pH
Silt Density Index

Proper well and wellhead piping design is also important. Several points to consider when designing raw water supply and transmission systems are presented below. An important factor in groundwater supply sources is keeping the source anaerobic. There are dissolved ions such as hydrogen sulfide and iron that are in solution in an anaerobic groundwater. In solution these constituents do not pose a problem to the membrane system. It is very important that air is not then mixed with the water, either in the well, the raw water transmission piping or the pretreatment. If air mixes with the water then the hydrogen sulfide will convert to elemental sulfur and dissolved metals will precipitate out and become foulants to the membrane system (1). An even more troublesome side effect of allowing air to contact a naturally anaerobic groundwater stems from the rapid increase in biological activity. A study was performed in the Netherlands by the Overijssel Water Supply Company and Kiwa Research and Constituency on a water supply that was a high iron anaerobic groundwater. Membrane pilot studies were performed on the water. The studies compared operation with direct membrane treatment and membrane treatment following aeration and filtration pre-treatment. The studies concluded that the direct anaerobic treatment was far less susceptible to particulate and biological fouling than the aerobically pre-treated water (2).

Summary of Recommendations for Raw Water Supply

• **Groundwater Wells**
– proper design – screen sizing, gravel pack selection
    • minimize particulate withdrawal
– casing and grout integrity
    • reduce aeration
    • isolate aquifer
– proper materials of construction
    • preferably non-ferrous
    • minimize biological contamination

• **Surface Water Intakes**
– evaluate seasonal variation by studying source for one year
    • physical and chemical variations
– location and elevation of intake

• minimize source water variation

– “modified intake” design, ie beach wells, bank filtration

• provides some pre-filtration”

All of these items involved with pilot studies will need to studied further to design the treatment system. The water quality in the San Juan River does vary over the year, so having a pilot study over a period of at least a year would be highly recommended. These abstract summaries are good road maps for determining the best methods to use to design a reliable and cost effective system.

7.6 Chlorine Booster Station

As it has been discussed in the above sections controlling the biofilm in the pipeline from the river to the end users will require keeping the chlorine levels constant throughout the pipe and will require chlorine booster stations. The type of chlorine to use along the pipeline would need to be researched for final design, but one option that could be used would be dry hypochlorite that is put into a solution for injection into the pipeline.

Figure 7-9. Chlorine Booster Station. Source Arch Constant Chlor®

Terry Brown, Maintenance Supervisor for Butler County Rural Water District #5, checks out the utility's new Arch Constant Chlor® Plus calcium hypochlorite feed system installed for efficient booster chlorination.

Figure 7-10. Calcium Hypochlorite Feed System. Source Arch Constrant Chlor®

7.7 Prelimary Plant Layout

Preliminary sizing for the water treatment building would be 75 by 120 feet, with extension for backwash process water and sludge belt press. The building would be a concrete masonary unit building with metal roof with the treatment trains built on site or they could be modular units built in the factor and assembled on site. The nanofiltration equipment will take about 3,300 square feet of the building.

The treatment plant would have office, workshop, laboratory, chemical rooms.

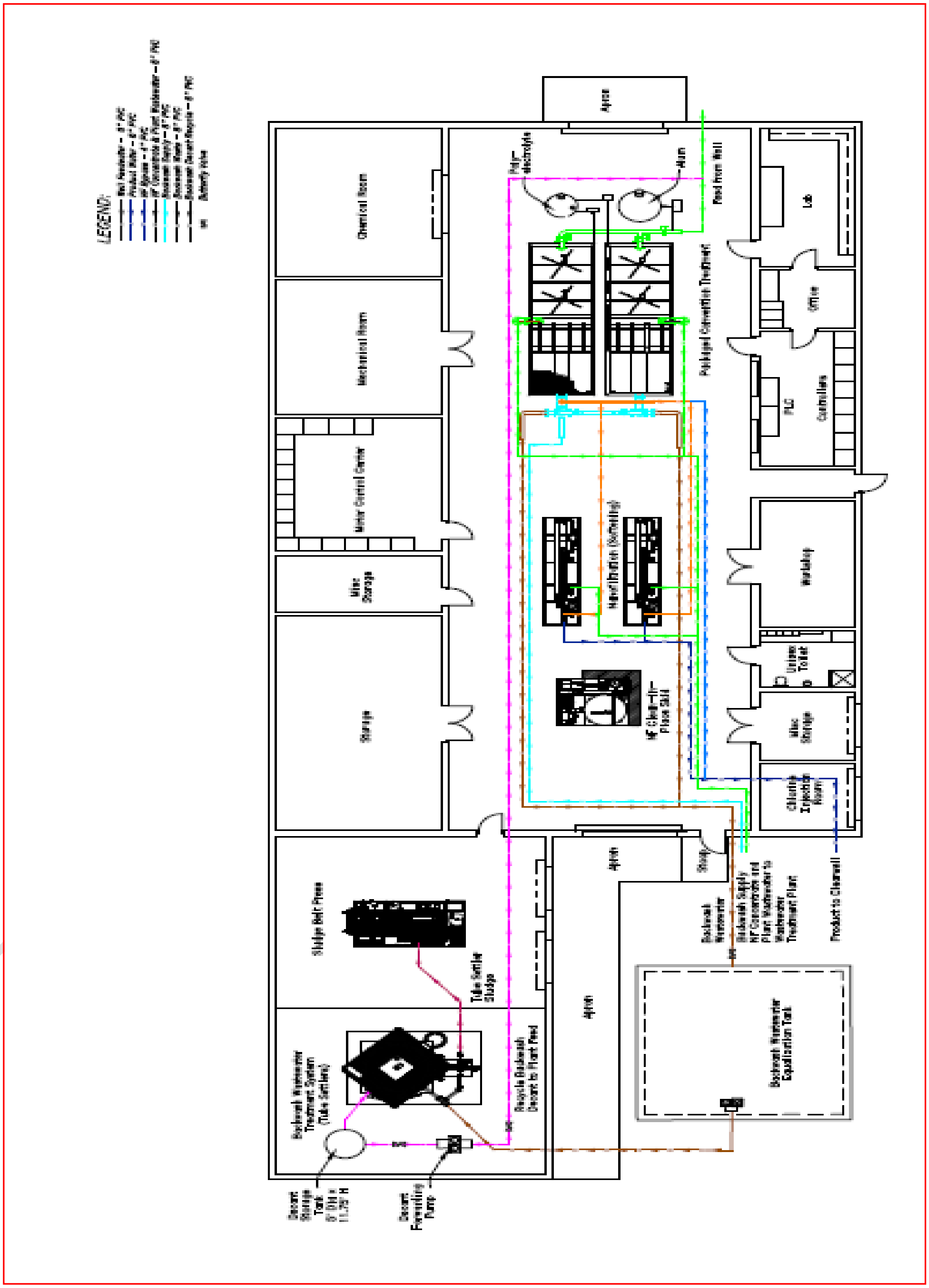


Figure 7-11. Approximate treatment plant layout.

8.0 Distribution System

For the purposes of this study, the distribution system refers to the pipelines conveying treated water from the storage tank to the various existing storage tanks located around the different communities. A second part of the distribution system refers to the pipelines carrying the water from the community storage tanks to the end user.

Evaluating this second part of the water distribution system is beyond the scope of this study. If and when upgrades are needed to the individual community distribution systems would need to be determined by the appropriate agencies within the Navajo Nation. It is anticipated that as demand increases, size upgrades to the pipelines would be required at some point in the future.

Ideally, the storage tanks for each treatment plant would be located at the highest point in the system allowing the treated water to be gravity fed to the various communities. However, finding a suitable location with a higher elevation, access, power supply, and that is somewhat centrally located proved difficult. It was concluded that pumping requirements would not change significantly no matter what the configuration and location of the storage and distribution system is.

Table 8.1 shows nominal pipe sizes and approximate lengths of distribution lines from each of the three treatment plants.

Table 8-1. Nominal pipe sizes and approximate lengths of distribution lines.

Distribution Pipeline	Nominal Pipe Size[1] (in)	Approximate Pipeline Length (mi)
South Line (Kayenta) from WTF:	14	20
Line to storage tank location #1:	14	3
Line to Oljato storage tank location #1:	8	1
Line to Halchita storage tank location #1:	6	1

[1]Based on 2.0 peaking factor

8.1 Appurtenant Structures

Like the raw water pipeline in Section 6, the pipelines in the distribution system would also require such structures as air-vac/blowoff valves. General considerations for these structures are similar to those for the raw water pipeline. It is assumed that two booster pump stations with associated air chambers and forebay tanks would be required in the distribution system.

9.0 Cost Estimates

Table 9-1. San Juan – Mexican Hat to Kayenta Water Supply Project Cost Estimate. Sheets 1 through 17

BUREAU OF RECLAMATION		ESTIMATE WORKSHEET					SHEET 1 OF 17
FEATURE:			PROJECT:				
	Water Pipeline 1820 gpm Capacity			San Juan – Mexican Hat to Kayenta Regional			
	Rock Excavation			Water Supply Appraisal Study			
	Transmission Pipeline		WOID:	SJMH	ESTIMATE LEVEL:		Appraisal
			REGION:	UC	UNIT PRICE LEVEL:		Jun-14
Civil			FILE:	C:\Users\csouthworth\AppData\Roaming\Microsoft\Excel\[Cost Estimate-BOR Format Final (version 1).xlsb]WT 4			
PLANT ACCOUNT	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
		Assumptions: Rock Excavation					
		Only clearing of light brush needed					
		Rock the full depth of trench cut, groundwater					
		is not an issue, rock type sandstone and					
		limestone. Bedding processed from trench					
		material with mobile screener based on					
		processed material in Means Cost Guide,					
		Vertical Trench walls, Frost Depth 18 to 24					
		inches plus 1' cover					
		Furnish and install 16" PVC C905 PR 305 DR 14					
		AWWA C905 PVC Pipe- North American Pipe		8,500	lin ft	$44.50	$378,250.00
		with indirect costs added. All other Means					
		Ron Hatt Sales Rep. 801-706-5744 Cell					
		Rock Excavation - 31 23 16.14 6200		8,500	lin ft	$60.00	$510,000.00
		Bedding 31.23 23.16 0100		8,500	lin ft	$11.50	$97,750.00
		Compacting Bedding 31.23.23.17 0500		8,500	lin ft	$1.45	$12,325.00
		Pipe Installation 33 11 13.25 3040		8,500	lin ft	$8.60	$73,100.00
		Backfill 31.23 16.13 3040		8,500	lin ft	$0.50	$4,250.00
		Warning Tape 33 05 26.10 0500		8,500	lin ft	$0.10	$850.00
		Fitting and Joint Restraint -Assume @700 ft.		8,500	lin ft	$4.40	$37,400.00
		Finish Grading - Means 31 22 16.10 3310		8,500	lin ft	$1.45	$12,325.00
		Furnish and install 16" PVC C905 PR 235 DR 18					
		AWWA C905 PVC Pipe- North American Pipe		6,400	lin ft	$35.50	$227,200.00
		with indirect costs added.		6,400	lin ft		
		Rock Excavation - Means Pg 231		6,400	lin ft	$60.00	$384,000.00
		Bedding - Means		6,400	lin ft	$11.50	$73,600.00
		Compacting Bedding		6,400	lin ft	$1.45	$9,280.00
		Pipe Installation		6,400	lin ft	$8.60	$55,040.00
		Backfill		6,400	lin ft	$0.50	$3,200.00
		Warning Tape		6,400	lin ft	$0.10	$640.00
		Fitting and Joint Restraint -Assume @700 ft.		6,400	lin ft	$4.40	$28,160.00
		Finish Grading		6,400	lin ft	$1.45	$9,280.00
		SUBTOTAL THIS SHEET					$1,916,650.00
JANTITIES				PRICES			
BY		CHECKED	BY		CHECKED		
Cary Southworth		Scott Winterton	Cary Southworth		Scott Winterton		
DATE PREPARED		PEER REVIEW / DATE	DATE PREPARED		PEER REVIEW / DATE		
06/09/14		S/6/16/2014	06/09/14		S/6/16/2014		

FEATURE:	PROJECT:			
Water Pipeline 1820 gpm Capacity	San Juan – Mexican Hat to Kayenta Regional			
Rock Excavation	Water Supply Appraisal Study			
Transmission Pipeline	WOID:	SJMH	ESTIMATE LEVEL:	Appraisal
	REGION:	UC	UNIT PRICE LEVEL:	Jun-14
Civil	FILE:	T:\Eng\Design\San Juan Pipeline\Appraisal Report\May 2014 TSC Comments\[Cost Estimate-BOR Format Final.xlsx]O&M		

PLANT ACCOUNT	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
		Assumptions					
		Rock the full depth of trench cut, groundwater					
		is not an issue, rock type sandstone and					
		limestone.					
		Furnish and install 16" PVC C905 PR 200 DR 21					
		AWWA C905 PVC Pipe- North American Pipe		6,800	lin ft	$30.70	$208,760.00
		with indirect costs added.					
		Rock Excavation - Means Pg 231		6,800	lin ft	$60.00	$408,000.00
		Bedding - Means		6,800	lin ft	$11.50	$78,200.00
		Compacting Bedding		6,800	lin ft	$1.45	$9,860.00
		Pipe Installation		6,800	lin ft	$8.60	$58,480.00
		Backfill		6,800	lin ft	$0.50	$3,400.00
		Warning Tape		6,800	lin ft	$0.10	$680.00
		Fitting and Joint Restraint -Assume @700 ft.		6,800	lin ft	$4.40	$29,920.00
		Finish Grading		6,800	lin ft	$1.45	$9,860.00
		Furnish and install 16" PVC C905 PR 165 DR 25					
		AWWA C905 PVC Pipe- North American Pipe		11,200	lin ft	$26.00	$291,200.00
		with indirect costs added.					
		Rock Excavation - Means Pg 231		11,200	lin ft	$60.00	$672,000.00
		Bedding - Means		11,200	lin ft	$11.50	$128,800.00
		Compacting Bedding		11,200	lin ft	$1.45	$16,240.00
		Pipe Installation		11,200	lin ft	$8.60	$96,320.00
		Backfill		11,200	lin ft	$0.50	$5,600.00
		Warning Tape		11,200	lin ft	$0.10	$1,120.00
		Fitting and Joint Restraint -Assume @700 ft.		11,200	lin ft	$4.40	$49,280.00
		Finish Grading		11,200	lin ft	$1.45	$16,240.00
		SUBTOTAL THIS SHEET					$2,083,960.00

JANTITIES		PRICES	
BY	CHECKED	BY	CHECKED
Cary Southworth	Scott Winterton	Cary Southworth	Scott Winterton
DATE PREPARED	PEER REVIEW / DATE	DATE PREPARED	PEER REVIEW / DATE
06/09/14	S/6/16/2014	06/09/14	S/6/16/2014

BUREAU OF RECLAMATION		ESTIMATE WORKSHEET					SHEET 3 OF 17
FEATURE:			PROJECT:				
	Water Pipeline 1820 gpm Capacity			San Juan – Mexican Hat to Kayenta Regional			
				Water Supply Appraisal Study			
	Rock Excavation		WOID:	SJMH	ESTIMATE LEVEL:		Appraisal
			REGION:	UC	UNIT PRICE LEVEL:		Jun-14
	Common Excavation Description		FILE:	T:\Eng\Design\San Juan Pipeline\Appraisal Report\May 2014 TSC Comments\[Cost Estimate-BOR Format Final.xlsx]O&M			
Civil							

PLANT ACCOUNT	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
		Assumptions					
		Rock the full depth of trench cut, groundwater					
		is not an issue, rock type sandstone and					
		limestone.					
		Furnish and install 16" PVC C905 PR 125 DR 32.5					
		AWWA C905 PVC Pipe- North American Pipe		4,200	lin ft	$20.20	$84,840.00
		with indirect costs added. All others Means					
		Rock Excavation - Means Pg 231		4,200	lin ft	$60.00	$252,000.00
		Bedding - Means		4,200	lin ft	$12.00	$50,400.00
		Compacting Bedding		4,200	lin ft	$1.45	$6,090.00
		Pipe Installation		4,200	lin ft	$8.60	$36,120.00
		Backfill		4,200	lin ft	$0.50	$2,100.00
		Warning Tape		4,200	lin ft	$0.10	$420.00
		Fitting and Joint Restraint -Assume @700 ft.		4,200	lin ft	$4.40	$18,480.00
		Finish Grading		4,200	lin ft	$1.45	$6,090.00
		Assumptions: Common Excavation					
		Common earth installation					
		Incl. pipe material, placement, bedding,					
		trenching, backfill, warning tape, fittings and					
		final grading along pipeline alignment					
		Assume earth material stockpiled for reuse					
		Assume 1:1/2 to 1 side slope, 3' wide, 4.5' deep trench					
		Assume earth material stockpiled for reuse					
		Pipe cost from NorthAmericanPipe.com					
		All other costs from RSMeans 2013					
		Groundwater is not an issue.					
		Roadcrossing are minimal with open cuts used					
		Bedding Material Imported from local sources					
		Backfill trench excavation not processed					
		Minimal fence relocation required					
		SUBTOTAL THIS SHEET					**$456,540.00**

JANTITIES		PRICES	
BY	CHECKED	BY	CHECKED
Cary Southworth	Scott Winterton	Cary Southworth	Scott Winterton
DATE PREPARED	PEER REVIEW / DATE	DATE PREPARED	PEER REVIEW / DATE
06/09/14	S/6/16/2014	06/09/14	S/6/16/2014

BUREAU OF RECLAMATION	ESTIMATE WORKSHEET	SHEET 4 OF 17

FEATURE:	**PROJECT:**
Water Pipeline	**San Juan – Mexican Hat to Kayenta Regional**
Common Excavation	**Water Supply Appraisal Study**
	WOID: SJMH — **ESTIMATE LEVEL:** Appraisal
	REGION: UC — **UNIT PRICE LEVEL:** Jun-14
Civil	**FILE:** T:\Eng\Design\San Juan Pipeline\Appraisal Report\May 2014 TSC Comments\[Cost Estimate-BOR Format Final.xlsx]O&M

PLANT ACCOUNT	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
		Common Excavation - Means					
		Furnish and install 16" PVC C905 PR 305 DR 14					
		AWWA C905 PVC Pipe- North American Pipe		19,800	lin ft	$45.00	$891,000.00
		with indirect costs added. All others Means					
		Common Excavation - 31.23.16.13 0120		19,800	lin ft	$8.00	$158,400.00
		Bedding - Means 31.23 16.13 0110		19,800	lin ft	$28.00	$554,400.00
		Compacting Bedding		19,800	lin ft	$4.00	$79,200.00
		Pipe Installation		19,800	lin ft	$8.60	$170,280.00
		Backfill		19,800	lin ft	$3.90	$77,220.00
		Warning Tape		19,800	lin ft	$0.10	$1,980.00
		Fitting and Joint Restraint -Assume @700 ft.		19,800	lin ft	$4.40	$87,120.00
		Finish Grading		19,800	lin ft	$1.45	$28,710.00
		Furnish and install 16" PVC C900 PR 235 DR 18					
		AWWA C905 PVC Pipe- North American Pipe		15,100	lin ft	$35.50	$536,050.00
		with indirect costs added. All others Means					
		Common Excavation - Means		15,100	lin ft	$8.00	$120,800.00
		Bedding - Means		15,100	lin ft	$28.00	$422,800.00
		Compacting Bedding		15,100	lin ft	$4.00	$60,400.00
		Pipe Installation		15,100	lin ft	$8.60	$129,860.00
		Backfill		15,100	lin ft	$3.90	$58,890.00
		Warning Tape		15,100	lin ft	$0.10	$1,510.00
		Fitting and Joint Restraint -Assume @700 ft.		15,100	lin ft	$4.40	$66,440.00
		Finish Grading		15,100	lin ft	$1.45	$21,895.00
		SUBTOTAL THIS SHEET					**$3,466,955.00**

QUANTITIES		PRICES	
BY	**CHECKED**	**BY**	**CHECKED**
Cary Southworth	Scott Winterton	Cary Southworth	Scott Winterton
DATE PREPARED	**PEER REVIEW / DATE**	**DATE PREPARED**	**PEER REVIEW / DATE**
06/09/14	S/6/16/2014	06/09/14	S/6/16/2014

BUREAU OF RECLAMATION **ESTIMATE WORKSHEET** SHEET 5 OF 17

FEATURE:		**PROJECT:**	
Water Pipeline 16 and 14 Inch		**San Juan – Mexican Hat to Kayenta Regional**	
Common Excavation		**Water Supply Appraisal Study**	
		WOID: SJMH	**ESTIMATE LEVEL:** Appraisal
		REGION: UC	**UNIT PRICE LEVEL:** Jun-14
Civil		**FILE:** T:\Eng\Design\San Juan Pipeline\Appraisal Report\May 2014 TSC Comments\[Cost Estimate-BOR Format Final.xlsx]O&M	

PLANT ACCOUNT	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
		Main Water Line:					
		Furnish and install 16" PVC C900 PR 200 DR 21					
		AWWA C905 PVC Pipe- North American Pipe		15,700	lin ft	$30.70	$481,990.00
		with indirect costs added. All others Means					
		Common Excavation - Means		15,700	lin ft	$8.00	$125,600.00
		Bedding - Means		15,700	lin ft	$28.00	$439,600.00
		Compacting Bedding		15,700	lin ft	$4.00	$62,800.00
		Pipe Installation		15,700	lin ft	$8.60	$135,020.00
		Backfill		15,700	lin ft	$3.90	$61,230.00
		Warning Tape		15,700	lin ft	$0.10	$1,570.00
		Fitting and Joint Restraint -Assume @700 ft.		15,700	lin ft	$4.40	$69,080.00
		Finish Grading		15,700	lin ft	$1.45	$22,765.00
		Furnish and install 16" PVC C900 PR 165 DR 25					
		AWWA C905 PVC Pipe- North American Pipe		26,200	lin ft	$26.00	$681,200.00
		with indirect costs added. All others Means					
		Common Excavation - Means		26,200	lin ft	$8.00	$209,600.00
		Bedding - Means		26,200	lin ft	$28.00	$733,600.00
		Compacting Bedding		26,200	lin ft	$4.00	$104,800.00
		Pipe Installation		26,200	lin ft	$8.60	$225,320.00
		Backfill		26,200	lin ft	$3.90	$102,180.00
		Warning Tape		26,200	lin ft	$0.10	$2,620.00
		Fitting and Joint Restraint -Assume @700 ft.		26,200	lin ft	$4.40	$115,280.00
		Finish Grading		26,200	lin ft	$1.45	$37,990.00
		SUBTOTAL THIS SHEET					**$3,612,245.00**

QUANTITIES		**PRICES**	
BY	**CHECKED**	**BY**	**CHECKED**
Cary Southworth	Scott Winterton	Cary Southworth	Scott Winterton
DATE PREPARED	**PEER REVIEW / DATE**	**DATE PREPARED**	**PEER REVIEW / DATE**
06/09/14	S/6/16/2014	06/09/14	S/6/16/2014

BUREAU OF RECLAMATION	ESTIMATE WORKSHEET	SHEET 6 OF 17

FEATURE:	**PROJECT:**
Water Pipeline 16 and 14 Inch	**San Juan – Mexican Hat to Kayenta Regional**
Common Excavation	**Water Supply Appraisal Study**
	WOID: SJMH — **ESTIMATE LEVEL:** Appraisal
	REGION: UC — **UNIT PRICE LEVEL:** Jun-14
Civil	**FILE:** T:\Eng\Design\San Juan Pipeline\Appraisal Report\May 2014 TSC Comments\[Cost Estimate-BOR Format Final.xlsx]O&M

PLANT ACCOUNT	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
		16-inch Pipe - Common Excavation					
		Furnish and install 16" PVC C900 PR 200 DR 32.5					
		AWWA C905 PVC Pipe- North American Pipe		9,700	lin ft	$20.20	$195,940.00
		with indirect costs added. All others Means					
		Common Excavation - 31.23.16.13 0110		9,700	lin ft	$8.00	$77,600.00
		Bedding - Means		9,700	lin ft	$28.00	$271,600.00
		Compacting Bedding		9,700	lin ft	$4.00	$38,800.00
		Pipe Installation		9,700	lin ft	$8.60	$83,420.00
		Backfill		9,700	lin ft	$3.90	$37,830.00
		Warning Tape		9,700	lin ft	$0.10	$970.00
		Fitting and Joint Restraint -Assume @700 ft.		9,700	lin ft	$4.40	$42,680.00
		Finish Grading		9,700	lin ft	$1.45	$14,065.00
		14-inch Pipe - Common Excavation					
		Furnish and install 14" PVC C900 PR 165 DR 14					
		AWWA C905 PVC Pipe- North American Pipe		24,400	lin ft	$34.60	$844,240.00
		with indirect costs added. All others Means					
		Common Excavation - 31.23.16.13 0110		24,400	lin ft	$8.00	$195,200.00
		Bedding - Means		24,400	lin ft	$28.00	$683,200.00
		Compacting Bedding		24,400	lin ft	$4.00	$97,600.00
		Pipe Installation		24,400	lin ft	$8.40	$204,960.00
		Backfill		24,400	lin ft	$3.90	$95,160.00
		Warning Tape		24,400	lin ft	$0.10	$2,440.00
		Fitting and Joint Restraint -Assume @700 ft.		24,400	lin ft	$4.10	$100,040.00
		Finish Grading		24,400	lin ft	$1.45	$35,380.00
		SUBTOTAL THIS SHEET					**$3,021,125.00**

QUANTITIES		PRICES	
BY	**CHECKED**	**BY**	**CHECKED**
Cary Southworth	Scott Winterton	Cary Southworth	Scott Winterton
DATE PREPARED	**PEER REVIEW / DATE**	**DATE PREPARED**	**PEER REVIEW / DATE**
06/09/14	S/6/16/2014	06/09/14	S/6/16/2014

BUREAU OF RECLAMATION	ESTIMATE WORKSHEET	SHEET 7 OF 17

FEATURE:	PROJECT:
Water Pipeline 1500 gpm Capacity	San Juan – Mexican Hat to Kayenta Regional Water Supply Appraisal Study
	WOID: SJMH · ESTIMATE LEVEL: Appraisal
	REGION: UC · UNIT PRICE LEVEL: Jun-14
Civil	FILE: T:\Eng\Design\San Juan Pipeline\Appraisal Report\May 2014 TSC Comments\[Cost Estimate-BOR Format Final.xlsx]O&M

PLANT ACCOUNT	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
		Main Water Line:					
		Furnish and install 14" PVC C900 PR 200 DR 18					
		AWWA C905 PVC Pipe- North American Pipe		10,300	lin ft	$27.40	$282,220.00
		with indirect costs added. All others Means					
		Common Excavation - Means		10,300	lin ft	$8.00	$82,400.00
		Bedding - Means		10,300	lin ft	$28.00	$288,400.00
		Compacting Bedding		10,300	lin ft	$4.00	$41,200.00
		Pipe Installation		10,300	lin ft	$8.40	$86,520.00
		Backfill		10,300	lin ft	$3.90	$40,170.00
		Warning Tape		10,300	lin ft	$0.10	$1,030.00
		Fitting and Joint Restraint -Assume @700 ft.		10,300	lin ft	$4.10	$42,230.00
		Finish Grading		10,300	lin ft	$1.45	$14,935.00
		Furnish and install 14" PVC C900 PR 165 DR 21					
		AWWA C905 PVC Pipe- North American Pipe		36,600	lin ft	$23.70	$867,420.00
		with indirect costs added. All others Means					
		Common Excavation - Means		36,600	lin ft	$8.00	$292,800.00
		Bedding - Means		36,600	lin ft	$28.00	$1,024,800.00
		Compacting Bedding		36,600	lin ft	$4.00	$146,400.00
		Pipe Installation		36,600	lin ft	$8.40	$307,440.00
		Backfill		36,600	lin ft	$3.90	$142,740.00
		Warning Tape		36,600	lin ft	$0.10	$3,660.00
		Fitting and Joint Restraint -Assume @700 ft.		36,600	lin ft	$4.10	$150,060.00
		Finish Grading		36,600	lin ft	$1.45	$53,070.00
		SUBTOTAL THIS SHEET					$3,867,495.00

QUANTITIES		PRICES	
BY	CHECKED	BY	CHECKED
Cary Southworth	Scott Winterton	Cary Southworth	Scott Winterton
DATE PREPARED	PEER REVIEW / DATE	DATE PREPARED	PEER REVIEW / DATE
06/09/14	S/6/16/2014	06/09/14	S/6/16/2014

BUREAU OF RECLAMATION			ESTIMATE WORKSHEET				SHEET 8 OF 17
FEATURE:			PROJECT:				
	Water Pipeline 1500 gpm Capacity			San Juan – Mexican Hat to Kayenta Regional			
				Water Supply Appraisal Study			
			WOID:	SJMH	ESTIMATE LEVEL:		Appraisal
			REGION:	UC	UNIT PRICE LEVEL:		Jun-14
Civil			FILE:	T:\Eng\Design\San Juan Pipeline\Appraisal Report\May 2014 TSC Comments\[Cost Estimate-BOR Format Final.xlsx]O&M			

PLANT ACCOUNT	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
		Furnish and install 14" PVC C905 PR 165 DR 25					
		AWWA C905 PVC Pipe- North American Pipe		7,200	lin ft	$20.00	$144,000.00
		with indirect costs added. All others Means					
		Common Excavation - Means		7,200	lin ft	$8.00	$57,600.00
		Bedding - Means		7,200	lin ft	$28.00	$201,600.00
		Compacting Bedding		7,200	lin ft	$4.00	$28,800.00
		Pipe Installation		7,200	lin ft	$8.40	$60,480.00
		Backfill		7,200	lin ft	$3.90	$28,080.00
		Warning Tape		7,200	lin ft	$0.10	$720.00
		Fitting and Joint Restraint -Assume @700 ft.		7,200	lin ft	$4.10	$29,520.00
		Finish Grading		7,200	lin ft	$1.45	$10,440.00
		Furnish and install 14" PVC C905 PR 125 DR 32.5					
		AWWA C905 PVC Pipe- North American Pipe		12,700	lin ft	$15.60	$198,120.00
		with indirect costs added. All others Means					
		Common Excavation - Means		12,700	lin ft	$8.00	$101,600.00
		Bedding - Means		12,700	lin ft	$28.00	$355,600.00
		Compacting Bedding		12,700	lin ft	$4.00	$50,800.00
		Pipe Installation		12,700	lin ft	$8.40	$106,680.00
		Backfill		12,700	lin ft	$3.90	$49,530.00
		Warning Tape		12,700	lin ft	$0.10	$1,270.00
		Fitting and Joint Restraint -Assume @700 ft.		12,700	lin ft	$4.10	$52,070.00
		Finish Grading		12,700	lin ft	$1.45	$18,415.00
		Air and Vacuum Relief Valves - 8 to 10 inch		103.0	EA	$10,000.00	$1,030,000.00
		SUBTOTAL THIS SHEET					$2,525,325.00

JANTITIES		PRICES	
BY	CHECKED	BY	CHECKED
Cary Southworth	Scott Winterton	Cary Southworth	Scott Winterton
DATE PREPARED	PEER REVIEW / DATE	DATE PREPARED	PEER REVIEW / DATE
06/09/14	S/6/16/2014	06/09/14	S/6/16/2014

BUREAU OF RECLAMATION **ESTIMATE WORKSHEET** SHEET 9 OF 17

FEATURE:		**PROJECT:**	
Secondaruy Water Pipeline		**San Juan – Mexican Hat to Kayenta Regional**	
		Water Supply Appraisal Study	
Steel Storage Tanks		**WOID:** SJMH	**ESTIMATE LEVEL:** Appraisal
		REGION: UC	**UNIT PRICE LEVEL:** Jun-14
Civil		**FILE:** T:\Eng\Design\San Juan Pipeline\Appraisal Report\May 2014 TSC Comments\[Cost Estimate-BOR Format Final.xlsx]O&M	

PLANT ACCOUNT	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
		Distribution lines Secondary Treatment to Tanks					
		Furnish and install 14" PVC C905 DR 18 - Kayenta Tank		20,000	lin ft	$87.00	**$1,740,000.00**
		to Kayenta Distribution Point					
		Furnish and install 8" PVC C900 DR 18- Oljato Tank #1		3,500	lin ft	$54.00	**$189,000.00**
		Furnish and install 6" PVC C900 DR 18- Halchita Line		3,000	lin ft	$26.00	**$78,000.00**
		Common earth installation					
		Incl. pipe material, placement, bedding, trenching & backfill					
		Assume 1:1/2 to 1 side slope, 3' wide, 3 to 4' deep trench					
		Assume earth material stockpiled for reuse					
		Pipe cost from NorthAmericanPipe.com					
		All other costs from RSMeans 2013					
		Tanks					
		Furnish and place 250k gallon Steel Tank for Halchita					
		Steel, Tank, ground level, ht/diam less than 1,					
		Means Unit Price, includes cathodic protection		1	ls	$318,000.00	**$318,000.00**
		Foundation 48" deep concrete ring, #5 steel at 12" o.c.					
		Site Work including foundation		1		$42,000.00	**$42,000.00**
		Includes rough grading,foundation, gravel					
		surfacing, pipe installation,finish grading,					
		fencing and gate, valves					
		Furnish and place 750k gallon Steel tank for Oljato-Monument Valley					
		Steel Tank		1	ls	$580,000.00	**$580,000.00**
		Site Work		1	ls	$60,000.00	**$60,000.00**
		Furnish and place 5M gallon Steel tank for Kayenta					
		Steel Tank		1	ls	$2,850,000.00	**$2,850,000.00**
		Site Work		1	ls	$260,000.00	**$260,000.00**
		SUBTOTAL THIS SHEET					**$6,117,000.00**

JANTITIES		**PRICES**	
BY	**CHECKED**	**BY**	**CHECKED**
Cary Southworth	Scott Winterton	Cary Southworth	Scott Winterton
DATE PREPARED	**PEER REVIEW / DATE**	**DATE PREPARED**	**PEER REVIEW / DATE**
06/09/14	S/6/16/2014	06/09/14	S/6/16/2014

BUREAU OF RECLAMATION	ESTIMATE WORKSHEET	SHEET 10 OF 17

FEATURE: River Intake Structure & Pretreatment Civil	**PROJECT:** San Juan – Mexican Hat to Kayenta Regional Water Supply Appraisal Study
	WOID: SJMH / **ESTIMATE LEVEL:** Appraisal
	REGION: UC / **UNIT PRICE LEVEL:** Jun-14
	FILE: T:\Eng\Design\San Juan Pipeline\Appraisal Report\May 2014 TSC Comments\[Cost Estimate-BOR Format Final.xlsx]O&M

PLANT ACCOUNT	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
		River Intake Structure & Pretreatment					
		Cofferdam		2,000	ft2	$45.00	$90,000.00
		Idaho Department of Transportation 2013 Schedule of Values					
		Dewatering 31 23 19.20 0650 + 0670		90	day	$1,100.00	$99,000.00
		Rock Excavation 31 23 16.16 1550		220	yd3	$730.00	$160,600.00
		Hand and Machine Rock Excavation					
		Concrete 03 30 53.40 3950 + 4500					
		36" wide footing, wall 16 feet high 15 inch thick		120	yd3	$500.00	$60,000.00
		Metal Work					
		Rock Anchoring and structural support frame		40	ton	$4,350.00	$174,000.00
		Metal Stairs 05 51 16.50		40	ea	$675.00	$27,000.00
		Grating Galv. 05 53 13.70		800	ft2	$53.00	$42,400.00
		18-inch Steel Pipe 33 11 13.40 1030		100	lin ft	$130.00	$13,000.00
		12-inch Steel Pipe		40	lin ft	$131.00	$5,240.00
		18 inch Pipe Bends		2	ea	$3,200.00	$6,400.00
		Light Weight Enclosure 13 34 19.50 0150		1,200	ft2	$25.00	$30,000.00
		Self Cleaning Screen		1	ls	$56,000.00	$56,000.00
		Lakos 24 inch screens, swivel for piping					
		Sand Seperator		1	ls	$47,000.00	$47,000.00
		Lakos JPX 1160 Seperator and automatic					
		backwash Tiffany Dawkins with Lakos					
		T: 503.575.5128 | E: tdawkins@lakos.com					
		Pumps and associated piping		1	ls	$140,000.00	$140,000.00
		Suction Pumps, piping, fittings and valves					
		Electrical and Standby Generator		1	ls	$162,000.00	$162,000.00
		Pre-engineered Building 13 34 19.50		1,000	ft2	$150.00	$150,000.00
		Includes, slab, doors					
		Fencing 32 31 13.20		500	lin ft	$28.00	$14,000.00
		Chain Link Gate		1	ea	$2,650.00	$2,650.00
		SUBTOTAL THIS SHEET					**$1,279,290.00**

QUANTITIES		PRICES	
BY	**CHECKED**	**BY**	**CHECKED**
Cary Southworth	Scott Winterton	Cary Southworth	Scott Winterton
DATE PREPARED	**PEER REVIEW / DATE**	**DATE PREPARED**	**PEER REVIEW / DATE**
06/09/14	S/6/16/2014	06/09/14	S/6/16/2014

BUREAU OF RECLAMATION **ESTIMATE WORKSHEET** SHEET 11 OF 17

FEATURE:	**PROJECT:**
Water Pipeline	**San Juan – Mexican Hat to Kayenta Regional**
River Intake Structure & Pretreatment	**Water Supply Appraisal Study**
Steel Storage Tanks	**WOID:** SJMH **ESTIMATE LEVEL:** Appraisal
Pumping Plants	**REGION:** UC **UNIT PRICE LEVEL:** Jun-14
Water Treatment Plants	**FILE:** T:\Eng\Design\San Juan Pipeline\Appraisal Report\May 2014 TSC Comments\[Cost Estimate-BOR Format Final.xlsx]O&M
Civil	

PLANT ACCOUNT	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
		Pumping/Chlorine Booster Plants					
		Furnish and install pumping plant					
		4.05 cfs, 480 Ft TDH - River		1	ls	$1,075,000.00	$1,075,000.00
		4.05 cfs, 440 Ft TDH - Booster 1		1	ls	$1,150,000.00	$1,150,000.00
		4.05 cfs, 480 Ft TDH - Booster 2		1	ls	$1,150,000.00	$1,150,000.00
		4.05 cfs, 450 Ft TDH - Booster 3		1	ls	$1,150,000.00	$1,150,000.00
		4.05 cfs, 450 Ft TDH - Booster 4		1	ls	$1,150,000.00	$1,150,000.00
		3.35 cfs, 380 Ft TDH - Booster 5		1	ls	$1,100,000.00	$1,100,000.00
		Cost includes foundation w ork, grading, utilities,					
		electrical service yard, final grading, fencing,					
		security, cement masonary unit buidling,					
		1 - 300kW standby generator, 1 - 12,000 gallon					
		forebay tank, 1 - 30,000 gallon hydropneaumatic,					
		buried piping and valves, interior piping and					
		valves, chorine monitors, heating and cooling,					
		grounding system, 1 - 500 kVa pad transformer,					
		electrical, chlorine and ammonia systems,					
		hydropneaumatic air system					
		Pumping Plant Building Size 30' X 80'					
		Metal Roof w ith R-30 insulation					
		6 - Metal Personnel and 1- Rollup Doors					
		3 - Pumps 300 hp - 224 kW					
		Pump includes pump, motor and suction can					
		Pump Quote from Flow w ay Pumps					
		Richard Pitt					
		Weir Flow ay Pumps, Inc.					
		2494 S. Railroad Ave. Fresno, CA 93706 USA					
		C: (559) 348-7553					
		E: richard.plitt@w eirminerals.com					
		SUBTOTAL THIS SHEET					**$6,775,000.00**

QUANTITIES		**PRICES**	
BY	**CHECKED**	**BY**	**CHECKED**
Cary Southw orth	Scott Winterton	Cary Southw orth	Scott Winterton
DATE PREPARED	**PEER REVIEW / DATE**	**DATE PREPARED**	**PEER REVIEW / DATE**
06/09/14	S/6/16/2014	06/09/14	S/6/16/2014

BUREAU OF RECLAMATION

ESTIMATE WORKSHEET

FEATURE:	**PROJECT:**
2.7 mgd Water Treatment System located at San Juan River	**San Juan – Mexican Hat to Kayenta Regional Water Supply Appraisal Study**
	WOID: SJMH — **ESTIMATE LEVEL:** Appraisal
	REGION: UC — **UNIT PRICE LEVEL:** Jun-14
Civil	**FILE:** T:\Eng\Design\San Juan Pipeline\Appraisal Report\May 2014 TSC Comments\[Cost Estimate-BOR Format Final.xlsx]O&M

PLANT ACCOUNT	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
		Water Treament					
		Furnish and install water treatment plant					
		Rough Grading		1	ls	$5,000.00	$5,000.00
		Foundation Trench		450	yd3	$6.00	$2,700.00
		Concrete Footing		182	yd3	$330.00	$60,060.00
		Footing Backfill		208	yd3	$5.60	$1,164.80
		Compacting Footing		208	yd3	$5.25	$1,092.00
		Gravel Surfacing		120,000	ft2	$1.60	$192,000.00
		Finish Grading		13,400	yd2	$2.80	$37,520.00
		Fencing		1,580	lin ft	$28.00	$44,240.00
		Gate		2	ea	$1,450.00	$2,900.00
		Pipe Rock Trenching, Bedding, Backfill,		200	lin ft	$110.00	$22,000.00
		and pipe installation					
		Buried Valves - 16 inch		4	ea	$10,000.00	$40,000.00
		Pad Tranformer 26 13 16.10 0300		1	ea	$24,200.00	$24,200.00
		Buried Conduit		300	lin feet	$34.50	$10,350.00
		Electrical Grounding		500	lb	$30.50	$15,250.00
		Treatment Building		13650	ft2	$200.00	$2,730,000.00
		Includes 6 inch concrete slab, concrete					
		masonary unit walls, metal roof, lighting,					
		electrical, heating and cooling, 20 feet high					
		(2) Solids CONTACT CLARIFIER™ Mechanisms SCS71		1	ls	$585,000.00	$585,000.00
		Two (2) 60' Dia. x 17' SWD - Westech					
		Substitute Stainless Steel Parts for Mechanisms		1	ls	$215,000.00	$215,000.00
		Tanks for mechanisms furnish and install		2	ea	$474,000.00	$948,000.00
		2 - 360,000 gallon concrete tanks					
		Includes site grading, foundation trench,		2	ea	$60,000.00	$120,000.00
		gravel surfacing, buried piping and valves,					
		electrical, field welding and painting					
		Clarifier Quote from Goblesampson and Westech					
		Dave Ritter Phone: (801) 268-8790					
		dritter@goblesampson.com					
		SUBTOTAL THIS SHEET					**$5,056,476.80**

QUANTITIES		PRICES	
BY	**CHECKED**	**BY**	**CHECKED**
Cary Southworth	Scott Winterton	Cary Southworth	Scott Winterton
DATE PREPARED	**PEER REVIEW / DATE**	**DATE PREPARED**	**PEER REVIEW / DATE**
06/09/14	S/6/16/2014	06/09/14	S/6/16/2014

FEATURE:	**PROJECT:**	
Mirco/Ultra Filtration	**San Juan – Mexican Hat to Kayenta Regional Water Supply Appraisal Study**	
	WOID: SJMH	**ESTIMATE LEVEL:** Appraisal
	REGION: UC	**UNIT PRICE LEVEL:** Jun-14
Civil	**FILE:** T:\Eng\Design\San Juan Pipeline\Appraisal Report\May 2014 TSC Comments\[Cost Estimate-BOR Format Final.xlsx]O&M	

PLANT ACCOUNT	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
		Micro/Ultra Filtration - Westech		1	ls	$1,230,000.00	**$1,230,000.00**
		Each ultrafiltration skid will be supplied with					
		the following components (qty 4):					
		• One (1) powder coated, welded steel skid					
		• Twenty-five (25) Toray HFU-2020N ultrafiltration					
		module with 0.01 micron pore size					
		• One (1) feed / backwash magnetic flow meter					
		w / transmitter (Siemens 5100)					
		• Pneumatically-actuated and manual valves (Bray)					
		• Schedule 80 PVC/HDPE piping					
		• One (1) filtered water turbidimeter (Hach 1720E)					
		• One (1) UL 508 listed, NEMA 4 local junction box					
		One (1) clean-in-place (CIP) system will be supplied					
		with the following componets (qty 1):					
		• One (1) powder coated, welded steel skid					
		• One (1) HDPE CIP tank w / lid					
		• Two (2) chemical metering pumps for NaOCl and					
		citric acid (Prominent)					
		• One (1) CIP pump (MDM or equal)					
		• One (1) pH sensor (GF Signet)					
		• One (1) temperature sensor (Dwyer)					
		• One (1) heater (Chromalox)					
		• One (1) UL 508 listed, NEMA 4 local junction box					
		Four (4) feed pumps w/ premium efficiency					
		motor (Gould's or equivalent)					
		• One (1) backwash supply pump w/ premium					
		efficiency motor (Gould's or equivalent)					
		• Four (4) 200 micron, automatic					
		backwashing pre-strainers (Forsta or eq.)					
		• One (1) compressed air system consisting					
		of air compressor, receiver, filter and dryer(Quincy)					
		• One (1) treated water storage tank					
		Quote by: David Ritter Goblesampson					
		SUBTOTAL THIS SHEET					**$1,230,000.00**

QUANTITIES		PRICES	
BY	**CHECKED**	**BY**	**CHECKED**
Cary Southworth	Scott Winterton	Cary Southworth	Scott Winterton
DATE PREPARED	**PEER REVIEW / DATE**	**DATE PREPARED**	**PEER REVIEW / DATE**
06/09/14	S/6/16/2014	06/09/14	S/6/16/2014

BUREAU OF RECLAMATION	ESTIMATE WORKSHEET	SHEET 14 OF 17

FEATURE:	**PROJECT:**
Nanofilation	**San Juan – Mexican Hat to Kayenta Regional**
UV Lamps	**Water Supply Appraisal Study**
	WOID: SJMH — **ESTIMATE LEVEL:** Appraisal
	REGION: UC — **UNIT PRICE LEVEL:** Jun-14
Civil	**FILE:** T:\Eng\Design\San Juan Pipeline\Appraisal Report\May 2014 TSC Comments\[Cost Estimate-BOR Format Final.xlsx]O&M

PLANT ACCOUNT	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
		Micro/Ultra Filtration(cont.)					
		One (1) raw water turbidimeter (Hach 1720E)					
		• One (1) raw water temperature sensor (Dwyer)					
		• Feed pumps and Backwash pump VFDs					
		• One (1) UL 508 listed, NEMA 4 master control					
		panel including the following:					
		i. PLC – Allen Bradley					
		ii. Door mounted, color touchscreen					
		iii. Contactors – ABB					
		iv. Solenoid valve block					
		v. Ethernet switch					
		Quote by: David Ritter Goblesampson					
		Nano Filtration					
		Siemens Aquarius Model 3640 gpm		1	ls	$1,950,000.00	**$1,950,000.00**
		One four train system, capable of running					
		1820 gpm on one train, Includes Steel					
		Tanks, alum and polymer feed system					
		3000 gallon FRP coagulant tank, 1500 gallon FRP					
		polymer tank, flocculator with variable pitch rotor					
		and drive, 7.5 degree tube settler, mixed media					
		filter and underdrain system, backwash blower,					
		auto valves, turbidimeter, local PLC					
		UV - Lamp Unit		1	ls	$215,000.00	**$215,000.00**
		Includes units and lamps					
		Quote: Mike Brown					
		mike@coombshopkins.com					
		Trojan Swift 4L12 UV Unit 1840 gpm unit					
		1 operating and 1 space unit					
		SUBTOTAL THIS SHEET					**$2,165,000.00**

QUANTITIES		PRICES	
BY	**CHECKED**	**BY**	**CHECKED**
Cary Southworth	Scott Winterton	Cary Southworth	Scott Winterton
DATE PREPARED	**PEER REVIEW / DATE**	**DATE PREPARED**	**PEER REVIEW / DATE**
06/09/14	S/6/16/2014	06/09/14	S/6/16/2014

BUREAU OF RECLAMATION	ESTIMATE WORKSHEET	SHEET 15 OF 17

FEATURE:	**PROJECT:**
Backwash Treatment	**San Juan – Mexican Hat to Kayenta Regional**
Belt Press for Sludge Disposal	**Water Supply Appraisal Study**
Clear Well	**WOID:** SJMH — **ESTIMATE LEVEL:** Appraisal
Backwash Equalization Tank	**REGION:** UC — **UNIT PRICE LEVEL:** Jun-14
Civil	**FILE:** T:\Eng\Design\San Juan Pipeline\Appraisal Report\May 2014 TSC Comments\[Cost Estimate-BOR Format Final.xlsx]O&M

PLANT ACCOUNT	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
		Backwash Water Treatment System					
		Siemens Contrafast Concentric System					
		Includes 680 gpm backwash system, steel		1	ls	$1,500,000.00	$1,500,000.00
		treating basin sandblasted and primed, center					
		column and reactor assembly, steel support,					
		bridge with steel checker flooring and hand rail,					
		stack drive variable speed flocculator assembly,					
		two sludge collection scraper arms,					
		peripheral launder system, tube settler, automatic					
		sludge blow down control					
		Belt Press					
		Siemens MDS 800 Skid Assembly Belt Press		1	ls	$280,000.00	$280,000.00
		Includes: Belt Press frame and pans					
		air compressor, piping assembly, 1.8 hp					
		air compressor, polymer blending,15-75 hp					
		progressive cavity pump, 3.0 hp					
		centrifical pump					
		12 gpm system					
		Quote by Mike Spring, 616-748-7609					
		Siemens Water Technologies					
		2155 112th Ave, Holland, MI					
		Clear Well Tank					
		54,600 gallons					
		Dimensions 40' long X 20' wide X 10' high, 1 foot					
		Concrete		104	yd3	$390.00	$40,560.00
		Cement		362	tons	$180.00	$65,160.00
		Reinforcement		13600	lbs	$1.35	$18,360.00
		Backwash Equalization Tank 20,000 gallons					
		Concrete 20' long X 20' wide X 8' high, 1 foot		53	yd3	$390.00	$20,670.00
		Cement		184	tons	$180.00	$33,120.00
		Reinforcement		6900	lbs	$1.35	$9,315.00
		SUBTOTAL THIS SHEET					**$1,967,185.00**

QUANTITIES		PRICES	
BY	CHECKED	BY	CHECKED
Cary Southworth	Scott Winterton	Cary Southworth	Scott Winterton
DATE PREPARED	PEER REVIEW / DATE	DATE PREPARED	PEER REVIEW / DATE
06/09/14	S/6/16/2014	06/09/14	S/6/16/2014

BUREAU OF RECLAMATION	ESTIMATE WORKSHEET	SHEET 16 OF 17

FEATURE:	**PROJECT:**
Secondary Treatment at Monument Valley and Kayenta	**San Juan – Mexican Hat to Kayenta Regional Water Supply Appraisal Study**
Transmission Power Line	**WOID:** SJMH · **ESTIMATE LEVEL:** Appraisal
Surge Tanks at Monument Pass and Kayenta	**REGION:** UC · **UNIT PRICE LEVEL:** Jun-14
Civil	**FILE:** T:\Eng\Design\San Juan Pipeline\Appraisal Report\May 2014 TSC Comments\[Cost Estimate-BOR Format Final.xlsx]Pipe 6

PLANT ACCOUNT	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
		Secondary Treatment at Distribution					
		Includes: 600 Square Foot Pre-engineered		1	ls	$100,000.00	**$100,000**
		Metal Building, 2 - Stainless Steel					
		Strainer, 2 - Bag Filter, 1 - Chlorine Monitor,					
		1 - Chlorine Booster/injection Equipment					
		Includes: 800 Square Foot Pre-engineered		1	ls	$150,000.00	**$150,000**
		Metal Building, 2 - Stainless Steel					
		Strainer, 2 - Bag Filter, 1 - Chlorine Monitor,					
		1 - Chlorine Booster/Injection Equipment					
		Transmission Lines - 3 phase power		15	w mi	$131,000.00	**$1,965,000**
		60 percent rock, 40 percent common					
		Means 33 71 13, no clearing required,					
		25 foot wood poles, 6 foot cross arms					
		Surge Tank - Monument Pass		1	ls	$175,000.00	**$175,000**
		Includes 30,000 gallon steel tank to handle negative					
		transient pressures					
		Surge Tank - Monument Valley to Kayenta		1	ls	$175,000.00	**$175,000**
		Assume surge tanks similar to hydropneumatic					
		tanks used for pumping plants					
		SUBTOTAL THIS SHEET					**$2,565,000**

QUANTITIES		PRICES	
BY	**CHECKED**	**BY**	**CHECKED**
Cary Southworth	Scott Winterton	Cary Southworth	Scott Winterton
DATE PREPARED	**PEER REVIEW / DATE**	**DATE PREPARED**	**PEER REVIEW / DATE**
06/09/14	S/6/16/2014	06/09/14	S/6/16/2014

BUREAU OF RECLAMATION	ESTIMATE WORKSHEET	SHEET 17 OF 17

FEATURE:	PROJECT:
Water Pipeline River Intake Structure & Pretreatment Steel Storage Tanks Pumping Plants Water Treatment Plants Civil	San Juan – Mexican Hat to Kayenta Regional Water Supply Appraisal Study
	WOID: SJMH — ESTIMATE LEVEL: Appraisal
	REGION: UC — UNIT PRICE LEVEL: Jun-14
	FILE: T:\Eng\Design\San Juan Pipeline\Appraisal Report\May 2014 TSC Comments\[Cost Estimate-BOR Format Final.xlsx]O&M

PLANT ACCOUNT	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
		Subtotal Sheet 1 thru 5					
		Sheet 1					$1,916,650.00
		Sheet 2					$2,083,960.00
		Sheet 3					$456,540.00
		Sheet 4					$3,466,955.00
		Sheet 5					$3,612,245.00
		Sheet 6					$3,021,125.00
		Sheet 7					$3,867,495.00
		Sheet 8					$2,525,325.00
		Sheet 9					$6,117,000.00
		Sheet 10					$1,279,290.00
		Sheet 11					$6,775,000.00
		Sheet 12					$5,056,476.80
		Sheet 13					$1,230,000.00
		Sheet 14					$2,165,000.00
		Sheet 15					$1,967,185.00
		Sheet 16					$2,565,000.00
		Subtotal 1 $48,105,246.80					
		SCADA SYSTEM (3%)		1	ls	$1,400,000.00	$1,400,000.00
		Mobilization and Bonds (5%)		1	ls	$2,400,000.00	$2,400,000.00
		Design Contingencies (15%)		1	ls	$7,400,000.00	$7,400,000.00
		Subtotal 2 $59,305,246.80					
		Procurement Strategies (2%)		1	ls	$1,100,000.00	$1,100,000.00
		Navajo Nation Sales Tax (5%)		1	ls	$2,900,000.00	$2,900,000.00
		Contract Costs (unit price level Jun 2014)				$63,400,000.00	
		Construction Contingencies (25%)		1	ls	$15,800,000.00	$15,800,000.00
		Field Cost Subtotal				$80,000,000.00	
		Field Cost w / Escalation to Notice to Proceed (3%) per yr		1	ls	$13,000,000.00	$13,000,000.00
		Escalation over 5 year period 2014 to 2019					
		Non-contract costs (25%)		1	ls	$24,000,000.00	$24,000,000.00
		Total Cost $117,000,000					
		SUBTOTAL THIS SHEET					$117,000,000.00

QUANTITIES		PRICES	
BY	CHECKED	BY	CHECKED
Cary Southworth	Scott Winterton	Cary Southworth	Scott Winterton
DATE PREPARED	PEER REVIEW / DATE	DATE PREPARED	PEER REVIEW / DATE
06/09/14	S/6/16/2014	06/09/14	S/6/16/2014

Table 9-2. Annual Operation & Maintenance Cost Estimates

Annual OM&R Cost Estimates	
[Pop. Growth Rate = 1.3% & Usage = 160 gpcd]	2060 Usage
Item	**Cost Estimate[1]**
Pumping Costs (raw water pipeline)	$620,000
Pumping Costs (distribution system)	$10,000
Power O&M (6 % of construction cost)	$118,000
Storage O&M (4% of total storage costs)	$165,000
Pumping Plant O&M (4% of total pumping costs)	$271,000
Pipeline O&M (0.5% of total pipeline costs)	$115,000
Water Treatment O&M (6.0% of total water treatment costs)	$640,000
Intake Structure O&M (6.0% of total intake costs)	$77,000
Total Annual O&M Costs:	2,020,000

an appraisal level of analysis. Estimates updated for July 2011 from January 2008 based on BOR Construction Cost Trends.

9.1 General Information

Cost estimates in this study are appraisal level. Estimates were obtained from a variety of sources, including previous water supply studies conducted in the region. For some items, a combination of sources was used in order to try and obtain the most likely estimate for this particular project. All costs are in 2014 dollars. Estimates from older sources were adjusted to 2014 dollars based on BOR Construction Cost Trends and RSMeans Heavy Construction Cost Data.

Estimates for mobilization (5 %), design contingency (15 %), procurement strategies (2 %), construction contingencies (25.0 %), field cost escalation to notice to proceed(2%) and non-contract costs(25%) are consistent with Reclamation guidelines for appraisal level reports. These percentages are fairly consistent with estimates from other water supply studies in the region. Non-contract costs, as shown in Table 12-1 (Reclamation, 2002, p. 26), are typically estimated based on a percentage of the construction costs.

Table 9-3. Percentage of Non-Contract Costs.

Activity	Percent of Non-Contract Costs
Planning / Land Acquisition	5.0
Investigations	3.5
Design and specifications	3.0
Contract administration	7.0

Cultural resources	1.0
Environmental permits	5.0
Total (rounded)	25

General cost considerations and assumptions for various project components are discussed in the following sections.

9.2 Intake Structure

At this stage in the study the specific type and design of intake structure has not been determined. For the purposes of this study it is assumed the intake structure would be a metal platform that is next to or cantilevers out over the river. The structure would have a platform that would house the pumps and piping for the intake and would be housed in a small enclosed metal shelter to protect the pumps and workers from the elements. As a result, one option was selected from the matrix that may prove to be the best alternative. This option is for the rotating self cleaning screen that can be lowered or raised into the river. Estimated cost for this option after gathering information from Lakos that provides the self cleaning screens is presented in the estimate totaling approximately $1.3 millon. Along with the intake the system would include automatic sand separators to remove the majority of the sediment prior to conventional treatment. Depending on which type of structure is selected, the estimate would naturally change somewhat. It is assumed that required pumping to lift the water from the river to the sand separator located on the bench next the existing water treatment plant is included in the intake cost estimate.

9.3 Pumping Plant

Cost estimate considerations in this section refer to the main pumping plant located at the San Juan River after sediment removal and treatment. The capacity of this plant is 4.05 cfs (2060 demands) with 480 feet of head required. The cost estimate for this plant as well as the other booster station pump plants was determined based on a cost of $1.075 million for the pumping plant required. This cost includes the site work, building, piping, valves, 3 pumps, electrical, standby generator, hydro pneumatic tanks and power connections. The pumping plant at the river could be integrated with the clear well to minimize cost and footprint.

9.4 Water Pipeline

The raw water pipeline is assumed to be 16-inch PVC pipe to the Monument Valley Water Treatment Facility and then will be reduced to 14-inch to continue on to Kayenta. Appurtenant structures on the pipeline are included with the design contingencies (15%).

9.5 Booster Station(s)

Similar to the main pumping plant, booster station costs are estimated based on $1.15 million per pumping plant. This cost includes the site work, building, piping, valves, 3 pumps, electrical and power connections.. In addition, each booster station requires a forebay tank. These tanks are assumed to be 12,000 gallons with a cost estimate of $75,000 for each one, based on information from the *North Central Arizona Water Supply Study*. In the next level of study, each of these tanks would be sized on an individual basis.

9.6 Water Treatment Plant

The water treatment plant costs are based on quotes that were received from manufacturers on equipment to meet the drinking water standards. The cost of the plant includes a solid contact clarifier, micro/ultra filtration, UV, and Nano filtration. The cost of the treatment plant also includes dealing with the waste by the use of a concentric clarifier and belt press. The overall cost of the treatment system is $10.4 million.

Cost estimate for OM&R costs were developed from percentage of construction cost and independently calculated and compared from EPA's Technologies and Cost Document for Final Long Term 2 Enhanced Surface Water Treatment Rule and Final Stage 2 Disinfectants and Disinfection Byproducts Rule published in 2005 to determine if the percentage represents similar costs. Since the comparison was similar the percentage of construction was applied for the O,M&R costs.

As outlined in EPA's Technologies and Cost Document for Final Long Term 2 Enhanced Surface Water Treatment Rule and Final Stage 2 Disinfectants and Disinfection Byproducts Rule O&M costs shown would include operator training, acid/anti scaling chemicals, Microfiltration membrane replacement, UV bulb replacement, Nanofiltration membrane replacement, cartridge replacement, labor, and power. Membrane replacement would be approximately 20 percent of the Mico and Nano filtration system cost.

9.7 Storage Tank

The storage tanks are sized based on 2020 demands with the assumption that they would be expanded at that time as necessary. The tanks are assumed to be steel and the cost estimate is projected from RSMeans data. A ring concrete foundation 4 foot in depth which would be in filled with compacted with gravel material was also included in the costs.

9.8 Distribution System

The distribution system consists of PVC pipelines of varying diameters and lengths. Estimates were calculated using RSMeans 2014 costs. Appurtenant structures on the pipeline are included with the design contingency of (15%).

9.9 O&M Costs

Annual operation and maintenance cost estimates are based on information in the technical memorandum, *Utah Navajo Municipal Water Projects, 2007*, and are shown in Table 12-4. Annual pumping costs are treated separately in the following section.

Table 9-4. Percentage of O&M Costs.

O&M Cost	Estimate
Power	6.0 % of total power line costs
Storage	4.0% of total storage costs
Pumping Plant	4.0% of total pumping plant costs
Pipeline	0.5% of total pipeline costs
Water Treatment	6.0% of total water treatment costs
Intake Structure	6.0% of total intake structure costs

9.10 Annual Pumping Costs

The annual cost of pumping water from the San Juan River to the water treatment plants was estimated based on the following assumptions:

- 16-inch and 14-inch, 305 pressure class PVC pipe with an actual inside diameter of 14.91 and 13.11 respectively. Some savings could be realized from a more refined design that accounts for larger inside diameters of the lower pressure class of pipe.
- Assumed Hazen-Williams roughness coefficient of 150 for PVC pipe
- Friction loss calculated from the Hazen-Williams equation
- San Juan River elevation of 4,065 ft
- Pipe length of 40 miles
- 80% pump efficiency
- 80% motor efficiency
- Energy charge of $0.04 per kW-h (current NTUA power cost from WAPA)
- Monthly demand charge of $6.00 per kW (current NTUA utility rate for general power)
- Because of the long length of the pipeline with long straight runs, it was assumed that friction losses would far exceed minor losses; therefore, minor losses were ignored.

Using the assumed San Juan River and water treatment plant elevations, a static lift of 1,595 feet was calculated. The friction slope was calculated by the Hazen-Williams equation, from which the friction head loss was determined and added to the static lift. For full build-out, the friction head loss was 612 feet, producing a total dynamic head of 2,896 feet. The total input horsepower to the system was then calculated based on the assumed pump and motor efficiencies above. Pumping time was determined by dividing the annual demand by the flow rate. Pumping time is expressed as the number of days pumping at 24 hours per day. The corresponding annual power demand (kW-h) was calculated, from which annual power costs (Table 9-5) were determine based on current NTUA rates for purchase power from Western Area Power Administration.

Table 9-5. Annual pumping costs.

Year:	2010	2060
Design Flow (MGD):	1.37	2.61
Velocity (fps):	1.75	3.34
Head Loss (ft):	147.9	612
TDH (ft):	2303	2,898
Input Horsepower:	846	1892
kW:	655	1411
Annual Pumping Cost:	**$490,000**	**$630,000**

The area of the project is located in one of the best areas in the country for the generation of power on an annual basis. The pumping of the water would require an approximate 1700 kW DC grid tie solar generation system. The system could be installed with panels at each pumping plant to limit distribution line costs. Not all power would be provided by the solar system, but it would offset the purchase of some of the electrical costs.

Based on methodology provided by Solar-Estimate.org, the area of the project would produce approximately 2,000 kWh/kW-year solar radiance. This radiance factor is reduced by 78 percent loss factor to provide the factor needed to calculate the amount of solar energy that could be produced, which is calculated at 1,560 kWh/kW-year solar radiance.

Energy Produced:

1,560 kWh/kW-year X 1,700 kW = 2,652,000 kWh-year

Offsetting the purchase of power:

$0.04 X 2,652,000 kWh = $106,080.00

This amount could be used to offset the purchase of the power and reduce the overall O, M& R costs of the project. Building a solar system of this size would take approximately 5 to 6 acres of land and have a capital cost of approximately 5 million dollars. Use of solar power would reduce the annual power costs from $630,000 to approximately $525,000 per year.

In line hydropower is also something that would need to be studied further to determine if it is a viable alternative for reducing the O, M & R costs for the project.

10.0 Ability to Pay, Willingness to Pay and Cost Benefit Analysis

10.1 General

Analyses of ability to pay, willingness to pay, and benefits for public water are presented in this chapter. This study covers the regional water demand for the areas surrounding Monument Valley in Utah and Kayenta in Arizona. Information on households in these areas show there is a distinct difference in household income. Location plays a large part for employment opportunities and is reflected in the outlying areas, outside of the Kayenta Township. It should be noted that water use patterns on the Navajo Nation, including the area of study, is significantly different from that of surrounding off-Reservation communities. In particular, approximately 40% of Navajo Nation residents have no piped water supply and rely solely on hauling water to their homes [Navajo Department of Water Resources, 2000, p. ES-3].

The average water usage for the residents that haul water is about 10 gallons per capita per day, the bare minimum required for survival. The average water usage for residents of the area with piped water is about 45 gallons per capita per day compared to 100+ gallons per capita per day in off-reservation communities.

10.2 Ability to Pay Concept

The ability to pay in a water supply context refers to the affordability of a water system. The ability to pay concept can be used by an agency to determine a threshold which triggers additional funding assistance and limits requirements of the beneficiaries to pay. Conversely, the concept can also be used to determine if the water users have the resources necessary to reach a threshold that the agency has established for a project to be considered viable. For instance, it may not be practical to construct projects that have such a large operation and maintenance expense that the intended water users are not able to afford the water provided.

This dilemma is especially acute for the Navajo Nation, where a significant portion of the population has very low income and yet would require public water system that, on a unit household basis, would be expensive to construct, operate, and maintain. For instance, the IHS, which requires no capital repayment for the systems constructed, still has established guidelines on project feasibility based on the unit cost per house and the unit cost for operation and maintenance. This situation has resulted in numerous Navajo households that are still lacking adequate access to water infrastructure. From a policy perspective, the

Navajo Nation leadership has continued to express support for the goal of serving all households on the Navajo Nation water directly from a public water system in the future.

There are a variety of methods that can be used to estimate the ability of the water users to pay for domestic water supplies. Reclamations Navajo-Gallup EIS (2009), refers to more than 10 different methods used to determine how much project water system beneficiaries should pay. Each of these methods is tailored to the specific circumstances of the communities being served.

The challenge for Reclamation, as water projects like this one move towards feasibility level of investigation, is to develop a methodology that is suited to the conditions in Indian country in general, and for the Navajo Nation in particular. Using several well-established criteria frequently used for ability to pay studies, these communities are extreme outliers. For instance, these households have significantly more people per household, which complicates methods based on median household incomes. These households have disproportionately less discretionary income. Furthermore, the current cost of water hauling in terms of time, money and wear and tear creates an enormous burden on these household budgets. These unit water hauling costs on their own would imply that rural Navajo people must be among the most affluent water uses in the United States, when the exact opposite is true. In addition, these communities are already suffering from a history of infrastructure deficiency.

Water is not the only lacking commodity in this area, many of these homes are also without adequate power and sewer. Consequently, methodologies based too heavily on the current conditions may result in a decision which may actually prevent these communities from prospering in the future. Whether they are formally established or not, thresholds for projects exist. Systems that expand beyond a practical point soon deteriorate. It is common sense that water projects must be initiated and implemented so that communities can incrementally afford their operation, maintenance and replacement costs. The challenge for Reclamation is to develop a methodology that accurately characterizes the circumstances facing these communities, and contributes to the positive changes that Navajo Nation and Reclamation are striving to achieve.

This study uses three methods to estimate the water users' ability to pay:

- **Simplified Budgeting Approach Method**. In applying this approach to the household sector, water payments are calculated as a percentage of discretionary income for municipalities throughout New Mexico and those percentages are applied to the study area. Discretionary income is defined as the median household income minus the estimated cost of food, housing, apparel, transportation, healthcare, and personal insurance and pensions. The upper end of the range of estimated water payments as a percentage of discretionary household income is then applied to the estimated discretionary income of households in the study area.

  In an effort to be consistent with similar studies conducted by the Bureau of

Reclamation, this ability to pay references estimates used in the Jicarilla Apache Nation Municipal and Industrial Water Supply Ability to Pay Analysis dated August 2011. Although this study was based on information collected for cities in the New Mexico area, the data is reasonably comparable to Arizona communities such as Kayenta Township, but may not comparably represent the outlying areas of the Kayenta Chapter, such as Cane Valley, and the Oljato Chapter due to higher density of family members per household and homes widely dispersed. Many of the individuals in these outlying areas area elderly who depend on family members that support their daily care and provide for them.

Also, similar water use and cost information used in the New Mexico area were not readily available for Arizona and Utah. The additional time and cost to be incurred in collecting the necessary information did not warrant pursuant of this option. Therefore, the range of ability to pay percentages used in the Jicarilla report, while not completely accurate, is used for this report. The author acknowledges that this approach may not accurately represent those in outlying areas with higher family household occupation and lower income.

- **EPA Threshold of Affordability Method.** For this appraisal level analysis, the EPA threshold of 2.5 percent of median household income is used as a measure of payment capability for residential water users. Rates over 2.5 percent of median income are generally considered to be unaffordable.

- **Estimated Current Household Water Charge Method.** This analysis estimates the actual cost to haul water to residential homes for the approximate 40% of Navajo residents currently without reliable water service. While other methods may rely more on chosen thresholds of affordability, this method represents the reality of what people who haul water actually pay to survive in their chosen locations.

10.3 Ability to Pay of Kayenta Township Households Using Simplified Budgeting

The ability to pay for domestic water service was completed by applying the percentage of discretionary income spent on domestic water supplies and the maximum percentage of water supply expenditures for municipalities throughout New Mexico to data for Kayenta Township households as an estimated range of household ability to pay.

The highest percentage and the top 10% from the range of percentages of discretionary income spent on water service for the 19 New Mexico municipalities was used for the ability to pay in the Jicarilla study. The same percentages would be used for this analysis. Table 10-1 shows the results for the highest water cost as a percentage of discretionary income and for the top 10% of water cost percentage for the New Mexico municipalities evaluated.

Table 10-1. Water cost as a percentage of discretionary income [Jicarilla Study, Aug. 2011]

Ability to pay Definition	Water cost as a percentage of discretionary income
Highest	7.802%
Top 10%	5.512%

It is important to note that Table 10-1 represents water payments made by households. Therefore the highest percentages are most likely to approach actual ability to pay since they represent the highest of water bills paid. It is also noteworthy that the percentages presented in Table 10-1 are averages and there would be some low income households in each municipality that cannot pay the average percentage of discretionary income for their water supplies and there would be some higher income households that can pay more than the average percentage.

In order to estimate the ability to pay of Kayenta Township and Oljato-Monument Valley households, representative household income and expenditures must be estimated. The total household income in the Kayenta Township and the outlying area near Monument Valley were estimated using median household income data from the U.S. Census Bureau. Table 10-2 shows the estimated median household income in the area. The total household income in the region is $59.9 million. Total income is used in this analysis to avoid representing ability to pay in terms of individual household expenditures. It should be noted that the Monument Valley-Oljato area in Utah have less median household income, when compared to the Kayenta Township.

Table 10-2. Estimated Median Household Income for the Kayenta Township and Oljato Monument Valley

Communities	Total Household[1]	Median Household Income[2]	Total Household Income
Kayenta	1602	$31,837	$51,002,874
Oljato-Monument Valley	287	$31,218	$8,959,566
TOTAL			$59,962,440

Source: [1]- U.S. Census Bureau. 2010 Census and information gathered by BOR.

Source: [2]- U.S. Census Bureau. American Community Survey, 2005-2009 ACS 5-year estimates.

Detailed household expenditures by region provided by the Bureau of Labor Statistics in their Consumer Expenditure Survey (CES) were used to estimate the percentage of income before taxes that is spent on necessary goods and services for the Kayenta Township and the other areas of the region.

These necessary goods and services include food, housing, apparel, transportation, healthcare, personal insurance and pensions. These percentages were applied to the total income to determine the discretionary income for the area as shown in Table 10-3.

Table 10-3. Estimated discretionary income for the Kayenta Township and Oljato-Monument Valley

Municipality	Income spent	Kayenta	Oljato-MV	Estimate
Total household income	-	$51,002,874	$8,959,566	$59,962,440
Food	10.48%	$5,345,101	$938,963	$6,284,064
Housing	27.23%	$13,888,083	$2,439,690	$16,327,773
Apparel	3.17%	$1,616,791	$284,018	$1,900,809
Transportation	15.09%	$7,696,334	$1,351,999	$9,048,333
Health Care	4.37%	$2,228,826	$391,533	$2,620,359
Insurance	8.64%	$4,406,648	$774,107	$5,180,755
Discretionary income	-	$15,821,092	$2,779,257	$18,600,349

The estimated ability to pay of the household sector based on the discretionary income estimate for the Kayenta District and the water cost percentages for New Mexico municipalities from Table 10-1 is presented in Table 10-4.

Table 10-4. Estimated ability to pay of Kayenta households for water supplies

Ability to Pay Definition	Highest	Top 10%
Estimated Kayenta Discretionary Income	$15,821,092	$15,821,092
Estimated Oljato-MV discretionary income	$2,779,257	$2,779,257
Estimated Total discretionary income	$18,600,349	$18,600,349
Water cost as a percentage of discretionary income	7.802%	5.512%

Estimated Kayenta Ability to pay Annual	$1,234,361	$872,058
Estimated Oljato-MV Ability to pay Annual	$216,837	$153,192
Estimated Total Ability to pay Annual	$1,451,199	$1,025,251
Estimated Ability to pay Monthly	$120,933	$85,437

Ability to Pay of Kayenta District Business and Industry Using Simplified Budgeting

Estimating the ability to pay of businesses and industries for water supplies is complicated by variation in type of business, variation in the importance of water costs as a cost of production by type of business and size of business, and difficulty in estimating representative revenues and costs for specific businesses. Additionally, there is uncertainty in the appropriate return on investment that should be allowed for a commercial enterprise and considered not part of ability to pay. As a result of these complexities, the approach used to estimate the Kayenta District business and industry ability to pay is to apply essentially the same method used for household ability to pay except that gross taxable revenues are used in place of median household income. It is assumed that using water payments as a percentage of gross taxable business receipts would account for differing scales of business activity and that average use over a variety of business types would lead to a representative percentage that can be applied over all businesses combined.

Similar to the household approach, commercial water payments are calculated as a percentage of gross taxable business receipts for municipalities throughout New Mexico and those percentages are applied to the study area. The upper end of the range of estimated water payments is then applied to the gross taxable business receipts for the study area. There is a large amount of variation in water use between different commercial sectors as well as within sectors due to differences in the size of establishments. However, very costly and time consuming surveys of commercial and industrial water users outside and within the study region would need to be undertaken to fully account for variation in business size and type. It is assumed that using water payments as a percentage of gross taxable business receipts would account for differing scales of business activity and that average use over a variety of business types would lead to a representative percentage that can be applied over all businesses combined.

The highest percentage and the top 10% from the range of percentages of taxable gross receipts spent on water service for 16 New Mexico municipalities evaluated for the Jicarilla Study was used for the ability to pay in this study. Table 10-5 shows the results for the highest water cost as a percentage of taxable gross receipts and for the top 10% of water cost percentage for the New Mexico municipalities evaluated.

Table 10-5. Water cost as a percentage of gross business receipts [Jicarilla Study, Aug. 2011]

Category	Water cost as a percentage of gross taxable business receipts
Highest	5.371%
Top 10%	2.550%

The percentages in Table 10-5 represent actual water payments, therefore the highest percentages are most likely to approach actual ability to pay since they represent the highest water bill percentages actually paid. Additionally, these percentages are averages and less profitable businesses would not be able to afford the estimated amount while more profitable businesses can pay more than the average ability to pay.

The Arizona Taxation & Revenue Department data for 2010 indicate total taxable gross receipts of $1.21 Billion for the Navajo County of which Kayenta District is a part. No information on the Kayenta District was available at the department. Departmental staff noted that they only keep track of these statistics on a county level. The total number of businesses recorded in Navajo County that generated the gross receipts equaled 5,777. This results in an average taxable gross receipt per business in 2010 of $209,802.97. The total number of businesses who paid water services in 2010 is 50 [NTUA 2010 Utility Statistics]. This results in total taxable gross receipts of $10,490,148 for the Kayenta Township. For the Oljato-Monument Valley area, five businesses paid $8.25M total gross receipts for the same period. The percentages in Table 10-5 would be applied to the gross taxable receipts estimate to estimate commercial ability to pay. The results are shown in Table 10-6.

Table 10-6. Estimated Kayenta Township & Oljato-Monument Valley commercial ability to pay based on water expenditures as a percentage of gross taxable business receipts

Ability to pay Definition	Estimated Kayenta gross taxable receipts	Estimated Oljato-MV gross taxable receipts	Estimated TOTAL gross taxable receipts	Ability to pay percentages	Estimated Annual ability to
Highest	$10,490,148	$8,250,000	$18,740,148	7.802%	$1,462,106
Top 10%	$10,490,148	$8,250,000	$18,740,148	5.512%	$1,032,957

Total Estimated Ability to Pay Using Simplified Budgeting

A range of ability to pay for Kayenta Township and Oljato-Monument Valley households and commercial establishments based on the estimates described in the Jicarilla Apache Nation Study is presented in Table 10-7. The average of $2,913,305 and $2,058,208 shown in Table 10-7 is $2,485,756. It is noted that Ray Benally of the Navajo Nation Department of Water Resources believes the methodology used here generates a greater ATP than the residents of the Navajo Nation can realistically afford.

Table 10-7. Kayenta Township ability to pay based on percentages of discretionary household income and gross taxable business receipts

Sector	Estimated Aggregate Ability to pay HIGH	Estimated Aggregate Ability to pay LOW
Household Supply	$1,451,199	$1,025,251
Commercial Supply	$1,462,106	$1,032,957
TOTAL	**$2,913,305**	**$2,058,208**

The estimated capital cost for the San Juan Pipeline Project is $117M plus initial annual operation and maintenance cost of approximately $1.82M. The annual cost to the area residents would be $7.04 million in the first year with annual increases until 2060, with a full repayment at 3.75 percent interest over a 50 year period. A 35% repayment plan would cost $2.46M and a 25% repayment deal would cost $1.76M, which includes annual OM&R and interest payments. Table 10-8 shows the total annual cost for each option including OM&R cost.

Table 10-8. Kayenta District Annual Repayment Options 2010

	100%	35%	25%
Capital Cost	$117,000,000		
Annual Payment 2010	$5,220,000	$1,827,000	$1,305,000
OM&R 2010	$1,820,500	$637,175	$455,125
TOTAL ANNUAL COST[2]	**$7,040,500**	**$2,464,175**	**$1,760,125**

[1]*Interest During Construction is based on a 4 year construction schedule at 3.75% interest.*

[2]*This payment options for Capital Cost are based on a 3.75 % interest rate over a 50 year period.*

Kayenta Township households are currently paying an average of $5.90 per thousand gallons of piped water per year [NTUA 2010 Utility Statistics]. As shown in Table 10-7, the household share for the project is approximately 52% of the total cost. From Table 10-8, assuming a 25% cost share, the households would be paying $915,265 [0.52 x $1.76M = $915,265] to cover the annual payment. This translates to an average monthly payment per household of $36.36 [$915,265 / 2216/12 = $34.42] assuming that 100% of the current households would be paying for the proposed project. The proposed project would increase the water use per piped water resident from 45 gpcd to 160 gpcd. The cost per thousand gallon of water for residents for the proposed project at a 25% cost share would be $1.96 [$915,265 / (2216 x 3.6 x 160 x 365 / 1,000) = $1.96].

If the project were to be paid at 100% cost by the local residents and businesses, then the cost per thousand gallon of water per year for the proposed project at a 0% cost share would be $15.11 [$7.04M / (2216 x 3.6 x 160 x 365 / 1,000) = $15.11]. The household share of the cost per thousand gallons would be $7.85 [0.52 x $15.11 = $7.85] compared to the $5.90 per thousand gallons they are currently paying.

It should be noted that conversations with the Navajo Nation have shown that the Nation is not planning on cost sharing for the OM&R. If no outside funding is available to assist with OM&R, the current population would have to pay 100% of the OM&R cost. The household share for the OM&R would be $946,660 [0.52 x $1.82= $946,660]. This translates to an average monthly OM&R payment per household of $35.60 [$94660/ 2216/12 = $35.60] assuming that 100% of the current households would be paying for the service. The initial cost of OM&R for the project is $1.82MM and both the businesses and residents will have to share this cost. The high estimated ability to pay as shown in Table 10-7 would cover for the cost of OM&R, with the low estimate showing an inability to pay.

The estimated ability to pay based on percentages of discretionary household income and percentages of gross taxable business receipts indicates that the low estimate ability to pay for the Kayenta District and Oljato-Monument Valley area in Table 10-7 would cover for the annual cost of the system with the 25% cost share as shown in Table 10-8. The high estimate ability to pay in Table 10-7 would cover the cost of the system with a 35% cost share as shown in Table 10-8. As shown in Table 10-9, if no cost sharing or OM&R assistance is made available and 100 percent of the cost of the project is to be covered, the current residents and businesses would not be able to afford the cost of this project. Paying for the full annual OM&R would allow payment of approximately 5.0% of the Capital and Interest During Construction, therefore, this shows that the project would need to be subsidized beyond a 75% federal cost share to be considered affordable, unless the current water charges method is used to estimate the ability to pay. This is based on using the upper limit of calculated Aggregate Ability to Pay.

Table 10-9. Kayenta District Annual Repayment Options with 100% OM&R Payments

	100%	**35%**	**25%**	**ATP High[3]**
Capital Cost	$117,000,000			
Annual Payment 2010	$5,220,000	$1,827,000	$1,305,000	
OM&R 2010	$1,820,500	$637,175	$455,125	
TOTAL ANNUAL COST[2]	**$7,040,500**	**$2,464,175**	**$1,760,125**	**$2,913,305**

[2]This payment option for Capital Cost is based on a 3.75% interest rate over a 30 year period.
[3]This column shows how much the community's upper limit aggregate Ability To Pay can afford after paying 100% OM&R.

10.4 EPA Threshold of Affordability Method

Using the area's estimated median household income of $59,962,440 and taxable business receipts of $18,740,148, we have a gross annual income of approximately $78,702,588. EPA affordability guidelines specify that communities should be able to pay 2.5% of gross earnings for incoming water service ($78,702,588 * .025 = $1,967,564). The $1,451,199 identified as the recipients average Ability to Pay in the Simplified Budget Approach is out of line by about 26% with the EPA affordability guidelines showing $1,967,564.

10.5 Estimated Current Household Water Charges Method

With nearly 40% of the residents in the Navajo Nation not having access to clean water in their homes, the average water usage for the residents that have to haul water from outside sources is about 10 gallons per capita per day, the bare minimum required for survival. The average water usage for residents of the area with piped water is about 45 gallons per capita per day compared to 160+ gallons per capita per day in off-Reservation communities.

According to the *Navajo Gallup Economic Benefit/Cost Analysis report in Appendix D Part II, dated October 1, 2007*, it estimated that the total economic cost for hauling water is approximately $113.00 per thousand gallons in 2005 dollars. Converting this to 2014 dollars using the RSMeans Cost Index of 1.27 results in $143 per thousand gallons. Using Ray Benally's (Director of the Department of Water Resources for the Navajo Nation) estimate of 4 people per household in the subject area, if each person uses 10 gallons of water per day, this would average 14,600 gallons per year. Based on the calculations and estimates given in this report, at $143 per thousand gallons the annual cost to haul water for a family of 4 is $2,088; approximately 6.55% of the Median Household Income.

10.5.1 Ability to Pay Summary

With each method providing a different viewpoint of the people in this region's ability to pay for improvements in water service, a simplified table is presented to compare the findings of all three methods more easily.

Table 10.10 Kayenta District Ability to Pay Estimates

Ability to Pay Approaches		
Simplified Budgeting (Low and High)	$2,058,208	$2,913,305
EPA Threshold (2.5%)	$1,967,564	
Current Water Charge (6.55%)*	$5,155,020	

* Note: The Current Water Charge estimate is based on 6.55% of household income plus taxable business receipts equaling $78,702,588. This assumes all residents and businesses need to haul water from outside sources.

Comparing the lowest of these estimates ($1,967,564) to the initial O&M cost per year ($1,820,500) presented in Table 10.11, there appears to be an ability to pay 100% of project O&M costs. Without assistance, the project cannot meet the 25% minimum required for local cost sharing on federal construction projects. It is noteworthy that various studies have determined that the ATP in low-income areas, such Monument Valley/Kayenta, may be much less than the 2.5% threshold of affordability as determined by the EPA (SP p. 25); possibly in the .5% to 1.5% range of MHI.

10.6 Willingness to Pay

Willingness to pay (WTP) is an estimated measurement of the increase in social welfare associated with the outputs generated by a program or project. Therefore, estimates of willingness to pay represent the benefits of a program or project. WTP represents the projected amount of money that the residents in the Oljato-Kayenta region would be willing to pay for the water provided by the proposed project; thereby reflecting the economic value of the water to the area.

This willingness to pay analysis is based on calculating the area beneath a generalized demand curve, as created by Jim Merchant of Dornbusch Associates for the Navajo Gallup Water Supply Project (used with permission). The demand for water in the city of Kayenta is derived from the exponential equation used to estimate demand for Navajo Gallup:

$$GPCD = 18.405 * HHY^{.372} * HHS^{-1.348} * P^{-.554}$$

GPCD = gallons per capita daily
HHY = median household income
HHS = persons per household
P = average price per water

This method utilizes the Navajo Gallup study's demand curve and accompanying exponents due to sufficient demographical similarities, while the coefficients were adjusted based on information gleaned from the 2010 Census and conversations with local area experts. For this exercise, the median household income comes from the 2010 Census for Kayenta and is $31,837, the calculated persons per household is four (4) and is derived from a conversation with Ray Benally (pg. 137 above), and the average price represents the amount that users in this demographic area would be willing to pay for water at the 160 gallons per capita daily level of consumption.

The WTP estimate presented herein is a measure of the economic benefits to households from improvements to the water supply. Some of these benefits could include values associated with goods and services provided as a result of economic development as well as health benefits. Including estimates for separate categories of economic development and health benefits will inherently lead to some double counting of benefits. However, these categories were estimated in the Navajo-Gallup study and are included in this analysis to ensure that these benefits are fully accounted for. It is acknowledged that benefits may be overstated.

10.7 Economic Benefit/Cost Analysis

This analysis uses a "benefits transfer" method to approximate the benefits and costs associated with the proposed San Juan Pipeline from Mexican Hat, Utah to Kayenta, Arizona. Due to some similarities in cultures, demographics, etc., this report relies on the Economic Benefit/Cost Analysis for the Navajo – Gallup Water Supply Project by James P. Merchant of Dornbusch Associates, completed in 2007, and the Jemez Water Supply Study prepared by NRCE for Reclamation in October 2011. This report uses a 3.75% discount rate (project planning rate) and a 50 year project life for all Net Present Value (NPV) calculations.

Interest during Construction. Interest during Construction (IDC) for Utah and Arizona together assumes a four year construction period with equal costs being expended each year. The interest rate used was the project planning rage of 3.75% and is compounded annually. When divided into separate projects of Utah and Arizona, the assumption is a two year construction period with equal costs being expended each year.

Willingness to Pay. Willingness to Pay (WTP) for the Benefit/Cost Analysis was calculated by measuring the area under the given demand curve over a 50-year period, based on a current average use of 45 GPCD (SJ p. 127) versus the 160 GPCD that would be available with the project. MHIs were taken from the 2010 Census for Kayenta ($31,837) and Oljato-Monument Valley ($31,218) (SJ p. 69) and increase at a rate of 0.69% per year based on an average annual population increase of 1.3% and an average annual 0.61% decrease in real (not nominal) Kayenta area MHI from 1989 to 2009.

Construction Employment Benefits. Construction Employment Benefits were estimated as a percentage (19.4%) of the Project Construction Costs (NG – Table 6). With unemployment on the Navajo Reservation being consistently higher than neighboring areas, it is assumed that a significant portion of the labor force could/would come from those not currently working.

Economic Development. The Economic Development section of this report projects significant increases in commercial activity if additional water and power were available. A recent discussion with Ronnie Biard, Manager of Goulding's Lodge, revealed water to be a major constraining factor for development and growth in the tourism industry in Monument Valley; evidenced by the thousands of people they turn-away each year due to a lack of room capacity. The development forecast for Utah is based on the NPV of a 1% increase in economic activity per year for 50 years. A discussion with Gabriel Yazzie, Development Services Director for Kayenta Township, revealed that businesses such as Wal-Mart, Quick Stop, and Church's Chicken have expressed interest in coming to Kayenta, and that supplementary water pressure would allow additional commercial activity in the region. The development forecast for Kayenta is based on the NPV of a 1% increase in economic activity per year for 50 years.

Health Benefits. A significant portion of the health benefits quantified in the Navajo Gallup Water Supply Project – Economic Benefit / Cost Analysis (Merchant) were calculated based on the project's potential to decrease the percentage of Navajo's hauling water from approximately 40% to 10% by increasing access to large quantities of clean water in the homes of thousands of people who would otherwise be hauling water for survival. As the proposed San Juan – Kayenta pipeline discussed in this study functions as more of a "trunk-line" conveyance facility without various laterals, delivering additional water to areas that already enjoy water service, albeit in smaller quantities, direct health benefits to individuals in the project service area upon completion of the project would be modest. However, it should be noted that with the availability of additional clean water in the region provided by the project, IHS's ability to install distributive infrastructure to outlying homes and communities would be greatly accelerated, which could result in sizable health benefits to families which would no longer have to haul water to their homes. As an appraisal level analysis, the health benefits from potential projects not directly associated with this project, which may or could be feasible if the San Juan – Kayenta Pipeline is constructed, are recognized as potentially significant, but are not being quantified in this study. The unquantified health benefits will be represented with "X". Further study would be required to quantify the health benefits that could be realized with a better supply of water.

Project Construction Costs. Project Construction Costs were based on the updated 2008 Cost Estimates indexed to 2014 dollars using the Bureau of Reclamation's "Construction Cost Trends" data sheet (http://www.usbr.gov/pmts/estimate/cost_trend.html). The NPV given is assuming an estimated $29,250,000 is spent each year for 4 years with a discount rate of 3.75%.

Operation, Maintenance, and Replacement Costs. Operation, Maintenance, and Replacement (OM&R) Costs were calculated based on the costs estimated to pump and treat the water from the San Juan River to the Project area, along with estimates to O&M the storage facilities, pumping plant, pipeline, water treatment and intake structures.

Water Costs. Water Costs were not included based on the information given regarding Navajo Water Rights (SJ p.21).

Power Generation Loss. Power Generation Loss was calculated on the estimated annual need in acre-feet of water to be diverted from the San Juan River currently in use at Glen Canyon Power Station. This represents the loss of revenue to the United States by using the water for other purposes. Equations for the loss of power generation can be found in the Navajo – Gallup B/C Analysis (NG pp. 37-38).

Salinity Increase. Salinity Increase costs were calculated on the estimated annual need in acre-feet of water to be diverted from the San Juan River currently flowing into Lake Powell. This represents the increased costs downstream due to increases in salinity. Equations and explanations for the increased salinity costs can be found in the Navajo – Gallup B/C Analysis (NG p.38).

Individual phases were also completed by separating the Utah and Arizona portions of the Project on a 30/70 basis as shown in Table 10-9.

Table 10-10. San Juan Pipeline Cost Comparison Summary

San Juan Pipeline Project Summary Cost Comparison Summary *(1.3% growth, 1.3 PF, & 160 gpcd for each Alt.)*						
	2010 ***(Alt. A)*** ***{ALL}***	**2060** ***(Alt. A)*** ***{ALL}***	**2010** ***(Utah)*** ***{15%}***	**2060** ***(Utah)*** ***{15%}***	**2010** ***(Arizona)*** ***{85%}***	**2060** ***(Arizona)*** ***{85%}***
Total Population	6,591	12,572	1,148	2,189	5,443	10,383
No. of Households	1,889	3,143	287	471	1,602	2,672
Water Usage *(ac-ft/yr)*	1,182	2,255	177	338	1,005	1,917
Capital Cost *($)*	$117,000,000	$117,000,000	$35,100,000	$35,100,000	$81,900,000	$81,900,000
Interest During Construction *(IDC)*	$10,600,000	$10,600,000	$1,590,000	$1,590,000	$9,010,000	$9,010,000
Capital Cost *($/household)*	$61,938	$37,226	$127,840	$77,824	$56,748	$34,029
OM&R Cost *($/yr)*	$1,820,500	$2,021,400	$273,075	$303,210	$1,547,425	$1,718,190
OM&R Cost *($/household/yr)*	$964	$643	$951	$643	$966	$643
Annual Payment *(OM&R+Repayment)*	$7,040,500	$7,241,400	$1,056,075	$1,086,210	$5,984,425	$6,155,190
Annual Payment ($/household)	$3,727	$2,304	$3,680	$2,304	$3,736	$2,304
ALT A IDC calculated based on a 4 year construction schedule at 3.75% interest / UT-AZ IDC based on 2 year schedule at 3.75%						
Repayment based on a 30 year repayment schedule at 3.75% interest						
Alt. A includes cost for entire project without phasing it between Utah & Arizona						
[Updated: August, 2014 by BOR-Provo]						

Table 10-12 is for the combined project of Utah and Arizona together, Table 10-13 is only Utah, and Table 10-14 is only Arizona.

Table 10-11. Summary of San Juan Pipeline Economic Benefits and Costs (3.375% discount rate, 50 year project life) Oljato-Monument Valley & Kayenta Township 2012

Benefits	Direct
Willingness to Pay	$21,700,000
Construction Employment	$20,730,000
Economic Development	$88,210,000
Health Benefits	X
Total Benefits	$130,640,000
Costs	
Project Construction	$106,810,000
IDC	$10,600,000
OM&R	$38,900,000
Water Costs	$0
Power Generation (Loss)	$930,000
Salinity Increase Cost	$900,000
Total Costs	$157,690,000
Benefit/Cost Ratio	..83+X

Table 10-12. Summary of San Juan Pipeline Economic Benefits and Costs (3.75% discount rate, 50 year project life) Oljato-Monument Valley 2012

Benefits	Direct
Ojato – MV WTP	$3,740,000
Construction Employment	$2,570,000
Economic Development	$38,830,000
Health Benefits	X
Total Benefits	$45,140,000
Costs	
Project Construction	$13,210,000
IDC	$760,000
OM&R	$6,370,000
Kayenta Water Costs	$0

Power Generation (Loss)	$160,000
Salinity Increase Cost	$160,000
Total Costs	$20,660,000
Benefit/Cost Ratio	2.18+ X

Table 10-13. Summary of San Juan Pipeline Economic Benefits and Costs (3.75% discount rate, 50 year project life) Kayenta Township 2012

Benefits	**Direct**
Kayenta WTP	$17,830,000
Construction Employment	$18,270,000
Economic Development	$49,380,000
Health Benefits	X
Total Benefits	$85,480,000
Costs	
Project Construction	$94,130,000
IDC	$4,310,000
OM&R	$36,070,000
Kayenta Water Costs	$0
Power Generation (Loss)	$790,000
Salinity Increase Cost	$770,000
Total Costs	$136,070,000
Benefit/Cost Ratio	0.63 + X

10.8 Summary

The above analysis showcases a projected willingness to pay, along with three different methods in calculating ability to pay. The first method combines average water use data, average water cost data, median household income data, and taxable gross receipts data for 19 New Mexico communities (16 communities for commercial water use data) used in the Jicarilla Apache Nation Water Supply Ability to Pay Analysis to estimate actual water payments made as a percentage of median household income and as a percentage of gross taxable business receipts. These percentages represent actual payments made, which is an indicator of affordability. This data was applied to the Kayenta District to determine the residents' ability to pay for the proposed San Juan Pipeline Project.

The second method uses the EPA threshold of 2.5% of gross median household income which equates to $1,967,564 and is not unusually dissimilar from the simplified budgeting method ability to pay amount of $1,451,199.

The third method shows that many residents are already paying approximately 6.55% of their Median Household Income to get water. This is more than 2 times the EPA threshold of affordability, but represents what these people need to do to survive.

This analysis indicates that the Kayenta Township and Oljato-Monument Valley area have the ability to pay the O&MR cost for the project. Combining both the capital cost and OM&R cost would result in a need for other funding sources in order for the project to move forward. As discussed in the framework for determining ability to pay section, the ability to pay estimates are based on an evaluation of financial resources available to the water supplier from water users or other outside sources.

The benefit to cost ratio for this project for the entire area (Kayenta Township and Oljato-Monument Valley) is .83 plus an unquantified amount for accrued health benefits, showing that there would be benefits to the community from this project.

If the project were to be divided between the Utah and Arizona state line, it would cost more for the Utah residents to pay for the entire project due to the fact that the majority of the infrastructure is on the Utah side and the majority of the population is on the Arizona side.

It would be more economical for the community to move forward with the waterline as one complete project and not separate between Utah and Arizona. Although, phasing this project may be an option if both communities work together to make it happen. If the project is phased, Arizona residents would have to pay their share of the project up front even though they may not receive water until their portion of the project is completed.

Another option that would need further investigation is the possibility of having the Halchita residents water needs be supplied from Mexican Hat due to the fact that Halchita no longer has a school in the area. The school was one of their major water users, now that it has been removed, the current water needs for the Halchita area may be supplied from the Mexican Hat Water Treatment facility, possibly reducing the water demand for the proposed project.

It should be noted that during times of low flow and/or high turbidity in the San Juan River, the project area will maintain the option to resume pumping from its current wells. The costs to pump, operate, and maintain the present distribution system were not included in this analysis as there will a significant offset by not incurring pumping and operating costs for water from the San Juan River.

This and other pressing issues should be further investigated in the next step moving forward with this project.

11.0 Recommendations

The preferred alternative is the most economical and viable option for the residents of the area to provide a sustainable water supply for the area. Alternative A and B would not provide enough water to supply the growing population and future potential business water needs of the region.

The original Benefit/Cost Analysis was performed based on projected growth rates after 50 years. The completion of these calculations with a population projection for 2010 at 160gpcd shows the San Juan Pipeline operation and maintenance costs to be approximately $1,820,500 per year.

According to the EPA's measures of affordability, the threshold for a community (system) to pay for drinking water supply is 2.5% of the median household income. For this report, we have summed together the Total Household Income ($59,962,440) with the Total Business Income ($18,740,148), which gives us a total income of $78,702,588 for the region. The EPA measure of affordability, 2.5% of this total, is $1,967,564 which equates to $1,014.50 for each establishment (residence or business) yearly as the maximum threshold of affordability of the system's drinking water supply.

The total annual cost of the project including capital cost and OM&R is $7,040,500. This equates to 8.95% of the total income for the area, which is more than three times the EPA measure of affordability. The total income for the area is sufficient to cover the OM&R cost of the project but would not be adequate to pay for the entire project. Outside funding sources would be required to cover capital costs and interest during construction. With a benefit to cost ratio of ..83 plus additional health benefits that may accrue, the economic benefits of this project could potentially outweigh the economic costs.

Also, it should be noted that upgrades and expansion cost to the existing system to accommodate the increase in water supply and to service outlying areas is not included in this analysis. Additional funding would be needed to build these facilities for delivery of the water.

Although the appraisal level report uncovered a number of issues of concern, nothing in the appraisal study would prohibit the Nation from proceeding to feasibility, with or without future Rural Water Program funding.

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Appendix A – Navajo Nation Endangered Species List

(adapted from Navajo Nation, Resources Committee Resolution, No. RCAU-103-05)

GROUP 1: Those species or subspecies that no longer occur on the Navajo Nation.

GROUP 2 (G2) & GROUP 3 (G3): "Endangered" -- Any species or subspecies whose prospects of survival or recruitment within the Navajo Nation are in jeopardy or are likely within the foreseeable future to become so.

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.

GROUP 4: Any species or subspecies for which the Navajo Nation Department of Fish and Wildlife (NNDFWL) does not currently have sufficient information to support their being listed in G2 or G3 but has reason to consider them. The NNDFWL would actively seek information on these species to determine if they warrant inclusion in a different group or removal from the list.

The NNDFWL shall determine the appropriate group for listing a species or subspecies due to any of the following factors:

1. The present or threatened destruction, modification, or curtailment of its habitat;
2. Over-utilization for commercial, sporting or scientific purposes;
3. The effect of disease or predation;
4. Other natural or man-made factors affecting its prospects of survival or recruitment within the Navajo Nation; or
5. Any combination of the foregoing factors

	Scientific Name	Common Name	Occurrence
GROUP 1:			
MAMMALS			
	Canis lupus	(Gray Wolf)	Extirpated
	Lontra canadensis	(Northern River Otter)	Unlikely
	Ursus arcto	(Grizzly or Brown Bear)	Extirpated
FISHES			
	Gila elegans	(Bonytail)	Unlikely
GROUP 2:			
MAMMALS			
	Mustela nigripes	(Black-footed Ferret)	Potentially Occur
BIRDS			
	Coccyzus americanus	(Yellow-billed Cuckoo)	Unlikely

Empidonax traillii extimus	(Southwestern Willow Flycatcher)	Known to Occur

AMPHIBIANS

Rana pipiens	(Northern Leopard Frog)	Potentially Occur

FISHES

Gila cypha	(Humpback Chub)	Unlikely
Gila robusta	(Roundtail Chub)	Potentially Occur
Ptychocheilus lucius	(Colorado Pikeminnow)	Potentially Occur
Xyrauchen texanus	(Razorback Sucker)	Potentially Occur

PLANTS

Astragalus cutleri	(Cutler's Milk-vetch)	Potentially Occur
Astragalus humillimus	(Mancos Milk-vetch)	Unlikely
Erigeron rhizomatus	(Rhizome Fleabane)	Unlikely
Pediocactus bradyi	(Brady Pincushion Cactus)	Unlikely
Sclerocactus mesae-verdae	(Mesa Verde Cactus)	Unlikely

GROUP 3:

MAMMALS

Antilocapra americana	(Pronghorn)	Likely
Ovis canadensis	(Bighorn Sheep)	Known to Occur

BIRDS

Aquila chrysaetos	(Golden Eagle)	Known to Occur
Buteo regalis	(Ferruginous Hawk)	Potentially Occur
Cinclus mexicanus	(American Dipper)	Potentially Occur
Strix occidentalis lucida	(Mexican Spotted Owl)	Potentially Occur

INVERTEBRATES

Speyeria nokomis	(Western Seep Fritillary)	Unlikely

PLANTS

Allium gooddingii	(Gooding's Onion)	Unlikely
Asclepias welshii	(Welsh's Milkweed)	Potentially Occur
Astragulus cremnophylax var. *hevroni*	(Marble Canyon Milk-vetch)	Unlikely
Carex specuicola	(Navajo Sedge)	Known to Occur
Erigeron acomanus	(Acoma Fleabane)	Unlikely
Pediocactus peeblesianus var. *fickeiseniae*	(Fickeisen Plains Cactus)	Unlikely
Penstemon navajoa	(Navajo Penstemon)	Unlikely
Platanthera zothecina	(Alcove Bog-orchid)	Known to Occur

GROUP 4:

MAMMALS		
Corynorhinus townsendii	(Townsend's Big-eared Bat)	Unlikely
Dipodomys microps	(Chisel-toothed Kangaroo Rat)	Unlikely
Dipodomys spectabilis	(Banner-tailed Kangaroo Rat)	Unlikely
Microtus mogollonensis	(Navajo Mountain Vole)	Potentially Occur
Perognathus amplus cineris	(Wupatki [Arizona] Pocket Mouse)	Unlikely
Vulpes macrotis	(Kit Fox)	Potentially Occur
BIRDS		
Accipiter gentilis	(Northern Goshawk)	Unlikely
Aechmophorus clarkii	(Clark's Grebe)	Unlikely
Aegolius acadicus	(Northern Saw-whet Owl)	Potentially Occur
Athene cunicularia	(Burrowing Owl)	Unlikely
Ceryle alcyon	(Belted Kingfisher)	Potentially Occur
Charadrius montanus	(Mountain Plover)	Potentially Occur
Dendragapus obscurus	(Blue Grouse)	Unlikely
Dendroica petechia	(Yellow Warbler)	Unlikely
Empidonax hammondii	(Hammond's Flycatcher)	Unlikely
Falco peregrinus	(Peregrine Falcon)	Potentially Occur
Glaucidium gnoma	(Northern Pygmy-Owl)	Unlikely
Gymnogyps californianus	(California Condor)	Unlikely
Otus flammeolus	(Flammulated Owl)	Unlikely
Patagioenasa fasciata	(Band-tailed Pigeon)	Unlikely
Picoides dorsalis	(American Three-toed Woodpecker)	Unlikely
Porzana carolina	(Sora)	Unlikely
Tachycineta bicolor	(Tree Swallow)	Unlikely
REPTILES		
Lampropeltis triangulum	(Milk Snake)	Unlikely
Sauromalus ater	(Chuckwalla)	Unlikely
FISHES		
Catostomus discobolus	(Bluehead Sucker)	Potentially Occur
Cottus bairdi	(Mottled Sculpin)	Potentially Occur
INVERTEBRATES		
Oreohelix strigosa	(Rocky Mountainsnail)	Unlikely
Oreohelix yavapai	(Yavapai Mountainsnail)	Unlikely
Oxyloma kanabense	(Kanab Ambersnail)	Unlikely
PLANTS		
Amsonia peeblesii	(Peebles Blue-star)	Unlikely
Asclepias sanjuanensis	(San Juan Milkweed)	Unlikely
Astragalus beathii	(Beath Milk-vetch)	Unlikely
Astragalus cronquistii	(Cronquist Milk-vetch)	Unlikely

Astragalus naturitensis	(Naturita Milk-vetch)	Unlikely
Astragalus tortipes	(Sleeping Ute Milk-vetch)	Unlikely
Camissonia atwoodii	(Atwood’s Camissonia)	Unlikely
Clematis hirsutissima var. *arizonica*	(Arizona Leather Flower)	Unlikely
Cymopterus acaulis var. *higginsii*	(Higgins Biscuitroot)	Unlikely
Cystopteris utahensis	(Utah Bladder-fern)	Unlikely
Erigeron sivinskii	(Sivinski’s Fleabane)	Unlikely
Errazurizia rotundata	(Round Dunebroom)	Unlikely
Lesquerella navajoensis	(Navajo Bladderpod)	Unlikely
Perityle specuicola	(Alcove Rock Daisy)	Potentially Occur
Phacelia indecora	(Bluff Phacelia)	Potentially Occur
Puccinella parishii	(Parish’s Alkali Grass)	Unlikely
Salvia pachyphylla	(Bigleaf Sage)	Unlikely
Sclerocactus cloveriae brackii	(Brack Hardwall Cactus)	Unlikely
Zigadenus vaginatus	(Alcove Death Camas)	Potentially Occur

Appendix B – Endangered Species List

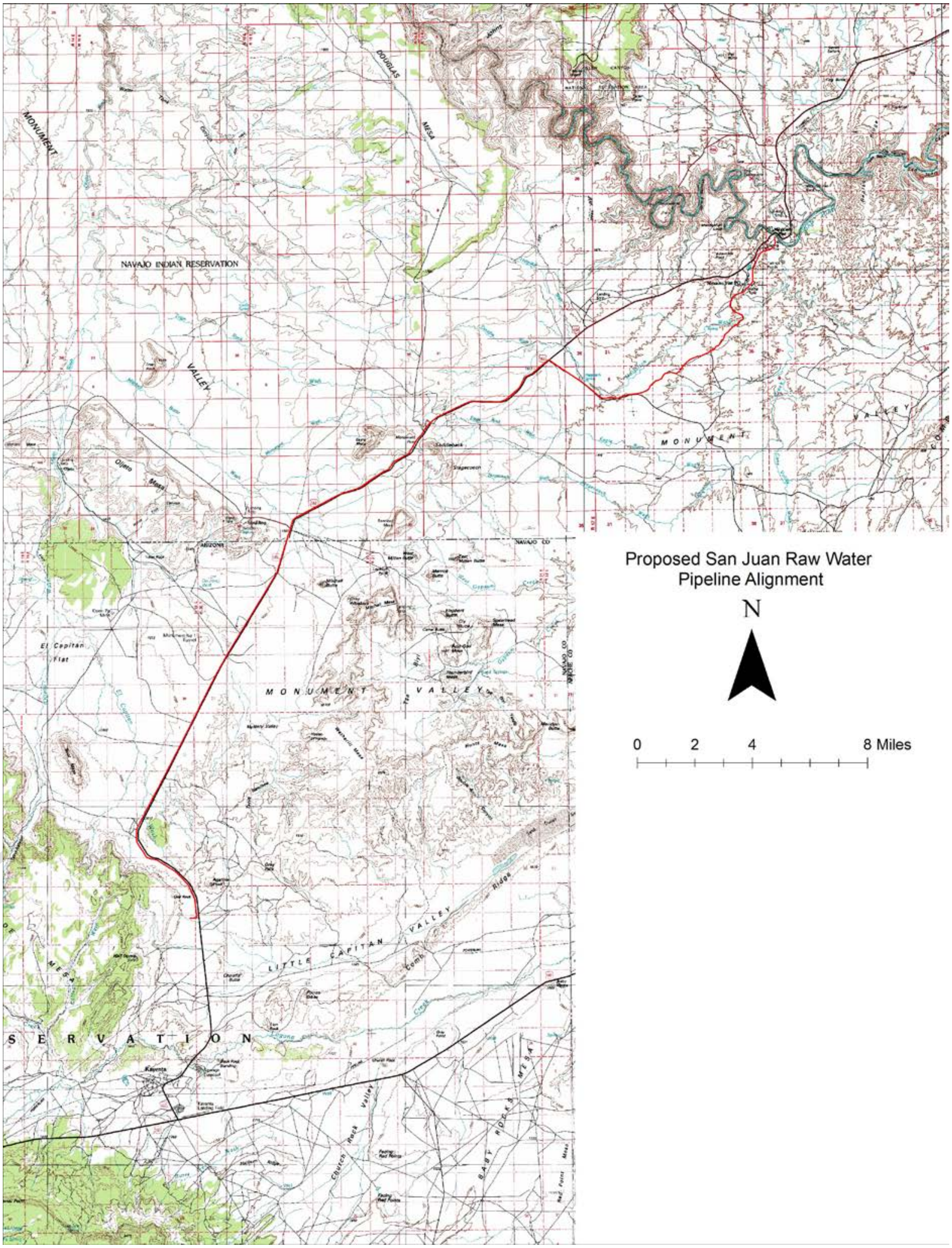
Endangered Species List for Navajo County, Arizona

Common Name	Scientific Name	Species Group	Status	Species Likely to Occur in Project Area
Navajo Sedge	*Carex specuicola*	Plants	T	Known to Occur
Peebles Navajo Cactus	*Pediocactus peeblesianus*	Plants	E	Unlikely
Welsh's Milkweed	*Asclepias welshii*	Plants	T	Potentially Occur
Little Colorado spinedace	*Lepidomeda vittata*	Fishes	T	Unlikely
Chiricahua leopard frog	*Rana chiricahuensis*	Amphibians	T	Unlikely
Mexican spotted owl	*Strix occidentalis lucida*	Birds	T	Potentially Occur

Endangered Species List for San Juan County, Utah

Common Name	Scientific Name	Species Group	Status	Species Likely to Occur in Project Area
Navajo Sedge	*Carex specuicola*	Plants	T	Known to Occur
Humpback chub	*Gila cypha*	Fishes	E	Unlikely
Bonytail	*Gila elegans*	Fishes	E	Unlikely
Colorado Pikeminnow	*Ptychocheilus lucius*	Fishes	E	Potentially Occur
Razorback Sucker	*Xyrauchen texanus*	Fishes	E	Potentially Occur
Yellow-billed Cuckoo	*Coccyzus americanus*	Birds	C	Unlikely
Mexican Spotted Owl	*Strix occidentalis lucida*	Birds	T	Potentially Occur
Southwestern Willow flycatcher	*Empidonax traillii extimus*	Birds	E	Known to Occur

Appendix C – Map of Proposed Alignment



Appendix D – Pumping Costs / Hydraulics

Pipe Pressures and Booster Station Requirements

Flow (Q):	4.05	cfs	Total Miles:	41	*should equal 40	
Settling Pond Elevation:	4,100	ft				
Pumping Plant Ending Elevation:	4,500	ft	**Total Pumping Costs:**	**$1,290,000**	$1,386,750	*(estimated steel comparison)*
Water Treatment Plant Elevation:	5,660	ft				
Number of Booster Stations:	4					

	Pumping Plant		Booster Station #1		Booster Station #2		Booster Station #3		Booster Station #4	Kayenta Distribution Line Booster Station #5		Oljato Distribution Line Booster Station #5	
Initial Elevation:	4,099	ft	4,473	ft	4,836	ft	5,169	ft	5,521	5,463	ft	5,200	ft
Ending Elevation:	4,524	ft	4,873	ft	5,236	ft	5,569	ft	5,741	5,763	ft	5,340	ft
Static Lift:	425	ft	400	ft	400	ft	400	ft	220	300	ft	140	ft
Pipe Length:	4	mi	3	mi	6	mi	4	mi	18.9	5	mi	3	mi
	21,912	ft	16,104	ft	29,040	ft	21,120	ft	99,792	26,400	ft	15,840	ft
Annual Demand:	2,931	acre-feet	2,931	acre-feet	2,931	acre-feet	2,931	acre-feet	2,931	1,513	acre-feet		acre-feet
Design Flow (Q):	2.61	MGD	2.61	MGD	2.61	MGD	2.61	MGD	2.61	1.35	MGD	0.00	MGD
	4.05	cfs	4.05	cfs	4.05	cfs	4.05	cfs	4.05	3.35	cfs	0.70	cfs
C_h:	140		140		140		140		140	140		140	
Inside Diameter (ID):	14.91	in	14.91	in	14.91	in	14.91	in	14.91	13.11	in	6.30	in
Area (A):	1.21	ft^2	1.21	ft^2	1.21	ft^2	1.21	ft^2	1.21	0.94	ft^2	0.22	ft^2
Velocity (V):	**3.34**	fps	**3.34**	fps	**3.34**	fps	**3.34**	fps	**3.34**	**3.57**	fps	**3.23**	fps
Hydraulic Radius (R):	0.31	ft	0.31	ft	0.31	ft	0.31	ft	0.31	0.27	ft	0.13	ft
Friction Slope (S):	0.002318	ft/ft	0.002318	ft/ft	0.002318	ft/ft	0.002318	ft/ft	0.002318	0.003058	ft/ft	0.005976	ft/ft
Head Loss (h_f):	50.8	ft	37.3	ft	67.3	ft	49.0	ft	231.3	80.7	ft	94.7	ft
Total Dynamic Head:	476	ft	437	ft	467	ft	449	ft	451	381	ft	235	ft
	206	psi	189	psi	202	psi	195	psi	196	165	psi	102	psi
Water Horsepower (whp):	218	whp	201	whp	215	whp	206	whp	207	145	whp	19	whp
Pump Efficiency (e_p):	80%		80%		80%		80%		80%	80%		80%	
Brake Horsepower (bhp):	273	bhp	251	bhp	268	bhp	258	bhp	259	181	bhp	23	bhp
Motor Efficiency (m_p):	80%		80%		80%		80%		80%	80%		80%	
Total Input Horsepower (hp):	341	hp	314	hp	335	hp	322	hp	324	226	hp	29	hp
kW:	255		234		250		240		241	169		22	
Pumping Time:	365	days	365	days	365	days	365	days	365	365	days	365	days
Yearly Power:	2.23E+06	kW-h	2.05E+06	kW-h	2.19E+06	kW-h	2.11E+06	kW-h	2.12E+06	1.48E+06	kW-h	1.90E+05	kW-h
Energy Charge:	$0.074	per KW-h	$0.074	per KW-h	$0.074	per KW-h	$0.074	per KW-h	$0.074	$0.074	per KW-h	$0.074	per KW-h
Monthly Demand Charge:	$20.18	per kW	$20.18	per kW	$20.18	per kW	$20.18	per kW	$20.18	$20.18	per kW	$20.18	per kW
	$226,773		$208,440		$222,733		$213,982		$215,118	$150,187		$19,341	
Annual Power Cost:	**$230,000**		**$210,000**		**$230,000**		**$220,000**		**$220,000**	**$160,000**		**$20,000**	
									Total Power Cost	$1,290,000			

Appendix E – Memorandum of Agreement

The Navajo Nation, Department of Water Resources
And
The Department of the Interior, Bureau of Reclamation,
Upper Colorado Region, Provo Area Office

THIS MEMORANDUM OF AGREEMENT (Agreement) is made pursuant to the Rural Water Supply Act of 2006 (Title I, Pub. L 109-451; 120 Stat. 3346; 43 U.S.C. 2401 et seq.) and 43 CFR Part 404 and Act of June 17, 1902 (32 Stat. 388), and acts amendatory thereof or supplementary thereto, particularly the Contributed Funds Act of March 4, 1921 (41 Stat. 1404; 43 U.S.C. § 395), among the Navajo Nation, Department(NNDWR) of Water Resources and the Department of the Interior, Bureau of Reclamation, Upper Colorado Region, Provo Area Office, hereinafter referred to as Reclamation, for the purpose of contributing funds to perform water planning services.

Whereas, Reclamation is in receipt of a request by the NNDWR

Whereas, under Reclamation law and policy, NNDWR is required to pay in advance all costs associated with this request and proposed action, including environmental and contracting services; and

Whereas, the Contributed Funds Act provides authority for the Secretary of the Interior, acting through Reclamation, to receive and expend without further appropriation, moneys ". . . received from any State, municipality, corporation, association, firm, district, or individual for investigations, surveys, construction work, or any other development work incident thereto involving operations similar to those provided for by the reclamation law . . ."; and

Now therefore, in consideration of the foregoing the parties agree to the following:

I. Implementing Actions

(a) Reclamation shall:

(1) Provide appraisal level report of regional water needs for the area between Mexican Hat, Utah and Kayenta, Arizona that can be carried forward to a feasibility level study. Scope shall include indentifying rural water supply problems in the project area, description of planning objectives and opportunities in the project area, determination if there is a federal interest in participating in a cost shared feasibility study and document the study process and provide recommendations for action. This includes determining the appropriate level of compliance, and analyzing the effects in accordance with the National Environmental Policy Act (NEPA), the Endangered Species Act (ESA), and other Federal cultural resource laws, and other applicable State and Federal laws as required. As the study progresses it may be necessary to modify or add to these items.

(b) NNDWR:

(1) Contribute funds to Reclamation, as outlined in Section IV of this Agreement, to be used toward Reclamation's cost of performing the above services. Assistance may be requested by Reclamation collecting data from local chapters and having access to review potential water development alignments and sites.

II. Term of the Agreement

This Agreement shall become effective on the date of the last signature hereto and shall remain in effect until the earlier of the following circumstances:

(a) Completion of the work as set forth in this Agreement;

(b) Reclamation notifying the party in writing that Reclamation has determined that further work pursuant to this Agreement is not in the best interests of the United States;

(c) Reclamation receiving written notification from NNDWR that either has determined that further work pursuant to this Agreement is not in either of its best interests; or

(d) If NNDWR declines to assume full responsibility for payment of Reclamation's costs to complete the anticipated actions.

If the Agreement is terminated, any unexpended funds previously advanced to Reclamation will be accounted for and returned to NNDWR within sixty (60) days of the termination of this Agreement.

III. Modification(s) to the MOA

Any of the parties may formally request modification of this Agreement. Modifications shall be made by mutual consent of all parties by the issuance of a written modification to this Agreement, signed and dated by both parties prior to any changes being performed.

IV. Budget and Method of Payment

(a) Authority. Reclamation may receive—and may expend funds received—for investigations and other work involving operations similar to those provided for by the Reclamation law pursuant to the Contributed Funds Act.

(b) Advance Payment. NNDWR agrees that funding will be provided through Reclamation's Rural Water Program to provide payment in advance of Reclamation's performance of tasks scheduled under Section I (a) of this Agreement. The estimated amount to be advanced to Reclamation is $115,000 for tasks related to preparation of the appraisal level report. Should Reclamation encounter any unforeseen costs that are extraordinary or significantly higher than this estimate, Reclamation will immediately notify NNDWR in writing. NNDWR will then be required to advance the additional funds necessary to complete the work. Until the additional funds are received by Reclamation, Reclamation shall be under no obligation to perform any further work on the activities listed herein.

(c) Separate Account. Reclamation shall keep separate the funds associated with the work funded by the Rural Water Program for use on the activities scheduled under Section I (a). Reclamation shall at all times hold NNDWR funds separate from all other funds and shall not commingle said funds with any other funds.

(d) Application of Contributed Funds. Reclamation will use the funds contributed by NNDWR to cover costs incurred by Reclamation in performing the activities described under Section I (a) of this Agreement.

(e) Return of Unexpended Funds. Reclamation shall return any of the funds contributed for use by Reclamation, which are not spent or obligated for the purpose of this Agreement.

(f) Bills for Collection. Bill of collection will not be sent, due to the funds being kept with Reclamation, but reporting of cost will be sent monthly to the NNDWR for review during the period of work on the report.

V. Principal Contacts

Any and all notices required to be given by the parties hereto, unless otherwise stated in this Agreement, shall be in writing and be deemed communicated when mailed in the United States mail, certified, return receipt requested, addressed as follows:

John Leeper, P.E. Branch Director Navajo Nation Division of Water Resources Route NN12, Roanhorse Dr. Bldg. F-004-033, Post Office Drawer 678, Fort Defiance, Arizona, 86504 Phone: (928) 729-4004 Fax: (928) 729-4126 E-mail: johnleeper@navajo.org	Bureau of Reclamation Cary Southworth Provo Area Office 302 East 1860 South Provo, UT 84606-7317 Phone: (801) 379-1000 Fax: (801) 379-1159 Email: csouthworth@usbr.gov

The parties may change their address for the purpose of this paragraph by giving written notice of such change to the other in the manner herein provided.

VI. General Provisions

(a) Nothing herein shall be construed to obligate Reclamation to expend or involve the United States of America in any contract or other obligation for the future payment of money in excess of the appropriations authorized by law and administratively allocated for the purposes and projects contemplated hereunder.

(b) No Member of or Delegate to the Congress, Resident Commissioner, or official of the District shall benefit from this Agreement other than as a water user or landowner in the same manner as other water users or landowners.

(c) Any information furnished to Reclamation, under this Agreement, is subject to the Freedom of Information Act (5 U.S.C. 552).

VII. Signatures

In Witness Whereof, the parties hereto have executed this Agreement as of the last date written below.

Larry Walkoviak Regional Director Upper Colorado Region Bureau of Reclamation	Date
John Leeper, P.E. Branch Manager Navajo Nation Department of Water Resources	Date

~~End of Agreement~~

ATTACHMENT A

Navajo Nation Mexican Hat (Halchita) to Kayenta Regional Water Appraisal Study

Plan of Study

Background

Under the Rural Water Program the Navajo Nation has been approved to perform an appraisal study of the Mexican Hat(Halchita), Utah to Kayenta, Arizona Regional Water Study. Reclamation has been asked to perform the study and coordinate the study effort.

The study is being conducted for planning of future water needs within the region and within the local Navajo Nation chapters.

I. Introduction

Due to increase populations and unreliable water sources, new water sources are being studied for the region of the Navajo Nation between Mexican Hat (Halchita), Utah and Kayenta, Arizona to address future critical need.

<u>Objective of Study</u> – Determine technical, environmental, cultural, economic and institutional feasibility for development of water resources from the San Juan River and other sources within the region.

The study will produce alternative project plans, one of which will be selected on the basis of environmental and cultural considerations, cost and public acceptance. The public will have an opportunity to assist in formulation and evaluation of the alternative though an open process with the local area chapters.

II. Public Involvement

Numerous Federal, State and local agencies, local chapters and private individuals will take a keen interest in the project and the study will have a high degree of public visibility. Many agencies will need to be consulted because of the roles and responsibilities related to environmental resources, water rights and quality of water, etc. A public involvement program will be conducted by Reclamation with assistance from the Navajo Nation.

Major Issues Likely to be Addressed in the Decision-Making Process – Major issues contemplated include:

Who would pay for a feasibility study; who would contribute?
What is the ability to pay for the resident and businesses within the region?
Who pays for the preferred alternative(s) if pursued in feasibility?
How will the project affect water quality in the region and San Juan River?
What effects will the project have on the San Juan River and endangered species?
What is the role of all interested/effected parties?

Assessment of Level of Public Interest Likely to be Generated by Proposed Action – Due to the existing and economic interest of the interested and effected parties, there will be a high level of public interest in the action(s) under consideration.

Identification of Public Involvement Expertise and Effort Needed – Between Reclamation and Navajo Nation, there should be sufficient expertise and capability in public involvement to address the issues and meet the needs.

III. Study Organizations and Management

The study will be managed by Reclamation as the Lead Agency, but with working partners in the Navajo Nation, various Federal and State Agencies and local chapters.

Other agencies –

U.S. Fish and Wildlife Service
Indian Health Service
Navajo Department of Water Resources
Navajo Utility Authority
Utah Department of Water Quality
Bureau of Indian Affairs

Planning Team –

Reclamation

Team Leader/Study Manager – Will Spitzenberg
Planning - Roger Hansen/Jonne Hower/Ben Radcliffe
Alternative formations – Scott Winterton, Will Spitzenberg, Cary Southworth
Environmental – Russ Findlay, Brian Joseph
Economics – Scott Taylor
Hydrology – Liz Verzella
Water Quality – Nick Williams
Public Involvement – Don Merrill

IV. Report Outline

Appraisal studies are brief, preliminary investigations to determine the desirability of proceeding to a feasibility study. Appraisal reports primarily use existing data and information to identify plans for meeting current and projected needs and problems of the planning area. An appraisal study identifies at least one potential solution that requires Federal involvement or identifies an array of options that have been screened and evaluated to substantiate Federal involvement.

For the appraisal study for the Mexican Hat(Halchita), Utah to Kayenta, Arizona Regional Water Study the following chapters will be covered.

CHAPTER 1—Introduction

Location of potential project
Study purpose, scope, and objectives
Study authority
Public involvement/scoping
Previous studies of the project area by Reclamation or others
Relationship of other water and related resources activities to our study

CHAPTER 2—Need for Action

This chapter defines the problems, needs, and opportunities toward which plan formulation is directed, e.g., municipal and industrial water, irrigation, fish and wildlife, environmental quality, recreation, flood control, or energy. Address needs associated with National, State, and local concerns. Clearly define the problem in each category and the resource needs to solve the problem.

State problems, needs, and opportunities for both current and future conditions.

CHAPTER 3—Opportunities, Resources, and Constraints

This chapter provides a general discussion of present and future conditions in those resource categories that have a bearing on the formulation of plans to address the identified needs. Cite physical, statutory, social, institutional, and environmental constraints that limit the capability of the resources to meet needs.

CHAPTER 4—ALTERNATIVES

Alternative formulation
Description of alternatives

No Action Alternative. Explain that this alternative serves as the basis for determining the effects of all viable alternatives.

Nonviable alternatives considered. Describe each significant nonviable alternative and give reasons for not considering it further.

Viable alternatives. Provide the following discussion of each viable alternative at a comparable level of detail.

Overview of plan concept

Plan accomplishments
Plan description
Project costs

CHAPTER 5--POTENTIAL EFFECTS OF ALTERNATIVES

- Setting
- Water resources
- Fish and wildlife resources
  - Incorporate what was learned on Green River Pumping Plant for endangered species
- Recreation
- Economics
  - Ability to Pay for Project
- Social Environment
- Cultural Resources
- Indian Trust Assets

CHAPTER 6--CONSULTATION AND COORDINATION

- Public Involvement
- Agency Consultation

CHAPTER7 --Conclusions and Recommendations

- Cost Estimate of Feasibility Study
- Conclusions
- Recommendations

V. Existing Data and Proposed Data Acquisition Program

See Attachment C for a breakdown of reports that will be used for references used to develop the study.

VI. General Study Program

General Approach to the Study - This plan formulation for the study will involve the development of several project plans using ideas and information from many sources. This process will be an iterative process, in which alternatives are first laid out in a rough form using information from previous studies and modified as water rights, engineering, environmental and economic finding dictate, and then refined through technical and public review until the best plan emerges.

The study will progress through the following phases, which will overlap somewhat as applicable.

Startup Phase (Month 1-2)	Organize study participants Establish public involvement program Initiate data gathering – previous studies and literature review Determine alternatives to study
Preliminary Phase (Month 3-6)	Conduct public involvement meeting and consider comments. Formulate preliminary alternative plan Provide further review of environmental impacts Assess viability of other alternative projects Prepare preliminary findings/appraisal report
Report Phase (Month 7-8)	Write report in draft form Send out for review by interested parties
Completion Phase (Month 9-10)	Prepare final appraisal report.

Major Decision Points – Major decisions to be made during the study are as follows:

1. Determine if there is sufficient ability to pay for the construction, operation and maintenance of the project.
2. Determine if feasibility report is warranted from the conclusions of the study.

Study Schedule – It is projected that the feasibility study will take ten months to have completed by July 2011. This is in attempt to have the study available for application for funding for feasibility level study, based on the findings to proceed forward in the appraisal report.

Study Cost – The current budget for the study is $115,500.

Attachment B
Schedule of Appraisal Study

Startup Phase (Nov. – Dec. 2010)	Organize study participants Establish public involvement program Initiate data gathering – previous studies and literature review Determine alternatives to study *Milestone 1 upon completion of phase*
Preliminary Phase (Jan. – Mar. 2011)	Conduct public involvement meeting and consider comments. Formulate preliminary alternative plan Provide further review of environmental impacts Assess viability of other alternative projects Prepare preliminary findings/appraisal report *Milestone 2 upon completion of phase*
Report Phase (Apr. – May 2011)	Write report in draft form Send out for review by interested parties *Milestone 3 upon completion of phase*
Completion Phase (Jun. – Jul. 2011)	Prepare final appraisal report for distribution. *Final Milestone upon completion of phase*

Attachment C

Navajo Nation Department of Water Resources
San Juan – Mexican Hat to Kayenta
Regional Water Supply Project

Technical Proposal

APPRAISAL LEVEL INVESTIGATION

Table of Contents

1.0 INTRODUCTION

As applied to Reclamation planning an appraisal study is a preliminary investigation conducted for the purpose of determining whether a more detailed study, known as a feasibility study, should be undertaken. The primary purpose for this Rural Water Supply Appraisal Study is to identify and analyze alternatives that can provide an adequate water supply of sufficient reliability and quality to support the current and anticipated population growth and associated, agricultural, livestock, municipal and commercial needs within the study area.

1.1 PURPOSE AND SCOPE OF STUDY

As applied to the Navajo Nation Utah Chapters the appraisal level report of findings will generate sufficient information to identify a range of alternatives that meet the project purpose and need and that can be carried forward to a feasibility level study. Issues involving hydrology, engineering, economics, environmental, and social effects of the alternatives must be sufficiently addressed in the appraisal study to identify significant issues that could potentially prevent the identification of viable alternatives. The viability of alternative plans depends on whether sufficient mitigation can be identified to alleviate potential adverse impacts.

This Technical Proposal is a guide for the appraisal level investigation as described by the Reclamation rural water program. Alternatives will be evaluated and those deemed preliminarily acceptable will be ranked by preliminary costs, reliability, performance as measured against impact evaluation criteria and other environmental issues, in accordance with the Rural Water Program Planning Guidelines. This evaluation will consider technical issues and their associated effects in determining costs and benefits and associated ranking matrices. Potential environmental impacts will be addressed to the extent they are likely to be a key factor in recommending a proposed plan. These impacts will be fully addressed in the Feasibility Study/NEPA/NHPA compliance and final design stages. The purpose of the study is to:

- Identify rural water supply problems
- Describe planning objectives and opportunities in the project area
- Determine if there is a Federal interest in participating in a cost shared feasibility study
- Document the study process and recommendations for action

As the study progresses it may be necessary to modify or add to these items.

1.2 PROJECT SPONSORS AND PARTNERS

This study has a large number of sponsors and partners. In addition, the Navajo Nation Department of Water Resources, Reclamation, Indian Health Service, the State of Utah Office of the State Engineer, and the Navajo Tribal Utility Authority (NTUA) intend to establish a

Technical Advisory Group (TAG) to coordinate short term, midterm and long term alternatives. The following list identifies some of the sponsors and partners:

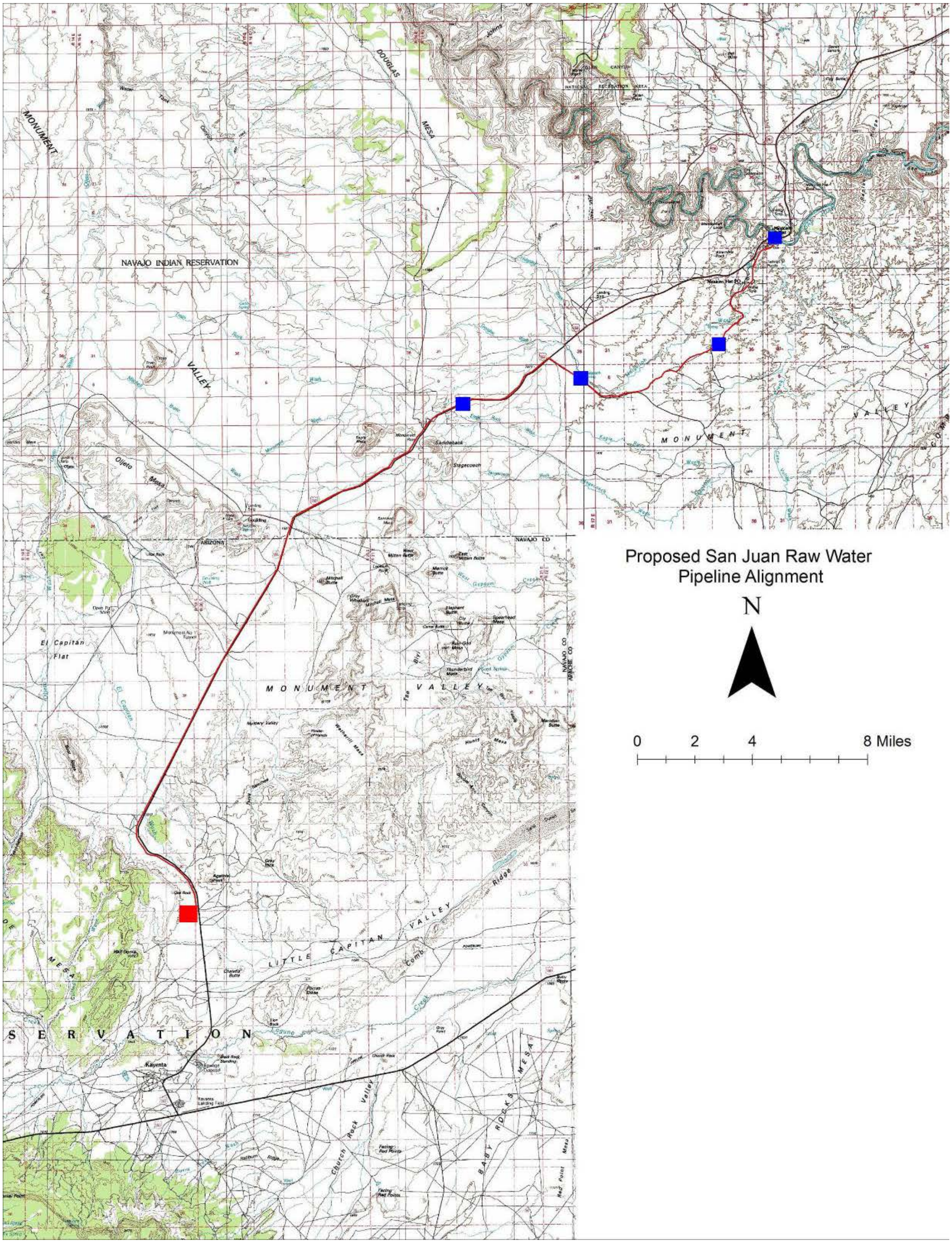
$ Navajo Nation – sponsor
$ Utah Area Chapters – sponsors
$ State of Utah, Office of the State Engineer - partner
$ Indian Health Service – partner
$ Navajo Tribal Utility Authority – partner
$ USDA Rural Development – partner
$ USDA Natural Resources Conservation Service – partner
$ Environmental Protection Agency – partner
$ Bureau of Indian Affairs - partner

1.3 DESCRIPTION OF THE PROJECT AREA

The Project Area (or Study Area) is the southwestern Navajo Nation that is comprised of the communities of between Mexican Hat and Kayenta including Halchita, Douglas Mesa, Cane Valley, Oljato, Boot Mesa, and Kayenta. Monument Valley Tribal Park and Goulding are also included. This area is shown in the following figure. It has a rural dispersed population of less than 50,000 residents. The water demands in this region exceed the developed water supply. A ten-year drought has exacerbated chronic water shortages in the region.

Chronic water shortages, inadequate public water system development and impaired or brackish groundwater impede planned economic development throughout the region. More than 50 percent of the residents are below federal poverty standards. The median per capita income of the area is less than 50 percent of the Utah rural average per capita income. Between 30 and 40 percent of the households haul water for domestic purposes. This water has been estimated to cost these residents more than 130 dollars per thousand gallons. Water quality in the alluvial system contains high levels of iron and manganese. Drought conditions have impacted the availability of sufficient water for all water uses. The chronic poverty and lack of water infrastructure are closely connected.

The region is supplied by four NTUA public water systems (Kayenta, Oljato, Cane Valley and Halchita). The region's water users who have direct access to a public water system are paying operation, maintenance and replacement costs to NTUA. A recent survey of more than 80 public water systems in the Western United States demonstrated that NTUA's rates were in the top ten percent.



NAVAJO INDIAN RESERVATION
M O N U M E N T   V A L L E Y
Proposed San Juan Raw Water
Pipeline Alignment
N
0
2
4
8 Miles

The public water systems in the region are reaching the end of their life cycles. Many opportunities exist to replace, extend and/or interconnect these systems to create economies of scale with federal, tribal and state programs that cannot provide a single comprehensive funding level sufficient to plan and construct a regional rural water supply project. Numerous cost sharing opportunities will be identified. This effort will also result in many water projects on the Indian Health Service Sanitation Deficiency List that may not be considered feasible today to become feasible.

The local Oljato alluvial system is extremely drought sensitive. Concerns regarding water quality and reliability create uncertainty regarding the ability of this supply to meet current and future water demands. Surface water storage generally developed for livestock water has been severely depleted over the last ten years of drought. This situation results in increased demands on the public water systems.

1.4 PREVIOUS AND CURRENT STUDIES

A bibliography based on the NDWR library includes numerous documents will be considered in the appraisal study. This appraisal level investigation can be quickly and economically completed because of the recent, comprehensive studies that have already been completed of the region. The following partial listing is of some of the key studies that will be used to define the problems, objectives, and opportunities, with information regarding the conclusions:

- $ U.S. Bureau of Reclamation, San Juan – Mexican Hat to Kayenta Regional Water Supply Study, April 2009
- $ U.S. Bureau of Reclamation, Mexican Hat Water Treatment Plant Appraisal Level Design, October 2009
- $ Navajo Department of Water Resources, Utah Navajo Municipal Water Projects, April 2007
- $ Navajo Department of Water Resources, Monument Valley Tribal Park and Oljato Water Supply Alternative Study, February 2008
- $ HDR Incorporated, Hopi Western Navajo Water Supply Study, 2003
- $ Brown & Caldwell, Navaho Utah Chapters Regional Water Plans and Analysis of the Existing Public Water System Upgrade Project Phase 1, Hydraulic Analysis, March 2010
- $ Brown & Caldwell, Navaho Utah Chapters Regional Water Plans and Analysis of the Existing Public Water System Upgrade Project Phase 2, Regional Chapter Water Plan, March 2010
- $ U.S.G.S., Hydrology and water quality of the Oljato Alluvial aquifer, Monument Valley Area, Utah and Arizona, 1999 and other various technical reports
- $ Indian Health Service Sanitation Deficiency List and Project Work Plans

1.5 STUDY MILESTONES

This study will include the following milestones:

- Initial Briefing: Develop the Plan of Study (POS) and preliminary planning objectives.
- Preliminary Findings Meeting: Presentation of potential alternatives; technical considerations such as costs, benefits, economic and financial requirements, environmental considerations and screening criteria.
- Preliminary Report: Develop Reclamation's "Appraisal Report" to accompany the study as required by the Rural Water Directives and Standards.

EXISTING AND FUTURE CONDITIONS

2.1 EXISTING CONDITIONS

The chronic conditions are well described in previous studies. Based on those studies water users are dispersed with more than 30 percent not connected to a public water system. The study area includes small communities and numerous rural residents distributed throughout the study area.

Developed water systems are inadequate to meet current and future demands. The region is supplied primarily by three public water systems consisting of wells located in alluvial basins and fractured rock aquifers. The alluvial system is drought sensitive and concerns regarding water quality and reliability create uncertainty regarding the viability of this supply source to meet current and future water demands. Water quality in the alluvial system contains high levels of iron and manganese. Drought conditions in Oljato have impacted the availability of sufficient water for all water uses.

Seasonal demand increases require water deliveries beyond the capacity of the public water systems. The Navajo Tribal Utility Authority provides operation and maintenance services for regional water users who have "metered" water service. Water users in the area who are not on the metered system rely on these water sources when drought shortages occur. Commercial developments and industrial water users in the region access the public water system absent any other developed water source in the region.

Depressed economic conditions and lack of comprehensive water management hinder water development and effect public health and safety. Various economic development and Chapter Land Use Plans project water demands for regional economic development that cannot be served by the current public water system. Rural water users access non-potable water sources for culinary water needs exposing residents to water borne pathogens. Water users who haul their potable water supplies from long distances in winter months risk hazardous driving conditions to meet their water demands. Short-term projected economic development is limited by assured water supply. Commercial and Industrial development is limited to the current developed water supply.

Regional groundwater uses may impact in-stream flow levels in the study area. Some groundwater uses may impact water quality in the project area. Impaired water is used by rural dispersed population during periods of drought resulting in adverse impacts to public health and safety.

All tasks carried out for this study will make maximal use of the existing studies and information. This appraisal level investigation will include further descriptions of the:

- Present Water and Related Development
  - Domestic, industrial, municipal, residential, and agricultural supply and use
- Socio and Economic Characteristics
  - Cultural, social, and economic background, including population demographics
  - Major industries, population centers, agriculture, and ranching
  - Recreation, fish, and wildlife
  - Indian Trust Assets
- Environmental Characteristics
  - Land resources, surface and groundwater resources, vegetation and wildlife, etc., and ecological importance.

2.2 SURFACE AND GROUNDWATER QUANTITY

The team will collect and evaluate existing data associated with the current water quality, supply, usage, projected demand and conservation of water within the project area. It will discuss with water suppliers in the project area their current sources of supply, their demands (including seasonal variances), how their systems meet those demands, conservation technologies utilized, and their anticipated development alternatives.

2.3 WATER SUPPLY INFRASTRUCTURE

The team will conduct an evaluation of the water supply, reliability, and condition of the existing community and rural domestic water systems within the study area to determine the capability of the current infrastructure to be upgraded and expanded to anticipate demands.

2.4 SURFACE AND GROUNDWATER QUALITY

The Team will:

$ Document the quantity and quality of the surface and groundwater resources within the study area. Water availability assessments utilizing approved evaluation criteria will be completed at an appraisal level to establish whether the sources of supply can be developed to meet demands allocated to that supply source.

- $ Conduct an evaluation of various demand management options and alternative water supplies, including wastewater reclamation, recycling, gray water reuse, and brackish or impaired water treatment.

- $ Document current and projected water demands to year 2060 by type, quantity, quality, reliability, and source of supply.

2.5 LAND, CULTURAL AND ENVIRONMENTAL RESOURCES

The team will identify potential significant environmental, social and cultural resource impacts associated with alternatives. Also, identify Atrends@ at end of study period (e.g. Migration of saline or brackish groundwater, increase in water level decline, etc.)

2.6 SOCIO-ECONOMIC CONDITIONS

The team will identify and summarize the extremely difficulty socio-economic conditions facing the resident of this study area. These conditions create serious limitation on the communities' ability to pay.

3.0 PROBLEMS AND OPPORTUNITIES

3.1 PROBLEM AND OPPORTUNITY STATEMENTS

The team will develop recommendations that may:

- $ Supplement existing supplies
- $ Improve water management and system reliability.
- $ Develop brackish groundwater
- $ Groundwater management
- $ Identify active and development of potential recharge sites.
- $ Improve public health and safety
- $ Assure water supply for economic development

3.2 PLANNING OBJECTIVES, CONSTRAINTS, AND OPPORTUNITIES

The team will identify constraints to achieving the stated objectives. Some of these constraints include:

- $ Groundwater, although the most relied-upon source of water in the regional study area, varies tremendously, with most water systems and sources affected by acts of nature, policy decisions, or legal action. The lack of well data in some areas and associated expense to develop data necessary to quantify the impacts of additional development on the aquifer is a substantial issue and constraint.

$ On-going water rights negotiations between the State of Utah and the Navajo Nation include negotiated assumptions regarding groundwater and surface water development that may be incompatible with Rural Water Project development.

$ Diffuse water development planning produce barriers and inconsistencies to organize comprehensive water development and management plans.

$ Federal water development authorities and constrained budgets inhibit water development in the study area.

$ Identify stakeholders and other entities that participate or have an obligation to development reliable water supplies for the region.

$ Increase public awareness with regard to water issues, problems and opportunities within the study area.

$ Document, for each demand area, existing conservation, reuse and demand management practices (as described in section 1.2) and characterize each practice as it relates to cost benefits 1,000 gallons.

$ Quantify current and future water demands (agricultural, livestock, residential, and commercial) within the study area to include rural dispersed water users to the extent they can be determined.

$ Conduct a water supply and reliability assessment, looking at potential water sources, including surface and groundwater, local and imported, impaired, brackish, water efficiency, conservation and alternative supplies. Report the impact of drought on current supplies and to the extent possible, impacts to future supply alternatives.

$ Quantify potential contributions to the local and regional water supply options such as increased wastewater reclamation, water recycling, gray-water reuse, brackish groundwater development, etc.

$ Coordinate and incorporate various investigations and groundwater modeling publications pertinent to the study area.

$ Formulate alternatives and establish criteria for recommended plan selection that will meet the identified needs and accommodate existing opportunities. Include both structural and demand management solutions in the formulation process. Include conceptual design and cost estimates for alternatives including the cost allocations for each entity (construction, operation, maintenance, replacement) identified.

$ Identify and report potential funding sources for implementation of the preferred alternatives.

$ Assess impacts, both positive and negative, (environmental, economic, growth) associated with alternatives for providing regional water supplies.

$ Recommend a preferred set of water supply and demand management options based on an appraisal level evaluation of the alternatives for their ability to meet the study purpose and needs and satisfy the established impact evaluation criteria.

$ Develop methods to protect and preserve regional groundwater resources.

$ Identify data gaps that limit the extent to which the potential viability of promising alternatives can be determined, and recommend additional data collection that should be conducted at the feasibility level to reduce these uncertainties.

$ Develop a scope-of-work for a feasibility level investigation.

4.0 ALTERNATIVES TO BE STUDIED

The following list represents a non-exclusive summary of water supply alternatives, in no particular order, that will be studied, to the extent appropriate, as part of this Study.

- Construct new or upgrade existing rural water supply infrastructure.
- Extend existing rural water supply infrastructure to increase service area.
- Inter-connect existing rural water infrastructure.
- Develop, treat, store and recover brackish groundwater.
- Develop, treat, store and recover regional groundwater.
- Develop, treat, store and recover impaired groundwater
- Improve Local Surface Water Impoundments including Livestock Water Tanks
- Explore potential of Renewable Energy Sources
- Drought Mitigation
- Additional Groundwater Exploration
- Environmental Enhancement
- Water Conservation

4.1 FORMULATE, EVALUATE, AND COMPARE ALTERNATIVES

Utilizing the results of the previous tasks, a series of water supply development projects and/or technologies (including conservation, reuse and brackish/impaired treatment) will be identified to deliver high quality, reliable water supplies to the designated participating entities in the study while meeting specific source of supply and environmental impact criteria. Preliminary construction and O&M costs will be developed for the selected alternatives and the cost of delivered water to each entity shall be estimated and reported as a price per thousand gallons. The most cost-effective set of projects and/or technologies which meets the objectives of the study within identified policy and environmental constraints will be identified. The team will summarize current and project water uses and will:

- Document and quantify existing and future M&I water uses throughout the study area
- Tie each community or entity to a specific sources and/or alternatives of supply. (i.e. point of diversion, groundwater source, conservation practice, conservation technology.)
- Document and quantify existing and future additional water uses
- Tie each use to a source of supply

The team will assess the quantity and quality of the surface water, groundwater & alternative water resources of the study area. The team will identify and review key studies and models for utilization by this study. The team will summarize study conclusions and identify areas of concern. The team may propose additional modeling as appropriate. The team will:

- $ Evaluate hydrology, water supply, and water quality findings within relevant water resource areas of concern.
- $ Develop conclusions as to whether water is available for future water use from each surface water source or surface/alluvial aquifer source.
- $ Identify areas suitable for recharge and water banking to the extent they exist.

The team will identify water supply development alternatives and/or technologies to deliver high quality, reliable water supplies to the designated communities and other participating entities in the study while meeting specific source of supply and environmental impact criteria. The team will analyze Water Supply Availability and Specific Water Development Plans.

- $ Establish alternative water supply projects to meet designated needs, giving consideration to provision of a reliable water supply, impacts, utilization of competent and cost-effective facilities and sites, mitigating flooding and sedimentation problems, meeting environment concerns, conservation measures and reasonable costs of water treatment, etc.
- $ Water development plans are to include analysis of demand management options and alternative water supplies, including reuse, recycling, and conservation
- $ Document major cost items at an appraisal level, including treatment plants, transmission lines, conservation systems, pump stations, power lines, and reservoirs for each alternative water plan.
- $ Make preliminary analysis of most cost effective alternatives. Identify level of demands unmet by recommended projects.
- $ Documenting water supply alternatives considered and eliminated from further analysis, and state reasons for elimination.
- $ For each alternative evaluate power demands of each alternative, possible power source, cost, and reliability.

4.2 COST ESTIMATES

The team will:

- $ Estimate the cost-benefits of the potentially viable alternatives analyzed over a 50-year period.
- $ In addition to domestic and industrial water benefits, consider and estimate, where appropriate and possible, the impacts of other water uses.
- $ Estimate costs of alternatives on a $/1000 gallon basis, and evaluate the capacity to pay.

5.0 AFFECTED ENVIRONMENT

5.1 ENVIRONMENTAL QUALITY, RESOURCES, AND ATTRIBUTES

Potential environmental impacts will be addressed in this study to the extent they are likely to be a key factor in the development of a range of potentially viable alternatives. In the case of severe impact on specific resources, potential mitigation requirements and appraisal level costs will be identified. The key requirement is to identify issues, which could potentially eliminate an alternative plan, based upon its effect on a specific resource, or that would significantly increase overall project costs by excessively increasing mitigation costs. The team will:

- Review existing documents for accuracy and completeness.
- Identify baseline conditions and complete analyses, as needed to identify potential environmental issues for each alternative. Identify potential mitigation of adverse impacts, as appropriate.
- $ Review existing documents for accuracy and completeness.
- $ Identify baseline conditions and complete analyses, as needed, to identify potential social and environmental justice impacts for each alternative. Identify potential mitigation of adverse impacts, as appropriate.
- $ Effort for this task should not exceed that which is necessary to identify issues which could potentially eliminate an alternative plan, or that would significantly increase overall project costs by significantly increasing mitigation costs.

5.2 CULTURAL RESOURCES

The Team will review existing documents for accuracy and completeness including:

- Identify baseline conditions and complete analyses, as needed, to identify potential cultural resources assessment impacts for each alternative. Identify potential mitigation of adverse impacts, as appropriate.
- $ Effort for this task should not exceed that which is necessary to identify issues which could potentially eliminate an alternative plan, or that would significantly increase overall project costs by significantly increasing mitigation costs.

6.0 CONSULT AND COORDINATE

The technical team will provide opportunities for consultation and coordination for each major milestone, along with coordination meeting throughout the study.

7.0 CONCLUSIONS AND RECOMMENDATIONS

Evaluate the alternatives using Reclamation's four tests of viability: completeness, effectiveness, efficiency, and acceptability. An alternative will not be considered further if it fails to meet one or more criteria. Criteria specific to the components of this study will be jointly developed for each test and applied to the plan selection process in the form of a matrix. This presentation will allow for the direct comparison of the alternatives and the selection of the most viable. A no action alternative will be developed to project a future without alternatives.

The Technical team will develop, in consultation/coordination with participating entities, as appropriate, an initial set of selection criteria, including weighting factors to apply to the criteria. The performance of an alternative will be measured against the weighted criteria and will be displayed in a matrix along with other technical evaluation results deemed appropriate for comparison purposes.

Completeness: The extent to which a given alternative plan (which may include a mix of multiple supply and demand management projects) provides and accounts for all necessary investments or other actions to ensure the realization of the planned effects. This may require relating the plan to other types of public or private plans if the other plans are crucial to realization of the contributions to the objective. Each alternative will be analyzed to assess whether it would respond to the study purpose and objectives without further investments or implementation of other plans not assumed to be already in place.

Effectiveness: The extent to which an alternative plan alleviates the specified problems and achieves the specified opportunities as stated in the study purpose and needs.

Efficiency: The extent to which an alternative plan is the most cost-effective means of alleviating the specified problems and realizing the specified opportunities, consistent with protecting the environment

Acceptability: The workability and viability of the alternative plan with respect to acceptance by the communities and entities participating in the study. Estimates of the extent of potential support for, or opposition to, implementation of the alternatives by affected parties will be used to measure acceptability.

The team will develop a recommended set of water supply alternatives and/or technologies based on the results of the individual project analyses and associated impact analyses on environmental and other resources. All viable alternatives must demonstrate that a firm water supply can be delivered. Document the basis for the recommendations, including the comparative performance and impacts of the selected and rejected alternatives.

STUDY ORGANZIATION

A Reclamation study manager will manage and direct Reclamation and Cooperating Partner activities and coordinate/facilitate the participation of other entities and interested publics. The following is a partial list of the participating entities, organizations, and groups expected to have an interest in this study:

Navajo Nation
Kayenta Chapter
Oljato Chapter
Natural Resources Conservation Service
Navajo Tribal Utility Authority
Bureau of Indian Affairs
Indian Health Services
Steering Committees
Others

As a means of guiding the performance of the study, securing effective cooperation and interchange of information, and improving consultation on a prompt and orderly basis among the entities and publics in connection with various administrative and technical matters which may arise from time to time, a Technical Advisory Group (TAG) will be established consisting of a representative from each of the partners chaired by a representative from Reclamation. The TAG will oversee the formulation of the project alternatives, level of detail of the study, general format of documentation of the project alternatives, and conformance with the study goals, budget, and schedule. The TAG will have the following specific duties on this study:

- Identify, nominate and approve members of the TAG and appoint them by letter
- Review the evaluation criteria and formally approve/disapprove the criteria
- Review the alternatives and formally select the preferred plan or plans
- Participate in periodic meetings
- Review and comment on drafts of documents developed for the Study

The Study Team will be comprised of individuals and consultants working for the Cooperating Partners and Reclamation. The Study Team will perform the activities associated with the study, such as gathering existing data, assisting the Technical Team, and writing the final report. The Study Team will have the following specific duties on this study:

- Gather the existing reports
- Update existing reports, if necessary

- $ Gather any additional technical data that is needed
- $ Formulate and perform public outreach activities
- $ Develop viable alternatives that meet the study purpose and needs
- $ Develop an assessment of potential impacts (legal, cultural resource, engineering, economic, and environmental) for each alternative
- $ Document the study results with preparation of draft and final reports
- $ Participate in periodic meetings

The Stakeholders are agencies such as Navajo Nation, Utah Chapters, Indian Health Services, Natural Resources Conservation District, Bureau of Indian Affairs, and local residents together with others such as watershed groups, who will be asked to provide consultation as needed. Stakeholders will have no specific responsibilities during the study.

DELIVERABLES

Draft and final reports will be prepared documenting the findings of the study, including analyses of existing and future water demand, supply reliability, potentially viable water supply alternatives and associated potential impacts, alternatives considered and eliminated from further consideration, and recommendations and conclusions regarding a preferred set of alternatives having the highest potential for meeting the purpose and needs of the study. Included in the report will be a summary of power needs by location, potential sources, reliability, and projected costs including delivery. All technical disciplines will generate supporting documents as appropriate to cover the details of their individual evaluations. This includes the possible development of monthly written status reports, weekly telephone conferences, and meetings at major milestones not to exceed one per quarter.

BUDGET

The budget is based on several key assumptions. First, the completion of the study will be augmented by the numerous studies that have already been completed in the study area. Second, Reclamation staff will be available to implement this study. And third, the Navajo Nation and other sponsors will provide technical assistance. The Navajo Nation has worked closely with the Phoenix Area Office on many different project and studies and there is an excellent working relationship. At this time it is not possible to provide the resumes of the principle investigators because the availability of Reclamation staff has not yet been determined.

Table 1. Mexican Hat Kayenta Navajo Rural Water Project Appraisal Level Study Budget Proposal

BUDGET ITEM DESCRIPTION	COMPUTATION		RECIPIENT FUNDING	RECLAMATION FUNDING	TOTAL COST
	$/Unit and Unit	Quantity			
SALARIES AND WAGES				90,000	120,000
FRINGE BENEFITS				13,500	18,000
TRAVEL (10 trips)	$1000/trip	10		10,000	18,000
EQUIPMENT				500	500
SUPPLIES/MATERIALS				500	500
CONTRACTUAL				0	0
OTHER				1,000	1,000
TOTAL DIRECT COSTS				115,500	115,500
INDIRECT COSTS				N/a	N/a
TOTAL PROJECT COSTS				115,500	115,500

APPENDIX F – Trucking Cost Estimate

2013 Peterbilt 388	http://www.truckertotrucker.com/listings/143288.cfm							Pop Grow	Pop	Current	Hauling	Gallons	Trips	Trucks needed		1.02	assuming 2% inflati	O&M	Gal. per year	Cost / GpY	Cost / Tho
149,000								1.013	11392	6835	4557	729,120	100	16.00	$297,428	$4,758,855.59		$430,000	266,128,800		
516	miles per day (6 trips)						Gal pp	160	11540.1	6835	4705.096	752,815	103	18.00	$303,377.04	$5,460,786.79		$662,400	274,777,606	$0.02	$24.91
500000							Gal p trailr	7310	11690.12	6835	4855.117	776,819	106	18.00	$309,444.58	$5,570,002.53		$664,000	283,538,847	$0.02	$24.53
86									11842.09	6835	5007.089	801,134	110	19.00	$315,633.48	$5,997,036.05		$665,600	292,413,984	$0.03	$25.25
968.9922	2.654773								11996.04	6835	5161.036	825,766	113	19.00	$321,946.15	$6,116,976.77		$667,200	301,404,498	$0.02	$24.90
http://www.nexttruckonline.com/trucks-for-sale/by-make/Peterbilt/388/results.html?s-sort_I									12151.98	6835	5316.984	850,718	116	20.00	$328,385.07	$6,567,701.38		$668,800	310,511,889	$0.03	$25.63
Resale at 500,000 = 56,500									12309.96	6835	5474.96	875,994	120	20.00	$334,952.77	$6,699,055.41		$670,400	319,737,675	$0.03	$25.30
									12469.99	6835	5634.99	901,598	123	21.00	$341,651.83	$7,174,688.34		$672,000	329,083,397	$0.03	$26.03
Trailer 2012 PRO FAB 170 bbl = 7310 gallons									12632.1	6835	5797.1	927,536	127	22.00	$348,484.86	$7,666,666.97		$673,600	338,550,613	$0.03	$26.76
http://www.truckpaper.com/list/list.aspx?HDRSO=Price&ETID=1&catid=350&bcatid=28&Pref=0									12796.32	6835	5961.317	953,811	130	22.00	$355,454.56	$7,820,000.31		$675,200	348,140,903	$0.03	$26.47
52,500									12962.67	6835	6127.669	980,427	134	23.00	$362,563.65	$8,338,963.96		$676,800	357,855,867	$0.03	$27.21
30 year resale = 15000			37,500						13131.18	6835	6296.184	1,007,389	138	23.00	$369,814.92	$8,505,743.24		$678,400	367,697,125	$0.03	$26.94
									13301.89	6835	6466.889	1,034,702	142	23.60	$377,211.22	$8,902,184.84		$680,000	377,666,320	$0.03	$27.28
Avg trip -	4 hours								13474.81	6835	6639.814	1,062,370	145	24.00	$384,755.45	$9,234,130.72		$681,600	387,765,114	$0.03	$27.43
									13649.99	6835	6814.986	1,090,398	149	25.00	$392,450.56	$9,811,263.89		$683,200	397,995,192	$0.03	$28.18
Replace truck every 3 years									13827.44	6835	6992.436	1,118,790	153	26.00	$400,299.57	$10,407,788.73		$684,800	408,358,262	$0.03	$28.93
6									14007.19	6835	7172.193	1,147,551	157	27.00	$408,305.56	$11,024,250.06		$686,400	418,856,051	$0.03	$29.68
8.75	MPG								14189.29	6835	7354.286	1,176,686	161	27.00	$416,471.67	$11,244,735.07		$688,000	429,490,312	$0.03	$29.46
9.828571	Gallons per run								14373.75	6835	7538.747	1,206,200	165	28.00	$424,801.10	$11,894,430.87		$689,600	440,262,818	$0.03	$30.22
4	Price diesel								14560.61	6835	7725.606	1,236,097	169	29.00	$433,297.12	$12,565,616.61		$691,200	451,175,367	$0.03	$30.98
39.31429	Cost fuel per run								14749.89	6835	7914.893	1,266,383	173	29.00	$441,963.07	$12,816,928.94		$692,800	462,229,778	$0.03	$30.79
235.8857	Cost fuel per day								14941.64	6835	8106.642	1,297,063	177	30.00	$450,802.33	$13,524,069.85		$694,400	473,427,897	$0.03	$31.56
3	drivers per truck								15135.88	6835	8300.883	1,328,141	182	31.00	$459,818.37	$14,254,369.62		$696,000	484,771,592	$0.03	$32.33
52000	Salary	benefits = 12k estimate							15332.65	6835	8497.65	1,359,624	186	31.00	$469,014.74	$14,539,457.02		$697,600	496,262,755	$0.03	$32.16
http://www.truckingtruth.com/trucking_blogs/truckermike/2011/02/my-2010-salary-finishing-									15531.97	6835	8696.974	1,391,516	190	32.00	$478,395.04	$15,308,641.19		$699,200	507,903,303	$0.03	$32.94
									15733.89	6835	8898.89	1,423,822	195	32.00	$487,962.94	$15,614,814.02		$700,800	519,695,178	$0.03	$32.78
295/75/22.5 tires 2 200,000 miles									15938.43	6835	9103.431	1,456,549	199	34.00	$497,722.20	$16,922,554.69		$702,400	531,640,347	$0.03	$34.51
600 a piece		simplytire website							16145.63	6835	9310.63	1,489,701	204	34.00	$507,676.64	$17,261,005.78		$704,000	543,740,803	$0.03	$34.36
10800									16355.52	6835	9520.523	1,523,284	208	35.00	$517,830.17	$18,124,056.07		$705,600	555,998,566	$0.04	$35.16
0.054	per mile tires								16568.15	6835	9733.145	1,557,303	213	36.00	$528,186.78	$19,014,723.97		$707,200	568,415,679	$0.04	$35.96
change oil	10,000 miles								16783.53	6835	9948.531	1,591,765	218	37.00	$538,750.51	$19,933,768.96		$708,800	580,994,215	$0.04	$36.77
400	cost								17001.72	6835	10166.72	1,626,675	223	38.00	$549,525.52	$20,881,969.87		$710,400	593,736,272	$0.04	$37.58
0.04	per mile oil								17222.74	6835	10387.74	1,662,038	227	38.00	$560,516.03	$21,299,609.26		$712,000	606,643,975	$0.04	$37.47
					500,000	188679.2	mpyear		17446.63	6835	10611.63	1,697,862	232	39.00	$571,726.35	$22,297,327.80		$713,600	619,719,479	$0.04	$38.29
replace truck every 2.65 years after 500,000									17673.44	6835	10838.44	1,734,151	237	39.60	$583,160.88	$23,093,170.89		$715,200	632,964,964	$0.04	$38.75
35094.34	truck								17903.2	6835	11068.2	1,770,911	242	41.00	$594,824.10	$24,387,788.04		$716,800	646,382,641	$0.04	$39.95
10188.68	Tires per year								18135.94	6835	11300.94	1,808,150	247	42.00	$606,720.58	$25,482,264.38		$718,400	659,974,747	$0.04	$40.79
7547.17	oil per year								18371.7	6835	11536.7	1,845,873	253	43.00	$618,854.99	$26,610,764.66		$720,000	673,743,551	$0.04	$41.64
86098.29	fuel per year								18610.54	6835	11775.54	1,884,086	258	43.00	$631,232.09	$27,142,979.96		$721,600	687,691,349	$0.04	$41.57
156000	Drivers								18852.47	6835	12017.47	1,922,796	263	44.00	$643,856.73	$28,329,696.29		$723,200	701,820,468	$0.04	$42.42
1500	Estimated insurance costs								19097.56	6835	12262.56	1,962,009	268	45.00	$656,733.87	$29,553,024.08		$724,800	716,133,267	$0.04	$43.29
1000	depreciation on trailer								19345.82	6835	12510.82	2,001,732	274	46.00	$669,868.55	$30,813,953.11		$726,400	730,632,131	$0.04	$44.15
$297,428	Cost per year for truck and trailer w/ diesel at $4 a gallon								19597.32	6835	12762.32	2,041,971	279	47.00	$683,265.92	$32,113,498.09		$728,000	745,319,481	$0.05	$45.03
									19852.09	6835	13017.09	2,082,734	285	47.50	$696,931.24	$33,104,233.67		$729,600	760,197,766	$0.05	$45.45
									20110.16	6835	13275.16	2,124,026	291	48.00	$710,869.86	$34,121,753.27		$731,200	775,269,469	$0.05	$45.89
8,450,000	Water treatment plants								20371.59	6835	13536.59	2,165,855	296	50.00	$725,087.26	$36,254,362.85		$732,800	790,537,104	$0.05	$47.70
720600	O&M treatment plants								20636.42	6835	13801.42	2,208,228	302	51.00	$739,589.00	$37,719,039.11		$734,400	806,003,218	$0.05	$48.60
									20904.7	6835	14069.7	2,251,152	308	52.00	$754,380.78	$39,227,800.68		$736,000	821,670,392	$0.05	$49.51
									21176.46	6835	14341.46	2,294,634	314	53.00	$769,468.40	$40,781,825.09		$737,600	837,541,239	$0.05	$50.43
									21451.75	6835	14616.75	2,338,681	320	54.00	$784,857.77	$42,382,319.36		$739,200	853,618,407	$0.05	$51.36
									21730.63	6835	14895.63	2,383,300	326	55.00	$800,554.92	$44,030,520.67		$740,800	869,904,579	$0.05	$52.30
																	Intake, Storage, Treat				
																$962,703,169.40	$14,200,000	$35,510,000			
										Pipe Expenditures			Trucking Expenditures							O&M intake, storage, treatm	
								1	790000	**$5,429,921**	0.03		$19,388,856				$1,012,413,169.40			720600	
								2	15800	$5,445,721			$6,843,787	Total Yearly Cost						720600	
								3		$5,461,521		$148,632,258.69	$6,954,603		$426,080,873.68					720600	
								4		$5,477,321		NPV	$7,383,236		NPV		$1,048,443,169.40			720600	
								5		$5,493,121			$7,504,777				Sum of costs			720600	
								6		$5,508,921			$7,957,101							720600	
								7		$5,524,721			$8,090,055							720600	
								8		$5,540,521			$8,567,288							720600	
								9		$5,556,321			$9,060,867							720600	
								10		$5,572,121			$9,215,800							720600	
								11		$5,587,921			$9,736,364							720600	
								12		$5,603,721			$9,904,743							720600	
								13		$5,619,521			$10,302,785							720600	
								14		$5,635,321			$10,636,331							720600	
								15		$5,651,121			$11,215,064							720600	
								16		$5,666,921			$11,813,189							720600	
								17		$5,682,721			$12,431,250							720600	
								18		$5,698,521			$12,653,335							720600	
								19		$5,714,321			$13,304,631							720600	
								20		$5,730,121			$13,977,417							720600	
								21		$5,745,921			$14,230,329							720600	
								22		$5,761,721			$14,939,070							720600	
								23		$5,777,521			$15,670,970							720600	
								24		$5,793,321			$15,957,657							720600	
								25		$5,809,121			$16,728,441							720600	
								26		$5,824,921			$17,036,214							720600	
								27		$5,840,721			$18,345,555							720600	
								28		$5,856,521			$18,685,606							720600	
								29		$5,872,321			$19,550,256							720600	
								30		$5,888,121			$20,442,524							720600	
								31		$5,903,921			$21,363,169							720600	
								32		$5,919,721			$22,312,970							720600	
								33		$5,935,521			$22,732,209							720600	
								34		$5,951,321			$23,731,528							720600	
								35		$5,967,121			$24,528,971							720600	
								36		$5,982,921			$25,825,188							720600	
								37		$5,998,721			$26,921,264							720600	
								38		$6,014,521	xx		$28,051,365							720600	
								39		$6,030,321			$28,585,180							720600	
								40		$6,046,121			$29,773,496							720600	
								41		$6,061,921			$30,998,424							720600	
								42		$6,077,721			$32,260,953							720600	
								43		$6,093,521			$33,562,098							720600	
								44		$6,109,321			$34,554,434							720600	
								45		$6,125,121			$35,573,553							720600	
								46		$6,140,921			$37,707,763							720600	
								47		$6,156,721			$39,174,039							720600	
								48		$6,172,521			$40,684,401							720600	
								49		$6,188,321			$42,240,025							720600	
								50		$6,204,121			$43,842,119							720600	
								51		$6,219,921			$45,491,921								
																				($16,166,295.78)	
										$297,070,971			$1,048,443,169.40								

APPENDIX G - CONTRIBUTORS

The following contributors to the Mexican Hat to Kayenta Appraisal Study are employees of the U.S. Department of the Interior, Bureau of Reclamation, Provo Area Office and Technical Service Center.

Name	Position Title	Contribution
Brian Joseph, MA	Archaeologist	Cultural Resources; Paleontology
Peter Crookston, MS	Environmental Protection Specialist	NEPA Compliance
Troy Ethington, MS	Geographer	Mapping; Graphic Design
W. Russ Findlay, MS	Fish and Wildlife Biologist	Wildlife Resources, Vegetation, T&E Species
Beverley Heffernan, AB	Chief, Water and Environmental Resources Division	NEPA Compliance; Environmental Justice; Indian Trust Assets; Agency Review
Rafael A. Lopez, BA	General Biologist	Wetlands, CWA Compliance, 404 Permit
David Nielsen, MS, PG	Geologist	Geology Writeup
Rachelle Vanderplas, BS	Geologist	Geology Writeup
Ira Terry PG	Geologist	Geology Report
Jeff Hearty, MS	Economist	Socioeconomics
Joseph Gemperline, PE	Civil Engineer	Technical Review
Steve Dundorf, PE	Civil Engineer	Water Treatment
Nick Clough, PE	Civil Engineer	Pipeline Review
Chris Perry	Economist	Policy Review
Zachary Rothmier	Economist	Policy Review
Cary Southworth, PE[a]	Supervisory Civil Engineer	Report Preparation
Brandi Rose	Program Manager	Regional Policy Review

a = Registered Professional Engineer

b = Registered Professional Geologist