

locations. The storage capacity for each of the municipal systems was based on the individual service area 5-day demand for the year 2020 for those communities with existing water distribution systems.

The city of Gallup and Jicarilla Apache Nation surface diversion requirements are 7,500 and 1,200 AFY, respectively, for all years in the proposed project. An independent analysis (volume II, appendix B) conducted by the city of Gallup identifies the system requirements for the city and the surrounding Navajo communities served by the Gallup Regional System. No storage is provided for the Jicarilla Apache Nation.

WATER TREATMENT CONSIDERATIONS

Water Quality

Water from the Navajo Indian Irrigation Project

The water source for the Cutter Reservoir diversion is Navajo Reservoir. The water quality parameters, shown in table F-4, indicate that the only treatment requirements are filtration and disinfection as required under the Surface Water Treatment Rule (SWTR), which is part of the Safe Drinking Water Act (SDWA). Further sampling and analysis would be required before final design and construction to verify that the data presented in table F-4 are correct, especially during low- and high-precipitation years.

Table F-4.—Water quality (NIIP source water)

Parameter	Average ¹	Design range	Secondary maximum contaminant level (MCL) ²
Electrical conductivity (umhos/cm)	195	205-187	
pH	7.72	7.75 – 7.71	
Temperature (degrees Fahrenheit)	46.7	49.1 – 45.3	
Turbidity (NTU) ³	2.6	3.16 – 1.47	
Total suspended solids (mg/L) ⁴	1.15	1.3 – 1	
Total dissolved solids (mg/L)	154	181 – 140	500
Sulfates, SO ₄ (mg/L)	32.5	38.2 – 2.29	250
Total organic carbon (mg/L)	4.47	8 – 2.29	
Chlorides (mg/L)	1.6	1.9 – 1.2	250

¹ Data from three samples collected from the Cutter diversion April 2000 to June 2000.

² Secondary standards for MCLs are established by the Environmental Protection Agency for control of aesthetic qualities relating to public acceptance and include contaminants that may affect taste, color, odor, and appearance.

³ Nestler Turbidity Units.

⁴ Milligrams per liter.

San Juan River Diversion

The San Juan River, upstream of the PNM diversion, would provide water to the SJRPNM water treatment plant. Table F-5 provides water quality parameters. As shown, the water quality meets all primary standards established by the Environmental Protection Agency (EPA) for the parameters shown, resulting in the need for filtration and disinfection to meet the requirements of the SWTR. Several samples exceeded the total dissolved solids (TDS) and sulfates secondary standards. Sulfates and TDS are constituents that cannot be substantially reduced by the proposed ultrafiltration system. Further investigation is required to confirm the reduction of water quality due to the increase of TDS and sulfates associated with storm water runoff flows at the SJRPNM diversion points. Since this water cannot be treated by the proposed system, the following operation scenarios are suggested during major runoff events:

Table F-5.—Water quality (San Juan alternatives)

Parameters	PNM historic ¹		Design ²	
	Average	Range	Range	Secondary maximum contaminant level (MCL) ³
EC (umhos/cm)	538	1,102 – 276	632 – 214	
pH	8.1	8.7 – 7.7	8.7 – 7.6.	
Temperature (degrees Fahrenheit)	53	71 – 32.2	75 – 33	
Turbidity (NTU) ⁴	166	1055 – 8	200 – 5.4 ⁵	
Total suspended solids (mg/L) ⁶	876.6	1080 – 21	262 – 21	
TDS (mg/L)	362	772 – 145	1000 – 24	500 ⁷
SO ₄ (mg/L)	140	322 – 65	200 – 38	250
TOC (mg/L)	5.7	10.5 – 2.9	4.76 – 2.89	
Chloride (mg/L)	14	23 – 6	26.6 – 2.91	250
T. hardness (mg/L)	163	232 – 84	232 – 84	

¹ Data for PNM is based on 34 samples collected at the diversion point between February 2003 through July 1, 2005.

² Design value for total suspended solids incorporates the reduction of turbidity and suspended solids by the pre-treatment settling pond.

³ Secondary standards for MCLs are established by EPA for control of aesthetic qualities relating to public acceptance and include contaminants that may affect taste, color, odor, and appearance.

⁴ Nestler Turbidity Units.

⁵ All source water with a turbidity of over 200 NTU will need to be pre-treated by diversion through the settling ponds.

⁶ Milligrams per liter.

⁷ State of New Mexico secondary MCL for TDS is 1,000 mg/L.



Water hauling is necessary for a quality water supply in parts of the Navajo Nation.

- Significant dilution may be provided in the SJRPNM settling ponds to reduce TDS and sulfate concentrations to below maximum contaminant level (MCL) limits.
- Storage capacity in the settling ponds, waste water polishing ponds, and treated water distribution system may be adequate to temporarily stop diverting water from the San Juan River to the treatment plant during large storm events. Once the concentrations of TDS at the diversion intakes are below 500 parts per million (ppm) TDS and 250 ppm sulfate, diversion of San Juan River water can resume.

Water Treatment

The water source for the SJRPNM Alternative is surface water from the NIIP and the San Juan River. The treatment systems used to provide drinking water to the consumers must comply with the SWTR.¹ The filtration and disinfection requirements under this rule protect consumers against the potential adverse effects of exposure to *Giardia lamblia*, *Cryptosporidium*, viruses, *Legionella*, and heterotrophic bacteria by requiring the inactivation of 99.9 percent (3 log) for *Giardia* cysts and 99.99 percent (4 log) for viruses.

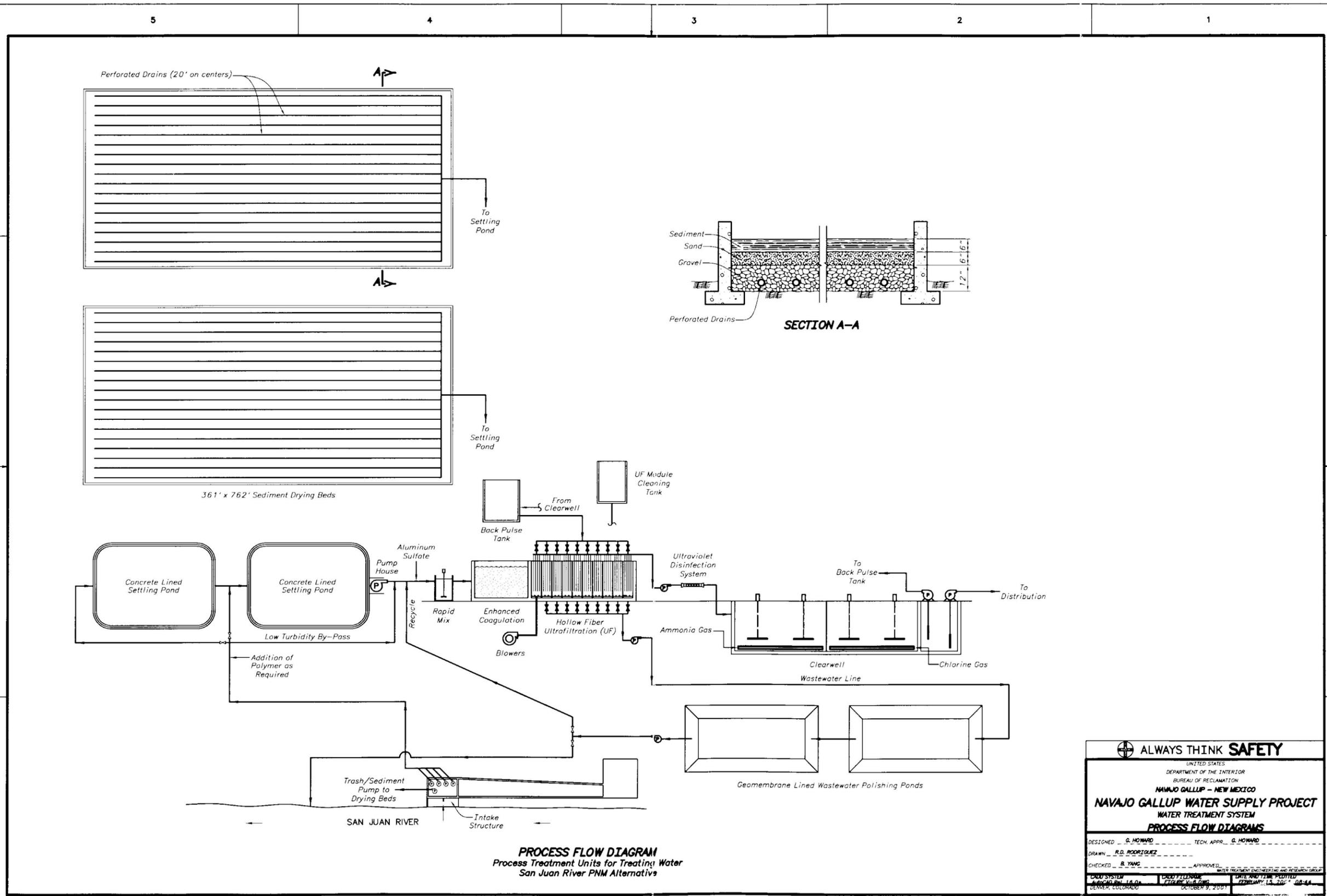
The inactivation of potential pathogens, as required by the SWTR, is accomplished by the use of EPA-approved technologies for filtration and disinfection methods. Newly adopted regulations to address the risk of disinfection byproducts (DBPs) include the Disinfectants - Disinfection Byproducts Rule and the Interim Enhanced Surface Water Treatment Rule, which requires continual monitoring of filtered water turbidity and routine DBP levels in the distribution system.

The relatively high concentrations of total organic carbons (TOC) in samples from the NIIP and San Juan River water sources, as shown in tables F-4 and F-5, in combination with the long detention times required to convey the treated water to some of the delivery points, indicate a potential for the production of DBPs that may exceed current and future regulatory limits at the treated water service points or within the domestic water storage and distributions systems used to distribute the water to consumers. In order to determine the expected reduction in TOC concentrations by the proposed treatment system and the potential of DBPs production over time, bench-scale distribution simulation studies using chloramine and free chlorine disinfection should be done. If bench scale analysis indicates that the DBP limits are exceeded, additional treatment systems to remove the DBPs before consumption may be required in some locations.

Description of the Proposed Water Treatment System

The proposed water treatment system consists of enhanced coagulation, ultrafiltration, and ultraviolet disinfection to provide multiple treatment barriers for removal of organic molecules, *Giardia*, *Cryptosporidium*, and viruses. The use of chloramines to provide a disinfection residual during the conveyance of treated water from the treatment plant to the service areas will not only provide treated water that is not conducive to the formation of disinfection byproducts, but will also provide an additional disinfection barrier. Figure F-5 illustrates the proposal. Before final design and construction, a

¹ The SWTR was published in the *Federal Register* on June 29, 1989, and is promulgated by EPA as a National Primary Drinking Water Regulation for public water systems using surface water sources or groundwater under the direct influence of surface water.



PROCESS FLOW DIAGRAM
 Process Treatment Units for Treating Water
 San Juan River PNM Alternative

ALWAYS THINK SAFETY

UNITED STATES
 DEPARTMENT OF THE INTERIOR
 BUREAU OF RECLAMATION
 NAVAJO GALLUP - NEW MEXICO
NAVAJO GALLUP WATER SUPPLY PROJECT
 WATER TREATMENT SYSTEM
PROCESS FLOW DIAGRAMS

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 CALLO SYSTEM ... CALLO FIELD STATION ... DATE AND TIME PLOTTED ...
 DENVER, COLORADO ... OCTOBER 9, 2001 ... FEBRUARY 13, 2002 ... 08:44

comprehensive pilot-scale operation of each process will be required to verify the effectiveness and operation of each unit process and resultant water quality.

Water Treatment Plants.—The proposed water treatment plants primarily include buildings that would house most of the water treatment features already described. Figure F-5 displays the water treatment plant structures (all plant structures, except intakes, must be located above the 100-year flood plain).

Main Treatment Building – The main treatment building would be approximately 24,500 square feet with a second floor mezzanine that would be approximately 22 feet wide and 122 feet long. The proposed building would be a pre-engineered, pre-fabricated structure with metal siding and suitable insulation and ventilation to meet the building code requirements of the State of New Mexico and all other applicable code requirements. The building would house the 10-foot-tall flocculation basins, 10-foot-tall concrete tanks containing the ultrafiltration modules for each train, UV units, vacuum pumps, and internal piping. The second floor mezzanine would contain the control room for the filters and UV units, air blowers used for module cleaning, and the motor control center. The chlorine storage room and ammonia storage room would be included in the main building, but would have outside entrances and separate heating, ventilation, and air conditioning (HVAC) systems to eliminate the risk to the operators if leakage occurred in any of the cylinders. The building is designed to house the treatment system required to meet 2040 demands.

The chlorine and ammonia storage room would house the 1-ton containers of each gas along with the chlorinators and ammoniators, which would meter the gases into the clear well for mixing. Trunnions are provided in the storage room to provide for the storage of full containers to meet a 2-month demand along with spare trunnions for storage of an equal amount of empty or full containers.

NIIP Cutter Diversion Treatment Plant – The Cutter diversion water treatment plant is a scaled-down version of the main treatment plant, with a building area of approximately 4,600 square feet. Like the larger plant, the flocculation basins would be located inside the building to protect the water from windblown sand and freezing temperatures. Due to its reduced size, all treatment components for the Cutter treatment plant would be located on a single floor.

Regional O&M Buildings – The preferred alternative (SJRPNM) includes a 2,500-square-foot regional O&M building located within the treatment plant compound. Buildings would be on a slab on grade with 15-foot eave heights. The facility would be used for spare equipment/parts storage and for maintenance areas relating to the treatment, conveyance, and pumping of water for the proposed project.

Clear Well – The below-grade clear well would provide a detention time of 30 minutes and would include injection manifolds, baffles, and mixers to properly mix ammonia and chlorine with treated water. After chloramination, the treated water would be pumped by the service pumping station into the distribution system.

Waste Water Storage/Treatment Ponds – Water generated during the routine cleaning of the filters would flow into one of two passive treatment ponds. In these ponds, fine suspended solids filtered by the hollow fiber system would be settled out and removed from the site. After passive treatment, the water could be conveyed back into the treatment plant, discharged back into the source, or discharged to surface waters. The useful life of a pond is estimated to be between 10 to 15 years before settled sediment would need to be removed and conveyed to the sediment drying beds. Each pond would be lined with a 45-mil-thick geomembrane system to reduce the impact on regional groundwater.

Sediment Drying Beds – With the construction of a new diversion upstream from the existing PNM diversion dam, all sediment removed by the intake structure and settling ponds would have to be retained and ultimately disposed of off-site. The determination of the frequency of pond cleaning, volume of sediment, volume of dried sediment, size of required sediment drying beds, and resulting O&M costs in this report was based on one water quality sample taken during one storm event. This event occurred on August 23, 2000, and analyses indicated a turbidity reading over 23,000 Nestler Turbidity Units (NTU) units and a suspended solids loading of over 15,000 milligrams per liter (mg/L). The drying bed size and costs should be taken as preliminary because additional sampling and analyses would be required prior to design and construction. Using this data point, the lead pond would need to be dredged of sediment after every 10 days of storm runoff, and two sediment drying beds with a surface area of approximately 6 acres each would be required. When the sediment in the 10-foot-deep lead pond became 2 feet deep, approximately 130,000 cubic feet of sediment would need to be removed and placed on one of the drying beds. The excavated sediment would be applied at an approximate depth of 6 inches on the surface of each bed.² The system would remove water from the sediment by drainage and evaporation, reducing the water content by approximately 50 percent with a dried sediment depth of 2.5 to 3 inches. Once dried, the sludge would be removed from the top of each bed and transported to a nearby abandoned open pit coal mine for final disposal. O&M costs associated with excavation and transport of sediment collected from the settling ponds are based on two cleaning cycles per year.

Sediment Removal Ponds – The settling basins considered in this alternative are required to reduce turbidity of the San Juan River water before treatment. Most of the

² Beds consist of perforated polyvinyl chloride pipes located in a gravel under-drain system. Sand would lie on top of the gravel.

sediment contained in the source water would be removed by the intake and the proposed settling ponds. Each pond is designed with a 3-hour detention time, providing optimum conditions for the reduction of turbidity to acceptable limits before treatment by the enhanced coagulation and ultrafiltration systems. Settling tests using San Juan River water (collected during a high turbidity of 4,266 NTU) have verified that a two-pond system with each pond to provide a detention time of 3 hours would be sufficient to reduce turbidity to acceptable limits before treatment. The settling basins would have minimal effects on the quality of the water, with the exception of some dilution of high TDS and sulfate concentrations occurring during high runoff conditions. To reduce the impact of the ponds on regional groundwater through infiltration, and to avoid the need to replace the liner after each sediment removal event, each pond would be lined with 6 inches of reinforced concrete. The settling pond(s), sized to meet the hydraulic requirements for the demand year 2040, are based on a 6-hour detention time and have the following specifications:

- Influent flow rate of 38.25 MGD
- A required volume of 9,653,000 gallons in settling pond(s)
- A surface area of 1.72 acres with a 10-foot depth and 1:1 side slopes

Source water from the NIIP would not require settling basins because the water would have already passed through a large surface impoundment that acts like a settling basin.

Enhanced Coagulation – In waters that have variable annual turbidity or moderate-to-high TOC concentrations, ultrafiltration systems typically include an enhanced coagulation step prior to filtration to coagulate small suspended materials in the water and to increase the filtration efficiency. This process increases the removal of organic matter before disinfection to meet the requirements of the Stage 1 and Stage 2 DPB Rule. This pre-treatment process uses aluminum sulfate or other coagulants in such a manner that the type and dosage can only be determined by laboratory and field tests (assuming aluminum sulfate would be the coagulant of choice and the required concentration would be 30 mg/L).

Hollow Fiber Ultrafiltration Treatment System – Previous studies have evaluated the potential for using conventional, diatomaceous earth and microfiltration/ultrafiltration for the treatment of surface waters associated with this project. A discussion of these studies is included in volume II, appendix A, section 8.5. Based on this analysis, ultrafiltration using hollow fiber membranes along with enhanced coagulation is the proposed method for filtration because the system is (1) able to treat water with varying turbidity, (2) able to meet current and future regulatory standards, and (3) easy to operate and maintain.

The hollow fiber ultrafiltration treatment system physically removes suspended particles greater than 0.1 micron in diameter by having a nominal and absolute pore size of 0.035 and 0.1 micron, respectively. Particles found in surface water that exceed this size

range are easily filtered. These particles include Giardia (5–15 microns in size), Cryptosporidium (4–6 microns in size), large viruses, and large organic molecules. The continuous hollow fiber ultrafiltration system manufactured by US Filter (CMF-S) or Zenon (ZeeWeed) are bundles or cassettes of tubular membranes that filter water through microscopic holes. Designed for large-scale systems, the pre-engineered cassettes are submerged into open-top concrete or steel tanks.

Ultraviolet Disinfection Units – Disinfection after ultrafiltration would be accomplished by state-of-the-art flow-through UV disinfection units that are located on the filtered water discharge line from each ultrafiltration treatment train. Each unit would consist of a stainless steel chamber containing eight UV lamps, an automatic cleaning system, a UV monitoring system, and a control cabinet. Each unit would provide a minimum UV dose of 40 microjoules per square centimeter to the filtered water before being routed to the clear well.

The proposed UV units would add an additional 3 log (99.9 percent) reduction of Giardia and Cryptosporidium and an additional 4 log (99.99 percent) reduction in viruses to the water following the ultrafiltration process. Based on this information, the unit processes of ultrafiltration and UV disinfection would provide a reduction of 9 log for Giardia and Cryptosporidium and 6 log for viruses. This reduction would far exceed the SDWA requirements.

Chloramination – The mixing of filtered and disinfected water with ammonia gas followed by chlorine gas in the clear well would provide a chloramine residual prior to being pumped by the service water pumping plant into the treated water mains leading to the service areas. This form of residual is being used to reduce the development of DBPs that would be generated by extended contact times in the conveyance and storage facilities if a free chlorine residual were used. Other benefits of a chloramine residual include prevention of taste and odor problems and the fact that the chloramine residual would last longer in the treated water transmission line and storage system, thus eliminating the number of re-chloramination stations (Reclamation, 2002).

Other Treatment Components.—

Chloramine Booster Stations – Each pumping plant would contain a chloramine booster station that would monitor the chloramine residual of the incoming water and automatically add, as required, additional chlorine to maintain the 0.5 ppm residual to the water being pumped by the plant. The capital and O&M costs of these re-chloramination systems are included as part of the unlisted items in the water treatment cost estimate.

Water Blending – Blending of good water quality produced by the proposed surface water treatment plants with low quality groundwater presently used by the city of Gallup and many of the Navajo Nation communities may increase turbidity in the mixed water.

Increased turbidity, a secondary MCL, in the blended water would decrease the aesthetic quality of the water. In order to predict and compensate for any reactions, a detailed water quality analysis for each well system is required. These data would then be used in the “Rothberg, Tamburnini & Windsor Model for Corrosion Control and Process Chemistry” or a similar model to predict turbidity formation. If the modeling determines chemical addition(s) are required to eliminate the formation of turbidity, followup laboratory verification is required. In order to provide funding for modeling and potential chemical injection systems, a 10-percent unlisted additive is included in the capital cost for each treatment system and each demand. To account for potential O&M costs of these systems, a 10-percent miscellaneous additive is provided.

Disinfection Byproduct Treatment – Included in the unlisted percentage in the capital cost for each alternative is funding for the installation of aeration systems and re-chlorination systems at each service point to remove DBPs that may be created during conveyance.

Pilot Plant Operation – Prior to final design of the selected alternative, a pilot study using the proposed treatment system would be required to optimize each treatment process and collect design data. The pilot plant should operate 24 hours a day over a minimum of 12 consecutive months to determine treatment requirements with changing water conditions. A line item providing a sum of \$200,000 to fund the pilot study is included in the capital cost. The study would provide or determine:

- The most efficient chemical to use for coagulation
- Chemical injection rates based on changing water quality
- Backwash requirements and membrane cleaning requirements
- Waste water quality and production rates
- The potential for DBP formation during conveyance
- Operation requirements
- The ability of the treatment system to meet current and future regulatory standards
- Data to update capital and O&M costs
- Training for future operators on the full-scale treatment system

Operation.—The overall operational system would monitor the demands in the treated water distribution system and activate/deactivate the treatment system to maintain required water levels or pressures in the treated water storage tanks. When in operation, the water treatment system master control panel would control the local control panels (LCP) for each treatment process. During automatic operation, the water treatment master control system monitors all LCPs and provides inputs for adjustments for optimal treatment efficiency. Operators would be required to monitor operations 24 hours a day,

along with routine duties such as calibrations of turbidity meters, chemical injection equipment, residual monitors, inventory control, and monthly reports. This control system would be integrated into the overall project control system.

Plant Operators.—Plant operation for all treatment plants and all demands would require a total staff of six personnel (four operators, one maintenance person, and one supervisor). The staff would ensure that at least one operator was at the plant during operation with suitable maintenance and supervisory support.

Chemicals.—Chemicals required include those for routine cleaning of the hollow fiber membranes, aluminum sulfate to flocculate the small suspended particles in the source water, and chlorine and ammonia gas to form a chloramine residual to keep the water disinfected during its transport from the treatment plants to service.

Power.—The annual cost for power to operate each plant would include power to operate vacuum pumps, air compressors, UV disinfection units, low-head lift pumps, lights, and HVAC units and a percentage increase for other loads required for operation of a large water treatment facility. For the Cutter diversion, a low lift pump would divert water from the waste water polishing ponds to the plant influent for recycling. Three low-head lift stations would be required for the SJRPNM component—one to transfer water from the river diversion to the settling ponds, one to transfer water from the settling ponds to the water treatment plant, and one to recycle water from the waste water ponds to the water treatment plant. To provide uninterrupted treated water, the New Mexico Environmental Department requires backup generators to be provided for all potable water treatment plants. These generators need to be rated to meet the power requirements during the average daily flow or 70 percent of the design flow.

Replacement of Equipment.—Annualized equipment replacement costs include annual replacement of UV light bulbs, the replacement of all hollow fiber cassettes every 10 years, and the replacement of mechanical equipment every 15 years. Details on the annualized cost of each are provided in volume II, appendix B.

Dredging and Disposing of Sediment.—When the settling and waste water polishing ponds contain a maximum of 2 to 3 feet of sediment, a dragline would be used to remove the sediment in the SJRPNM settling pond and each of the waste water polishing ponds. The sediment would be dried on the sand drying beds and, when dry, would be transported off-site for disposal. The estimated frequency for dredging and disposing of sediment is every 10 days of storm runoff for the SJRPNM lead settling pond and every 15 years for the waste water polishing pond.