Section 5
Full-Scale Facility Estimated Costs

This section provides the estimated capital costs and O&M costs the Full-Scale Facility, as well as costs for the overall project.

The capital costs were estimated based on the proposed Full-Scale Facility capacity of 18 mgd, while the O&M costs were estimated for the annual average purified water production of 15 mgd. The difference in the capacity for the capital and O&M costs is based on the seasonal variation of recycled water demands, which impacts how much tertiary effluent that can be treated at the Full-Scale Facility. The Full-Scale Facility will operate at the design capacity (18 mgd) in winter months when recycled water demands are lowest and will operate at a reduced production in summer months when recycled water demands are highest. This will result in an annual average purified water production of 15 mgd.

5.1 Estimated Capital Costs for the Full-Scale Facility

This section provides the estimated capital costs for the conceptual Full-Scale Facility. The conceptual design for the Full-Scale Facility is described in Section 4. The estimated construction cost for the Full-Scale Facility is presented in Table 5-1 below.

Appendix D includes additional breakdown of estimated construction cost for each of the process areas and buildings. The breakdown includes Total Amount and Grand Total columns. The Total Amount column represents the direct costs to the contractor, which include labor, materials, subcontractors, and equipment. The Grand Total includes the contractor direct costs plus construction allowances, permits and sales tax, which are estimated as summarized below based on previous construction project experience:

- Maintenance of traffic allowance – 5 percent
- Miscellaneous metals allowance – 2 percent
- Painting allowance – 2 percent
- Instrumentation and controls allowance – 8 percent
- Electrical allowance – 18 percent
- City of San Diego permits – 1 percent
- Sales tax (materials, equipment, and other) – 7.75 percent

Table 5-1 Estimated Construction Cost for the Full-Scale Facility[1]

Parameter	Capital Cost[2,3]
Construction Costs[4]	
AWP Facility Influent Pump Station	$2,800,000
Site Civil/Yard Piping[5,6]	$5,800,000
Operations, Maintenance, and Administration Building	$1,600,000
Membrane Filtration Break Tank and Pump Station	$4,000,000
Chemical Storage Area #1 (Pre-Treatment Chemical Facility)[7]	$2,400,000
Membrane Filtration Facility[8]	$25,300,000
Reverse Osmosis Facility[9]	$21,300,000
UV Disinfection and Advanced Oxidation System[10]	$9,900,000
Chemical Storage Area #2 (Post-Treatment Chemical Facility)[11]	$2,100,000
Construction Subtotal	**$75,200,000**
Contingency (30% of Construction Total)	$22,600,000
Overhead & Profit	$9,800,000
Insurance & Bond	$2,900,000
Construction Total	***$110,500,000***
Implementation Costs	
Engineering & Pre-Construction (20% of Total Construction Cost)	$22,100,000
Environmental Documentation	$1,000,000
Construction Management (10% of Total Construction Cost)	$11,100,000
Implementation Total	***$34,200,000***
Total Capital Cost (Construction Total + Implementation Total) [12]	**$144,700,000**

Notes:

1) This table presents costs for the Full-Scale AWP Facility only. For costs related to the Purified Water Pump Station and Purified Water Pipeline, refer to Table 5-4 and the Demonstration Project Report.
2) Includes installation costs and indirect costs (project management, field management and support, training, quality assurance and control, project safety, construction allowances, permits, and sales tax).
3) All costs are in February 2012 dollars. The Engineering News Record (ENR) Construction Cost Index is 9267.57 and the ENR Building Cost Index is 5144.49 for February 2012.
4) Construction duration is assumed to be 30 months. Based on a 40 hour work week with no overtime.
5) No rock excavation is assumed to be required. Only nominal dewatering is assumed to be needed. No consideration for contaminated soils or hazardous materials (e.g. asbestos, lead) is included. Site grading, drainage and containment are included with assumptions made based on the aerial photograph.
6) Includes pressure membrane filtration feed pipeline, gravity membrane filtration backwash, pressure RO concentrate pipelines, and chemical feed pipelines.
7) Includes sodium hypochlorite, ammonium hydroxide, sulfuric acid, and antiscalant.
8) Includes citric acid and sodium hydroxide system for membrane filtration chemical cleaning systems.
9) Includes cartridge filters and RO feed pumps.
10) Hydrogen peroxide system is included with the UV disinfection and advanced oxidation system.
11) Includes calcium chloride and sodium hydroxide.

5.2 Estimated O&M Costs for the Full-Scale Facility

The O&M cost estimate for the Full-Scale Facility considers power costs, chemical costs, equipment replacement costs, maintenance costs, laboratory costs, and labor costs. Table 5-2 presents the estimates for annual O&M costs for the Full-Scale Facility. Additional detail is provided in Appendix B. The largest annual O&M costs are anticipated to be power (33 percent), maintenance and equipment replacement (13 + 17 = 30 percent), labor (17 percent), and chemical consumption (16 percent).

Table 5-2 Estimated Annual O&M Costs for the Full-Scale Facility

Parameter	Annual O&M Cost[1]	Approximate Percentage of Annual O&M Costs
Power Costs[2]		
AWP Facility Influent Pump Station	$306,000	
Membrane Filtration System	$43,000	
Reverse Osmosis System	$1,614,000	
UV Disinfection and Advanced Oxidation System	$185,000	
Miscellaneous Equipment	$7,000	
Buildings	$481,000	
Power Costs – Subtotal	***$2,636,000***	***33%***
Chemical Costs		
Membrane Filtration Pretreatment	$223,000	
Reverse Osmosis Pretreatment	$431,000	
Hydrogen Peroxide for Advanced Oxidation	$216,000	
Post Treatment	$358,000	
Membrane Cleaning	$103,000	
Chemical Costs – Subtotal	***$1,331,000***	***16%***
Replacement of Consumables (Equipment Replacement)		
Membrane Filtration Membranes	$441,000	
Reverse Osmosis Cartridge Filters and Reverse Osmosis Membranes	$319,000	
UV Lamps and Ballasts	$281,000	
Replacement of Consumables – Subtotal	***$1,041,000***	***13%***
Maintenance Costs[3]	***$1,409,000***	***17%***
Other Costs (Compliance Testing and Security)[4]	***$310,000***	***4%***
Labor Costs[5]	***$1,418,000***	***17%***
Total Annual O&M Cost[6]	**$8,145,000**	**100%**

Notes:

1) All costs are in February 2012 dollars.
2) Power cost is assumed to be $0.12/kWh.
3) Assumed to be 1.7% of the equipment construction cost based on a review of actual maintenance costs for the Orange County Water District's Groundwater Replenishment System.
4) The annual compliance testing cost is assumed to be $150,000/year. This is based on half of the Demonstration Facility compliance testing cost of $300,000/year.
5) Estimated staffing = 12 personnel plus outside lab allowance, based on information provided by the City. The estimated staffing of 12 personnel was based on assessment of the department wide resources and additional needs to support and integrate this new facility as part of the City's existing treatment facilities. However, it is anticipated that this labor estimate will be updated in the future when the full-scale facility is constructed and the evaluation of new treatment technology provided at that time.
6) This table presents costs for the Full-Scale Facility only. For costs related to the Purified Water Pump Station and Purified Water Pipeline, refer to Table 5-5 and the Demonstration Project Report.

The O&M cost estimate is based on the preliminary design criteria developed for the Full-Scale Facility (see Section 4). The assumptions used for the O&M cost estimate are summarized below:

- The power consumption for each major water purification process was estimated taking into consideration efficiency of equipment and motors, and variation in equipment performance over time (e.g., membrane fouling over time will increase membrane feed pumping pressure and, therefore, increase power consumption). The average power demand for the Full-Scale Facility (annual average purified water production of 15 mgd) is approximately 2.1 to 3.1 megawatts, and the estimated total annual power consumption is 18,200,000 to 27,400,000 kilowatt-hours per year.
- The chemical consumption was estimated based on a range of dose rates defined in the design criteria.
- The replacement costs for microfiltration membrane modules assume a seven-year membrane life. The replacement costs for RO cartridge filters and RO membrane modules are based on other AWP facilities of similar size. The replacements costs for UV lamps and ballasts are based on 12,000 hours of life per lamp and seven years of life for ballasts based on information provided by Trojan.
- The annual maintenance cost for equipment is assumed to be 1.7 percent of the equipment construction cost based on a review of actual maintenance costs for GWRS.
- The annual compliance testing cost is assumed to be $150,000 per year. This is based on half of the Demonstration Facility compliance testing cost of $300,000 per year.
- The labor cost assumes 12 personnel based on information provided by the City of San Diego.

5.2.1 Comparison with Data from the Demonstration Facility

The estimated annual O&M costs for the Full-Scale Facility were compared to the O&M cost of the Demonstration Facility based on the first three quarters of operations. The estimated unit O&M costs for the Full-Scale Facility for most of the process areas are within 5 percent to 30 percent of the O&M costs for the Demonstration Facility (see Table 5-3). The differences are within an appropriate level of contingency since the Demonstration Facility has been operating within the first year of the equipment and membrane life, and many variables are anticipated to change over the course of the facility operation as the membranes age and water quality changes.

The largest difference between the estimated O&M costs for the Full-Scale Facility and the actual costs for the Demonstration Facility was for the RO system in which the estimated O&M costs for the Full-Scale Facility were estimated to be 60 percent higher than the Demonstration Facility. The differences between the two costs are discussed in more detail below. Additional information about energy conservation opportunities for the Full-Scale Facility RO system, including a discussion of using a two-stage RO system and energy recovery devices, are presented in Section 3.

Table 5-3 Full-Scale Facility Estimated O&M Costs Compared with the Demonstration Facility Operations Data

Process Area	Comparison	Notes
Membrane Filtration System	Full-Scale Facility unit power consumption estimate is approximately 10% lower than the unit power consumption of the Demonstration Facility.	Power consumption for Demonstration Facility included power consumption from chemical cleaning of RO system (chemical cleaning system was shared with RO, but measured as part of MF system).
RO System	Full-Scale Facility unit power consumption estimate is approximately 60% higher than the Demonstration Facility data.	RO feed pressure during first year of Demonstration Facility was operated at 126 psi (pump was sized for 175 psi). For the Full-Scale Facility the RO feed pumps are sized to operate at average feed pressure of 180 psi at year 2.5 (pump is sized for 230 psi at year 5). The increase in average pressure takes into consideration membrane age and potential increase in influent water TDS. Also, the Demonstration Facility did not have cartridge filters, which require additional booster pumping. These are included in the estimated O&M costs for the Full-Scale Facility.
UV System	Full-Scale Facility unit power consumption estimate is the same as the Demonstration Facility data.	Used 70% of maximum power draw value to estimate power consumption for the Full-Scale Facility.
Sodium Hypochlorite	Full-Scale Facility chemical usage estimate is 25% higher than the Demonstration Facility data.	Assumed 5 mg/L dose for the estimated O&M costs for the Full-Scale Facility. Dosed 3.8 mg/L at the Demonstration Facility. Higher dose is based on expected changes in water quality from both variations in the supply and higher salt passage as the RO membranes age.
Ammonium Hydroxide	Same	Assumed 1.5 mg/L dose for the estimated O&M costs for the Full-Scale Facility. Same dose was used at the Demonstration Facility.
Antiscalant	Full-Scale Facility chemical usage estimate is 29% higher than Demonstration Facility data.	Assumed 4.0 mg/L dose for the estimated O&M costs for the Full-Scale Facility. Dosed 3.0 mg/L at the Demonstration Facility.
Hydrogen Peroxide	Full-Scale Facility chemical usage estimate is 25% higher than Demonstration Facility data.	Assumed 5.0 mg/L dose for the estimated O&M costs for the Full-Scale Facility. Dosed 3.0 mg/L at the Demonstration Facility.
Sulfuric Acid	Not used at Demonstration Facility.	Assumed 60 mg/L dose for the estimated O&M costs for the Full-Scale Facility in the event that water quality changes. Did not use at the Demonstration Facility.

RO Booster Pumps

The Demonstration Facility does not include booster pumps or cartridge filters, which are included in the Full-Scale Facility conceptual design. Cartridge filters were not needed at the Demonstration Facility since concrete or concrete-lined tanks and piping, which could introduce debris into RO feed water, were not used between the membrane filtration and RO membranes. Cartridge filters are typically used upstream of the RO membranes to remove any particulate material inadvertently introduced after the membrane filtration system (spalled concrete, impurities in chemicals such as sulfuric acid, etc.). RO booster pumps are required to pump water through the cartridge filters ahead of the main RO feed pumps. In a larger facility, avoiding the use of concrete and concrete lined materials will be more challenging. While it has been done successfully in a handful of membrane

filtration/RO facility, planning for the Full-Scale Facility should allow for a more conventional design approach with RO booster pumps and cartridge filters, as presented in Section 4.2.3. Based on these assumptions, it was estimated that four duty RO booster pumps rated at 200 horsepower each will be required for the Full-Scale Facility.

RO Recovery

The RO system Trains A and B were operated at both 80 and 85 percent recovery during the testing period and has operated well at both recoveries. The pumping requirements for the Full-scale Facility are based on a recovery of 85 percent to maximize water production.

Influent Water Quality

The water quality of the tertiary filter effluent, which feeds the Demonstration Facility, has been lower in TDS when compared with historic TDS levels prior to 2011. The TDS concentrations influence the feed pressures required for the RO system, as higher TDS results in higher osmotic forces that must be overcome in the RO process. The TDS observed at the Demonstration Facility since August 2011 has averaged 860 mg/L. There has been a downward trend in the TDS levels in the NCWRP effluent since 2006, when TDS concentrations were as high as 1,260 mg/L. TDS levels can change depending on San Diego's source of drinking water (low salinity State Project Water vs. higher salinity Colorado River Water) and conservation efforts, which tend to drive TDS higher. It is expected that the TDS levels could again approach 1,100 to 1,150 mg/L if the drought, which started in 2011, continues or the contribution of water from the Colorado River increases. The estimated RO feed pressure for the Full-Scale Facility is based on 1,100 mg/L, instead of the 860 mg/L that is currently being measured at the Demonstration Facility, to represent the average of the range of TDS that the Full-scale Facility could potentially treat. This higher TDS results in a higher RO feed pressure and higher power consumption when compared to the Demonstration Facility.

Membrane Age

The other factor that influences the RO feed pressure is the membrane age. As the membranes age, higher pressures are required to force the flow through the membranes. RO membrane projection software (Hydranautics IMSDesign v2009) was used to compare the feed pressures required at year one and year five of an RO membrane. At year one with 85 percent recovery and 1,100 mg/L TDS, the feed pressure required is estimated to be 132 psi for a two-stage system including energy recovery. At year five the feed pressure is estimated to be 206 psi for the same operating conditions and system configuration. The average over the life of the membrane must be considered; therefore, 180 psi was used for the estimated O&M costs. This is compared to current pressure of 126 psi at the Demonstration Facility after twelve months of operation (June 2011 to May 2012) under lower influent TDS conditions and operating at both 80 to 85 percent recovery.

5.3 Estimated Costs for the Full-Scale Project

The estimated costs for the Full-Scale Project incorporate the Full-Scale Facility, Purified Water Pump Station, and the Purified Water Pipeline. Table 5-4 presents the estimated construction costs for the Full-Scale Project, Table 5-5 presents the estimated O&M costs for the Full-Scale Project, and Table 5-6 presents the estimated additional auxiliary program costs to support the Full-Scale Project. The Full-Scale Project and the associated costs are discussed in more detail in the Demonstration Project Report.

Table 5-4 Estimated Construction Costs for the Full-Scale Project

Parameter	Capital Cost
Total Full-Scale Facility Capital Cost (Construction Total + Implementation Total)[1]	**$144,700,000**
Purified Water Pipeline System Construction Costs[2]	
Purified Water Pump Station	$8,000,000
Purified Water Pipeline	$114,200,000
Pipeline System Construction Total	***$122,200,000***
Pipeline System Implementation Costs	
Contingency (30% of Construction Total)	$36,700,000
Engineering & Construction Management (30% of Construction Total)[3]	$36,700,000
Environmental Documentation and Mitigation	$24,400,000
Land Acquisition	$4,500,000
Pipeline System Implementation Total	***$102,300,000***
Total Pipeline System Capital Cost (Construction & Implementation)[2]	**$224,500,000**
Total Capital Cost (Full-Scale Facility and Pipeline System)	**$369,200,000**

Notes:

1) Refer to Table 5-1 for a breakdown of the Full-Scale Facility construction cost.
2) From the Demonstration Project Report.
3) Includes costs associated with regulatory compliance and permitting.

Table 5-5 Estimated Annual O&M Costs for the Full-Scale Project

Parameter	Annual O&M Cost[1]
Full-Scale Facility[1]	$8,145,000
Treatment at North City to Support Full-Scale Facility[2]	$3,965,000
Purified Water Pump Station[2,3]	$1,885,000
Purified Water Pipeline[2,4]	$1,500,000
Total Annual O&M Cost	**$15,495,000**

Notes:

1) Refer to Table 5-2 for a breakdown of the Full-Scale Facility O&M costs.
2) From the Demonstration Project Report.
3) Includes power and maintenance.
4) Includes maintenance.

Table 5-6 Estimated Auxiliary Program Costs for the Full-Scale Project[1]

Parameter	Auxiliary Cost
Auxiliary Upfront Cost	
Source Control Program Upfront Cost[2]	$500,000
Auxiliary Annual Cost	
Source Control Program Annual Costs[3]	$50,000
Public Outreach Annual Program Costs[4]	$700,000

Notes:

1) From the Demonstration Project Report.
2) Source control upfront costs include a chemical inventory program and GIS tracking database (approximately $50,000), a pollutant prioritization program to be completed by existing City staff (approximately $50,000 for initial set-up work), and a local limits evaluation for North City (approximately $400,000). For additional information on source control program costs, refer to the Enhanced Source Control Plan for the Full-Scale Advanced Water Purification Facility Technical Memorandum (RMC, 2013).
3) Source control annual costs include $25,000/yr for annual updates to the chemical inventory program and GIS tracking database, an average of $10,000/yr for periodic updates to the pollutant prioritization program, and $15,000/yr, on average, for updates to the local limits analysis. For additional information on source control program costs, refer to the Enhanced Source Control Plan for the Full-Scale Advanced Water Purification Facility Technical Memorandum (RMC, 2013).
4) Public outreach annual costs include initial start-up of outreach efforts. Annual public outreach costs will be scaled back following full-scale reservoir augmentation project operations.