

# UDWQ POTW Nutrient Removal Cost Impact Study: Analysis of Oakley City Water Reclamation Facility

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In partial fulfillment of the Utah Division of Water Quality *Publicly Owned Treatment Works (POTW) Nutrient Removal Cost Impacts Study*, this Technical Memorandum (TM) summarizes the process, financial and environmental evaluation of the Oakley City Water Reclamation Facility (OCWRF) to meet the four tiers of nutrient standards presented in Table 1.

The thirty mechanical POTWs in the State of Utah were categorized into five groups to simplify process alternatives development, evaluation, and cost estimation for a large number of facilities. Similar approaches to upgrading these facilities for nutrient removal were thus incorporated into the models developed for POTWs with related treatment processes. The five categories considered were as follows:

- Oxidation Ditch (OD)
- Activated Sludge (AS)
- Membrane Bioreactor (MBR)
- Trickling Filter (TF)
- Hybrid Process (Trickling Filter/Solids Contact (TF/SC) or Trickling Filter/Activated Sludge (TF/AS))

The OCWRF fits in the MBR Category.

TABLE 1  
Nutrient Discharge Standards for Treated Effluent

Tier	Total Phosphorus, mg/L	Total Nitrogen, mg/L
1N	0.1	10
1	0.1	No limit
2N	1.0	20
2	1.0	No limit
3	Base condition <sup>(1)</sup>	Base condition <sup>(1)</sup>

Note: <sup>(1)</sup> Includes ammonia limits as per the current UPDES Permit

## 1. Facility Overview

This facility is designed for an average flow rate of 0.25 million gallons per day (mgd) and currently receives an average annual influent flow of approximately 0.1 mgd. The facility operates an anoxic/aerobic activated sludge process ahead of the MBRs to treat its influent wastewater. The MBR system is designed to meet the POTW's BOD, TSS and TN effluent limits. The secondary effluent is discharged to the receiving waters after UV disinfection. Residual secondary solids generated from the process are dewatered using a Sludge Bagger unit and disposed of to a landfill. A process flow diagram of the existing facility is presented in Figure 1 and the major existing unit processes are summarized in Table 2.

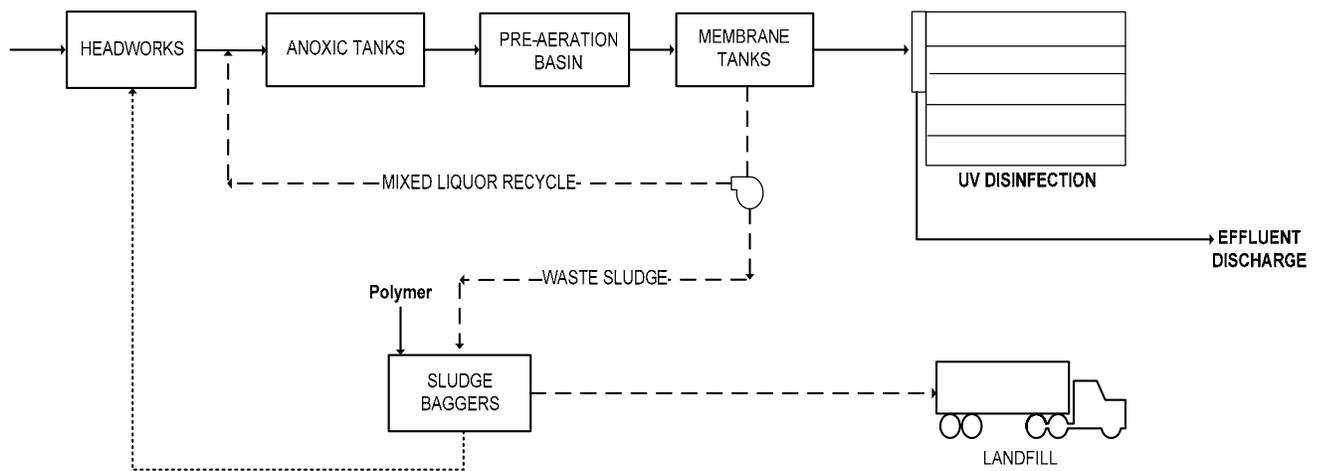


FIGURE 1  
Process Flow Diagram

TABLE 2  
Summary of Major Unit Processes

Unit Process	Number of Units	Size, Each	Details
Anoxic basins	2	28,000 gal	Rectangular
Aeration/Filtration Basin	2	51,200 gal	Fine bubble diffused aeration
Dewatering	1	----	Sludge bagger with polymer addition facility

## 2. Nutrient Removal Alternatives Development, Screening and Selection

For all the other treatment categories, a nutrient removal alternatives matrix was prepared to capture an array of viable approaches to meet the various Tiers of nutrient control. This was not done for the MBR category as they are inherently capable of achieving 1 mg/L total phosphorus and 10 mg/L total nitrogen limit. The most viable approach to upgrade the MBR facilities was to implement chemical phosphorus removal. The processes that were

modeled and described in subsequent sections are considered proven methods for meeting the nutrient limits. There may be other ways to further optimize the process to reduce capital and operation and maintenance (O&M) costs that are beyond the scope of this project. This TM can form the basis for an optimization study in the future should that be desired by the POTW.

OCWRF operates all of the facilities listed in Table 2 and is able to achieve biological nutrient removal to a certain extent. A goal of this project was to make maximum use of the existing infrastructure in the upgrade approaches selected for meeting the various tiers of nutrient limits. Upgrades were added to the system models as required to meet increasingly stringent discharge limits. Figure 2 shows the basic upgrade approach used between each tier of nutrient control with the bullet points A through D below describing each upgrade step:

- A. From Tier 3 (existing) to Tier 2 phosphorus control, a metal-salt addition system was initiated ahead of the MBR basins to be operated only as required for chemical phosphorus removal.
- B. From Tier 2 to Tier 2N, no additional process modifications were required.
- C. To go from Tier 2 to Tier 1 level of phosphorus control, higher amounts of metal-salt was added ahead of the MBR basins to bring down the effluent phosphorus concentration to 0.1 mg/L.
- D. To add nitrogen removal to Tier 1, no additional process modifications were required.

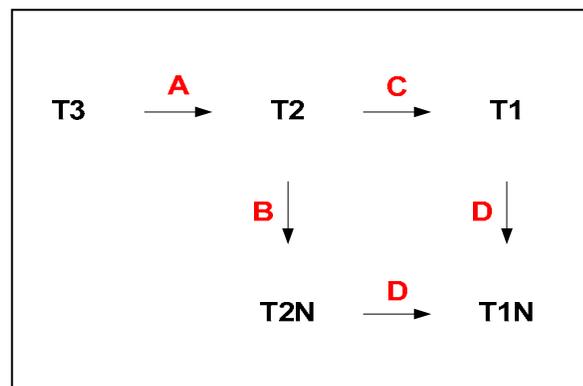


FIGURE 2  
Upgrades Scheme for Meeting Increasingly More Stringent Nutrient Control

### Data Evaluation and Modeling of Upgrades

The selected progression of the upgrades conceived for meeting the different tiers of nutrient control for OCWRF was analyzed using the following four steps;

- Step 1. Review, compile, and summarize the process performance data submitted by the POTW;

- Step 2. Develop and calibrate a base model of the existing POTW using the summarized performance data;
- Step 3. Build upon the base model by sequentially modifying it to incorporate unit process additions or upgrades for the different tiers of nutrient control and use model outputs to establish unit process sizing and operating requirements;
- Step 4. Develop capital and O&M costs for each upgrade developed in Step 3.

No data was received from OCWRF. Therefore, the design criteria and data submitted by the POTW to the State Department of Water Quality as Discharge Monitoring Report was summarized and evaluated to (a) develop, and validate the base process model, and (b) size facilities to conserve the POTW's current rated capacity. Table 3 provides a summary of the reported information used as the model input conditions. See Process Modeling Protocol (Attachment B) for additional information.

TABLE 3  
Summary of Input Conditions

Input Parameter	2009 <sup>(1)</sup>	2029 <sup>(2)</sup>	Design <sup>(3)</sup>
Flow, mgd	0.1	0.2	0.3
BOD, lb/day	142 (170 mg/L)	285 (170 mg/L)	625 (250 mg/L)
TSS, lb/day	185 (220 mg/L)	367 (220 mg/L)	625 (250 mg/L)
TKN, lb/day	25 (30 mg/L)	50 (30 mg/L)	75 (30 mg/L)
TP, lb/day	5 (6 mg/L)	10 (6 mg/L)	15 (6 mg/L)

<sup>(1)</sup> Historic conditions 2007-2009

<sup>(2)</sup> Assumed based on increase in population from Census report

<sup>(3)</sup> Estimated design maximum month capacity of POTW. Assumed 1.2 times (peaking factor) the design annual average flow provided by the POTW

The main sizing and operating design criteria that were important for capturing the costs associated with the system upgrades for OCWRF are summarized in Table 4.

TABLE 4  
Main Unit Process Sizing and Operating Design Parameters

Design Parameter (Nutrient Tier)	Value
Influent design temperature	10 deg C
Target metal:PO <sub>4</sub> -P molar Ratio (All tiers)	2:1
Metal salt storage (Tier2 and Tier2N) <sup>(1)</sup>	5 days
Metal salt storage (Tier1 and Tier1N)	14 days
Membrane flux rate	12 gpm/ft <sup>2</sup>

<sup>(1)</sup>Target dosing ratio ahead of the MBR basins

### 3. Nutrient Upgrade Approaches

The following paragraphs provide details of the upgrade approaches for the different Tiers of nutrient control as presented previously in Figure 3.

#### Tier 2 Phosphorus (A)

The effluent limit for the Tier 2 alternative is 1.0 mg/L total phosphorus. As per process modeling, OCWRF is able to meet this limit with the existing infrastructure and mode of operation. However, a metal-salt feed point was added to the existing facilities ahead of the MBR basins. This feed point would be operated as required for chemical phosphorus removal. A process flow diagram for this treatment approach is presented in Figure 3. Upgrades are indicated in red.

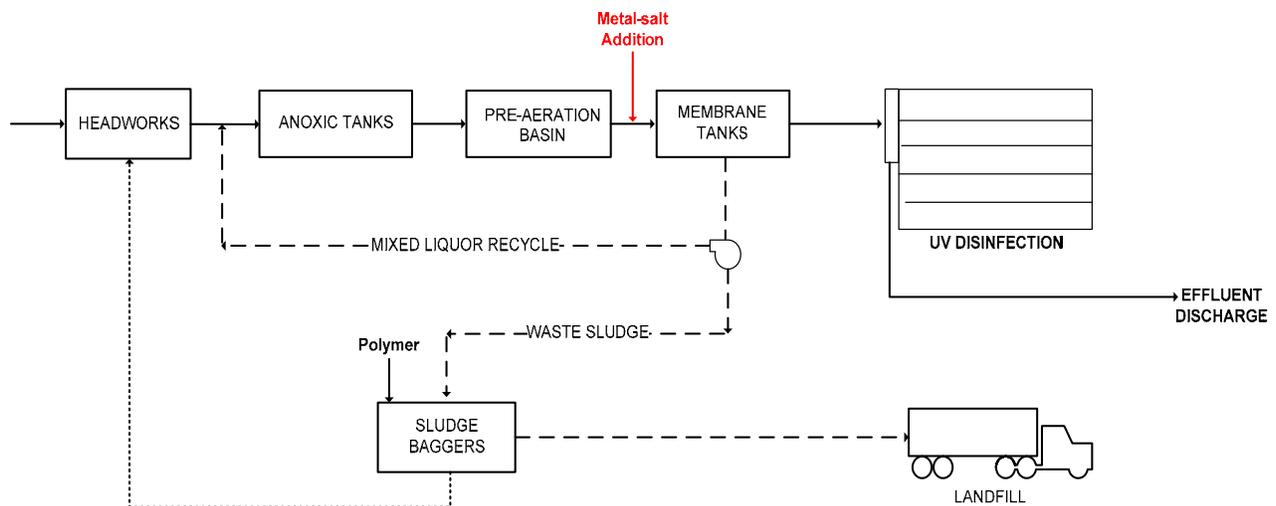


FIGURE 3  
Modifications to POTW for Tier 2 Nutrient Control

#### Tier 2N – Phosphorus & Nitrogen (B)

The metal-salt feed point approach ahead of the MBR basins in Tier 2 would not require any other adjustment for this Tier to achieve moderate amounts of total nitrogen control along with phosphorus. According to process modeling, the existing process is already exhibiting sufficient biological nitrogen removal to meet this limit; therefore, the process flow diagram for this approach would be the same as presented in Figure 3.

#### Tier 1 Phosphorus (C)

The upgrades for this alternative is essentially the same as proposed for Tier 2 alternative for phosphorus control, thus the process flow diagram is the same as presented in Figure 3. However, greater application rate of metal salts was required to bring down the effluent phosphorus concentration to 0.1 mg/L, and this resulted in an expansion of the metal-salt feed facility proposed for Tier 2 and 2N.

### Tier 1N Phosphorus & Nitrogen (D)

The approach and process flow diagram for this approach is the same as presented for Tier 1 level of phosphorus control. As per process modeling, the existing process is already exhibiting sufficient biological nitrogen removal to meet this limit, thus no additional modifications were required.

## 4. Capital and O&M Cost Estimates for Nutrient Control

This section summarizes the cost-impact results from the nutrient control process analysis. These outputs were used in the financial cost model and subsequent financial analyses.

Table 5 presents a summary of the major components identified for facility upgrades in order to meet the various Tiers of nutrient standards. For all the Tiers, metal-salt storage facility and new metal-salt feed pumps were installed ahead of the MBR basins. It was assumed that the building that houses the existing anoxic, aerobic and MBR tanks has sufficient space to house the metal-salt storage systems.

TABLE 5  
Major Facility Upgrade Summary

Processes	Tier 2	Tier 2N	Tier 1	Tier 1N
Metal-salt feed pumps and storage facility	X	X	X	X

The capital cost estimates shown in Table 6 were generated for the facility upgrades summarized in Table 5. These estimates were prepared in accordance with the guidelines of the Association for the Advancement of Cost Engineering (AACE) International and defined as a Class 4 estimate. The expected accuracy range for the estimates shown in Table 6 is -30%/+50%.

TABLE 6  
Capital Cost Estimates

Unit Process Facility	Tier 2	Tier 2N	Tier 1	Tier 1N
Metal-salt feed pumps and storage facility	\$120,923	\$120,923	\$241,847	\$241,847
<b>TOTAL TIER COST</b>	<b>\$120,923</b>	<b>\$120,923</b>	<b>\$241,847</b>	<b>\$241,847</b>

December 2009 US Dollars

Incremental O&M costs associated with meeting each tier of nutrient standard were generated for the years 2009 and 2029. The unit costs were assumed based on the average costs in the State of Utah, and are presented in Table 7. A straight line interpolation was used to estimate the differential cost for the two years. O&M estimates for each upgrade included the following components:

- Biosolids management: hauling, and disposal
- Chemical consumption costs: metal-salt, and polymer.

No energy costs were included because the energy required to operate the metal-salt feed pumps would be insignificant when compared to the total energy demand of the facility.

TABLE 7  
Operating and Maintenance Unit Costs

Parameter	Value
Biosolids hauling	\$8/wet ton
Biosolids tipping fee	\$6/wet ton
Alum	\$480/ton
Polymer	\$1/lb

Increase O&M relative to the current O&M cost (Tier 3) are presented in Table 8 and shown graphically in Figure 4.

TABLE 8  
Estimated Impact of Nutrient Control on O&M Costs

	Tier 2		Tier 2N		Tier 1		Tier 1N	
	2009	2029	2009	2029	2009	2029	2009	2029
Biosolids	\$0	\$0	\$0	\$0	\$520	\$520	\$520	\$520
Metal-salt	\$70	\$120	\$70	\$120	\$17,550	\$25,000	\$17,550	\$25,000
Polymer	\$30	\$80	\$30	\$80	\$130	\$180	\$130	\$180
<b>Total O&amp;M</b>	<b>\$100</b>	<b>\$200</b>	<b>\$100</b>	<b>\$200</b>	<b>\$18,200</b>	<b>\$25,700</b>	<b>\$18,200</b>	<b>\$25,700</b>

Note: \$ (US) in December 2009.

Costs shown are the annual differential costs relative to the base line O&M cost of the POTW

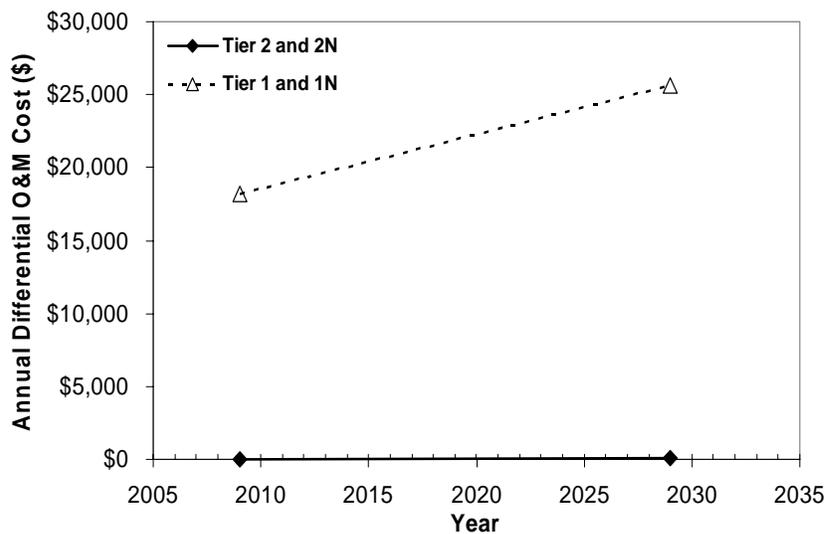


FIGURE 4  
Impact of Nutrient Control on O&M Costs over 20 year evaluation period

## 5. Financial Impacts

This section presents the estimated financial impacts that would result from the implementation of nutrient discharge standards for OCWRF. Financial impacts are summarized for each POTW on the basis of three primary economic parameters: 20-year life cycle costs, user charge impacts, and community financial impacts. The basis for the financial impact analysis is the estimated capital and incremental O&M costs established in the previous section.

### Life Cycle Costs

Life cycle cost analysis refers to an assessment of the costs over the life of a project or asset, emphasizing the identification of cost requirements beyond the initial investment or capital expenditure.

For each treatment upgrade established to meet the studied nutrient limits (Tier 2, Tier 2N, Tier 1, and Tier 1N), a multi-year life cycle cost forecast was developed that is comprised of both capital and O&M costs. Cost forecasts are organized with initial capital expenditures in year 0 (2009), and incremental O&M forecasts from year 1 (2010) through year 20 (2029). The cost forecast for each treatment alternative was developed in current (2009) dollars, and discounted to yield the net present value (NPV).

The NPV was divided by the estimated 20-year nutrient discharge mass reduction for each tier, resulting in a cost per pound estimate for nutrient removal. This calculation represents an appropriate matching of costs with receiving stream load reduction over the same time period. Table 9 presents the results of the life cycle cost analysis for the OCWRF.

TABLE 9

<i>Nutrient Removal: 20-Year Life Cycle Cost per Pound<sup>1</sup></i>				
	<b>Tier 2</b>	<b>Tier 2N</b>	<b>Tier 1</b>	<b>Tier 1N</b>
Phosphorus Removal (pounds) <sup>2</sup>	meets limit	meets limit	8,360	8,360
Nitrogen Removal (pounds) <sup>2</sup>	-	meets limit	-	meets limit
<b>Net Present Value of Removal Costs<sup>3</sup></b>	<b>\$ 123,266</b>	<b>\$ 123,266</b>	<b>\$ 575,616</b>	<b>\$ 575,616</b>
NPV: Phosphorus Allocation	123,266	123,266	575,616	575,616
NPV: Nitrogen Allocation <sup>4</sup>		-		-
<b>TP Cost per Pound<sup>5</sup></b>	<b>NA</b>	<b>NA</b>	<b>\$ 68.85</b>	<b>\$ 68.85</b>
<b>TN Cost per Pound<sup>5</sup></b>		<b>NA</b>		<b>NA</b>
1 - For facilities that are already meeting one or more nutrient limits, "meets limit" is displayed for nutrient removal mass and "NA" is displayed for cost per pound metrics				
2 - Total nutrient removal over a 20-year period, from 2010 through 2029				
3 - Net present value of removal costs, including capital expenditures and incremental O&M over a 20-year period				
4 - For simplicity, it was assumed that the nitrogen cost allocation was the incremental difference between net present value costs across Tiers for the same phosphorus limit (i.e. Tier 2 to Tier 2N); differences in technology recommendations may result in different cost allocations for some facilities				
5 - Cost per pound metrics measured over a 20-year period are used to compare relative nutrient removal efficiencies among treatment alternatives and different facilities				

## Customer Financial Impacts

The second financial parameter measures the potential impact to user rates for customers served by the POTW. The financial impact is measured both in terms of potential rate increases for the POTW's associated service provider, and the resulting monthly bill impacts for the typical residential customer of the system.

Customer impacts were estimated by calculating annual increased revenue requirements for the POTW. Implementation of each treatment upgrade will increase the annual revenue requirements for debt service payments (related to initial capital cost) and incremental O&M costs.

The annual cost increase was then divided by the number of customers served by the POTW, as measured by equivalent residential units (ERUs), to establish a monthly rate increase per ERU. The monthly rate increase associated with each treatment alternative was estimated by adding the projected monthly rate increase to the customer's current average monthly bill. Estimated financial impacts for customers of the OCWRF are presented in Table 10.

TABLE 10

<i>Projected Monthly Bill Impact per Equivalent Residential Unit (ERU) for Treatment Alternatives</i>				
	<b>Tier 2</b>	<b>Tier 2N</b>	<b>Tier 1</b>	<b>Tier 1N</b>
Initial Capital Expenditure	\$ 121,000	\$ 121,000	\$ 242,000	\$ 242,000
Estimated Annual Debt Service <sup>1</sup>	\$ 9,700	\$ 9,700	\$ 19,400	\$ 19,400
Incremental Operating Cost <sup>2</sup>	200	200	18,600	18,600
Total Annual Cost Increase	\$ 9,900	\$ 9,900	\$ 38,000	\$ 38,000
Number of ERUs	430	430	430	430
Annual Cost Increase per ERU	\$23.02	\$23.02	\$88.37	\$88.37
<b>Monthly Cost Increase per ERU<sup>3</sup></b>	<b>\$1.92</b>	<b>\$1.92</b>	<b>\$7.36</b>	<b>\$7.36</b>
Current Average Monthly Bill <sup>4</sup>	\$27.50	\$27.50	\$27.50	\$27.50
<b>Projected Average Monthly Bill<sup>5</sup></b>	<b>\$29.42</b>	<b>\$29.42</b>	<b>\$34.86</b>	<b>\$34.86</b>
<b>Percent Increase</b>	<b>7.0%</b>	<b>7.0%</b>	<b>26.8%</b>	<b>26.8%</b>
1 - Assumes a financing term of 20 years and an interest rate of 5.0 percent				
2 - Incremental annual increase in O&M for each upgrade, based on chosen treatment technology, estimated for first operational year				
3 - Projected monthly bill impact per ERU for each upgrade, based on estimated increase in annual operating costs				
4 - Estimated 2009 average monthly bill for a typical residential customer (ERU) within the service area of the facility				
5 - Projected average monthly bill for a typical residential customer (ERU) if treatment upgrade is implemented				

## Community Financial Impacts

The third and final parameter measures the financial impact of nutrient limits from a community perspective, and accounts for the varied purchasing power of customers throughout the state. The metric is the ratio of the projected monthly bill that would result

from each treatment alternative to an affordable monthly bill, based on a parameter established by the State Water Quality Board to determine project affordability.

The Division employs an affordability criterion that is widely used to assess the affordability of projects. The affordability threshold is equal to 1.4 percent of the median annual gross household income (MAGI) for customers served by a POTW. The MAGI estimate for customers of each POTW is multiplied by the affordability threshold parameter, then divided by 12 (months) to determine the monthly 'affordable' wastewater bill for the typical customer. The projected monthly bill for each nutrient limit was then expressed as a percentage of the monthly affordable bill. The resulting affordability ratio for each nutrient limit for the OCWRF is shown in Table 11.

TABLE 11

<i>Community Financial Impacts: Affordability of Treatment Alternatives</i>				
	Tier 2	Tier 2N	Tier 1	Tier 1N
Median Annual Gross Income (MAGI) <sup>1,2</sup>	\$ 49,900	\$ 49,900	\$ 49,900	\$ 49,900
Affordability Threshold (% of MAGI) <sup>3</sup>	1.4%	1.4%	1.4%	1.4%
<b>Monthly Affordability Criterion</b>	<b>\$58.22</b>	<b>\$58.22</b>	<b>\$58.22</b>	<b>\$58.22</b>
Projected Average Monthly Bill	\$29.42	\$29.42	\$34.86	\$34.86
Meets State's Affordability Criterion?	Yes	Yes	Yes	Yes
<b>Estimated Bill as % of State Criterion</b>	<b>51%</b>	<b>51%</b>	<b>60%</b>	<b>60%</b>
1 - Based on the average MAGI of customers within the service area of the facility				
2 - MAGI statistics compiled from 2008 census data				
3 - Parameter established by the State Water Quality Board to determine project affordability for POTWs				

## 6. Environmental Impacts of Nutrient Control Analysis

This section summarizes the potential environmental benefits and impacts that would result from implementing the process upgrades established for the various tiers of nutrient control detailed in Section 3. The following aspects were considered for this evaluation:

- Reduction of nutrient loads from POTW to receiving water bodies
- Changes in chemical consumption
- Changes in biosolids production
- Changes in emissions from biosolids hauling and energy production.

As per process modeling of the base condition (Tier 3), OCWRF is able to meet an effluent total nitrogen concentration of 10 mg/L and Tier 2 level of phosphorus control with its existing infrastructure. Table 12 summarizes the annual reduction in nutrient loads in the OCWRF effluent discharge if the process upgrades were implemented. The values shown are for the current (2009) flow and load conditions. It should be noted that any increase in flow or load to the POTW will result in higher reductions.

TABLE 12  
Estimated Environmental Benefits of Nutrient Control

	Tier 2	Tier 2N	Tier 1	Tier 1N
Total phosphorus removed, lb/year	----	----	275	275
Total nitrogen removed, lb/year	----	----	----	----

**Note:** Nutrient loads shown are the annual differential loads relative to the baseline (Tier 3) condition of the POTW for the year 2009.

The nutrient content of POTWs' discharges and their receiving waters were also summarized to examine the potential of various treatment alternatives for reducing nutrient loads to those water bodies. The POTW loads were paired with estimated loads in the upstream receiving waters to create estimated downstream combined loads. Those combined stream and POTW loads could then be examined for the potential effects of future POTW nutrient removal alternatives. The average total nitrogen and phosphorus concentrations discharged by each POTW were either provided by the POTW during the data collection process or obtained from process modeling efforts. Upstream receiving historical water quality data was obtained from STORET. Data from STORET was summarized in order to yield average total nitrogen and total phosphorus concentrations that could then be paired with the appropriate POTW records. It should be noted that the data obtained from STORET were not verified by sampling and possible anomalies and outliers could exist in historical data sets due to certain events or errors in measurement.

Table 13 shows the total phosphorus and total nitrogen concentration discharged by OCWRF for baseline condition (Tier 3) and for each Tier of nutrient standard. The STORET ID from where historical water quality data were obtained is also presented in the Table.

TABLE 13  
Estimates of Average TN and TP Concentrations for Baseline and Cumulative Treatments to Receiving Waters (mg/L)

STORET LOCATION	STORET ID	FLOW (cfs)	Tier 3		Tier 2		Tier 2N		Tier 1		Tier 1N	
			TP	TN	TP	TN	TP	TN	TP	TN	TP	TN
OCWRF	----	0.155	1.00	10.00	1.00	N/A	1.00	10	0.10	N/A	0.10	10
Weber River	4928030	134.98	0.108	0.676	----	----	----	----	----	----	----	----
<b>Combined Concentrations</b>			<b>0.109</b>	<b>0.687</b>	<b>0.109</b>	<b>N/A</b>	<b>0.109</b>	<b>0.687</b>	<b>0.108</b>	<b>N/A</b>	<b>0.108</b>	<b>0.687</b>

The process upgrades established to meet the four tiers of nutrient standards require increased chemical consumption and biosolids production. Metal-salt would be needed to be added to meet the more stringent phosphorus limits. This would result in increased chemical sludge production and consequently increased biosolids production. Table 14 summarizes these environmental impacts of implementing the process upgrades to achieve

the various tiers of nutrient control. The values shown are on an annual basis and are for the current (2009) flow and load conditions.

TABLE 14  
Estimated Environmental Impacts of Nutrient Control

	Tier 2	Tier 2N	Tier 1	Tier 1N
<b>Chemical Use:</b>				
Metal-salt use, lb/year	150	150	73,000	73,000
<b>Biosolids Management:</b>				
Biosolids produced, ton/year <sup>(1)</sup>	0	0	20	20
Particulate emissions from hauling trucks, lb/VMT-year <sup>(2)</sup>	0	0	0	0
Tailpipe emissions from hauling trucks, lb/VMT-year <sup>(3)</sup>	0	0	0	0
CO <sub>2</sub> emissions from hauling trucks lb/VMT-year <sup>(4)</sup>	0	0	0	0

**Note:** Values shown are the annual differential values relative to the base line condition (Tier 3) of the POTW for the year 2009

<sup>(1)</sup> Since additional biosolids generated due to proposed upgrades is not significant, it is assumed that no additional hauling would be required to transfer this amount of biosolids to the landfill.

<sup>(2)</sup> Includes PM<sub>10</sub> and PM<sub>2.5</sub> emissions in pounds per vehicle miles traveled (lb/VMT). The emission factors to estimate particulate emissions were derived using the equations from *AP-42, Fifth Edition, Vol. I, Section 13.2.1.: Paved Roads (11/2006)*.

<sup>(3)</sup> Tailpipe emissions in pounds per vehicle miles traveled (lb/VMT) resulting from diesel combustion of hauling trucks were based on *Emission standards Reference guide for Heavy-Duty and Nonroad Engines, EPA420-F-97-014 September 1997*. It was assumed that the trucks would meet the emission standards for 1998+.

<sup>(4)</sup> CO<sub>2</sub> emission factor in pounds per vehicle miles traveled (lb/VMT) for hauling trucks were derived from *Rosso and Chau, 2009, WEF Residuals and Biosolids Conference Proceedings*.