UDWQ POTW Nutrient Removal Cost Impact Study: Analysis of Moab City Wastewater Treatment Plant

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COPIES: Moab Wastewater Treatment Plant

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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 Moab City Wastewater Treatment Plant (MWWTP) 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 MWWTP fits in the Trickling Filter 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	Base condition

1. Facility Overview

MWWTP has a design flow of 1.5 million gallons per day (mgd) and currently receives an average annual influent flow of approximately 0.9 mgd. The facility operates a rock media trickling filter system with primary treatment. Chlorine is added to the secondary clarifiers for disinfection prior to discharge to the Colorado River. Primary solids and wasted solids are stabilized by anaerobic digestion and dewatered with sludge drying beds. A process flow diagram is presented in Figure 1 and an aerial photo of the POTW is shown in Figure 2. The major unit processes are summarized in Table 2.

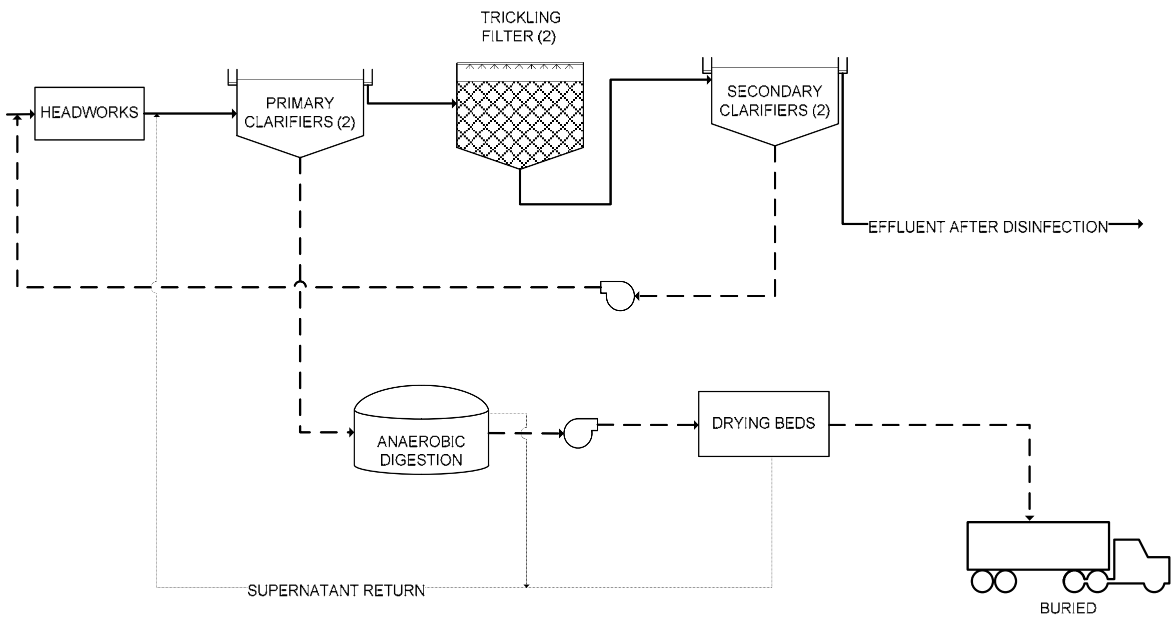

FIGURE 1
Process Flow Diagram

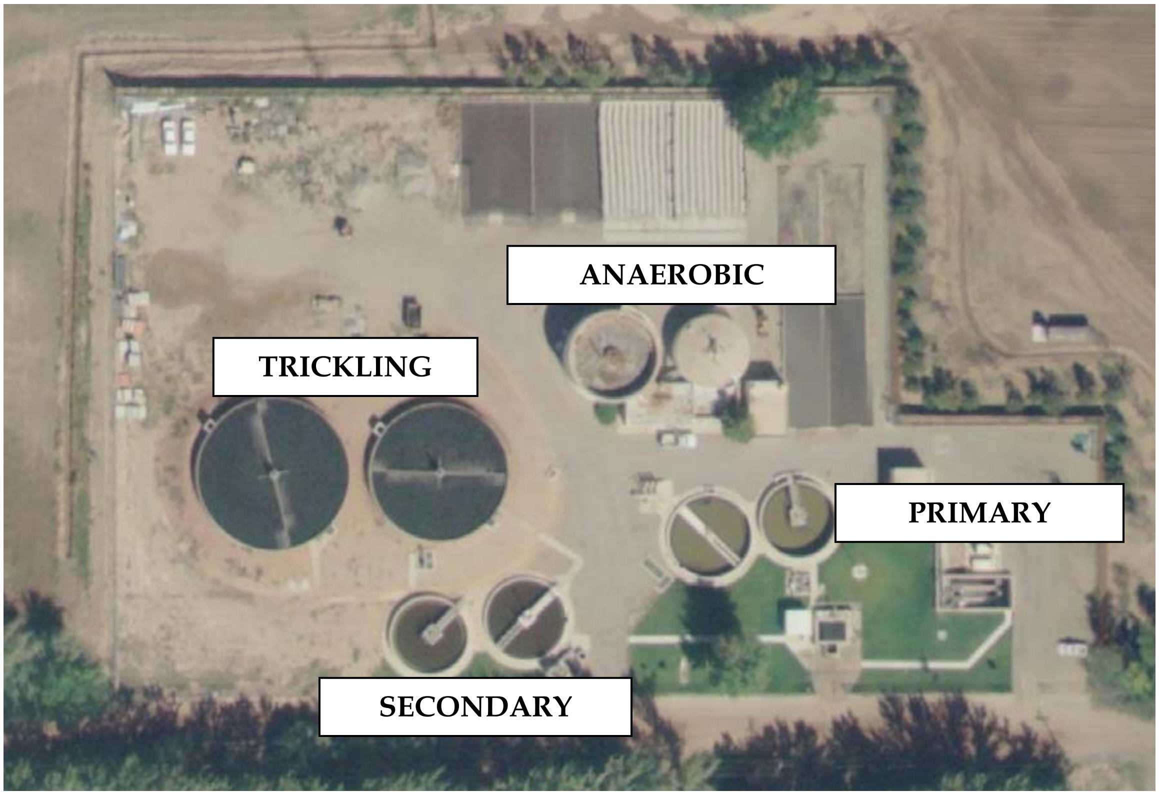

FIGURE 2
Aerial View of the Facility

TABLE 2
Summary of Major Unit Processes

Treatment step	Number of Units	Size, each	Details
Primary Clarifiers	2	40-ft diameter	8-ft SWD
Trickling Filters	2	72-ft & 80-ft diameter	7-ft depth, rock
Secondary Clarifiers	5	40-ft diameter	7-ft SWD
Anaerobic Digestion	2	48-ft diameter, 35,600-ft^3	Mesophilic

2. Nutrient Removal Alternatives Development

A nutrient removal alternatives matrix was prepared in order to capture an array of viable approaches for TF facilities (See Attachment A). This matrix considers biological and chemical phosphorus removal approaches as well as different activated sludge configurations for nitrogen control. The alternatives matrix illustrates that there are several strategies for controlling nutrient limits. The processes that were modeled and described in the subsequent sections are considered proven methods for meeting the nutrient limits. There may be other ways to further optimize 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.

MWWTP currently operates two rock media trickling filter units with primary treatment. As with all of the POTWs, the approaches were developed with the goal of utilizing the existing infrastructure to the maximum extent possible. Because the facility's trickling filters are relatively shallow (7ft depth) and utilize rock media as opposed to more efficient plastic media, it was decided to move toward an activated sludge system as nutrient limits become more stringent. Figure 3 shows the selected upgrade approach used between each tier of nutrient control with the bullet points A through D describing each upgrade step:

A. From Tier 3 (existing) to Tier 2 phosphorus control, the existing primary and secondary treatment system was supplemented with a metal-salt feed and storage system for chemical phosphorus removal.

B. To go from Tier 2 to Tier 2N, the trickling filters were replaced with an extended aeration process using oxidation ditches. New anaerobic basins located between the primary clarifiers and aerobic zones provided an environment for phosphorus release. The aerobic-anoxic zones within the oxidation ditch allowed phosphorus uptake and nitrogen removal (nitrification/denitrification). New secondary clarifiers that were designed for solids separation of an activated sludge replaced the existing clarifiers. In addition, a return activated sludge (RAS) pumping station was needed. Metal-salt feed and storage remained as a redundant system for P removal.

C. To go from Tier 2 to Tier 1 phosphorus control, deep bed granular media filters were added downstream of the existing secondary clarifier units. An additional chemical feed point was implemented upstream of the filter system.

D. To go from Tier 2N to Tier 1N, deep bed granular media filters were added downstream of the new secondary clarifiers.

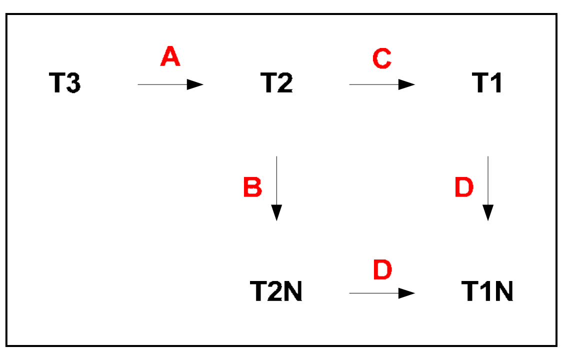

FIGURE 3
Upgrades Scheme for Meeting Increasingly More Stringent Nutrient Control

Data Evaluation, Initial Modeling, and Calibration

The selected progression of upgrades conceived for meeting the different tiers of nutrient control for MWWTP 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.

The facility information and data received by MWWTP per the initial data request was 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 for additional information.

TABLE 3
Summary of Input Conditions

Input Parameter	2009 (1)	2029 (2)	Design (3)
Flow, mgd	0.9	1.25	1.5
BOD, lb/day	2,000 (266 mg/L)	2,750 (264 mg/L)	3,300 (264 mg/L)
TSS, lb/day	1,870 (250 mg/L)	2,750 (264 mg/L)	3,300 (264 mg/L)
TKN, lb/day	310 (41 mg/L)	427 (41 mg/L)	512 (41 mg/L)
TP, lb/day	35 (5 mg/L)	52 (5 mg/L)	63 (6 mg/L)

(1) Historic conditions 2007-2009
(2) Projected by the POTW, and updated at the POTW Workshop October, 2009.
(3) Design maximum month capacity of POTW updated at the POTW Workshop October, 2009.

The main sizing and operating design criteria that were associated with the system upgrade for MWWTP are summarized in Table 4.

TABLE 4
Main Unit Process Sizing and Operating Design Parameters

Design Parameter (Nutrient Tier)	Value
Influent design temperature (All Tiers)	10 deg C
Anaerobic fraction of bioreactor (T2N, T1N)	15%
Anoxic fraction of bioreactor (T2N, T1N)	20% - 30%
Target metal:PO_4-P molar Ratio (Tier 1 and 1N)	1:1, 2:1, 7:1 (1)
Metal-salt storage (All Tiers)	14 days
Granular filter loading rate (T1 and T1N)	5 gpm/ft^2 (2)

(1)Target dosing ratio at the primary clarifiers, secondary clarifiers and upstream of polishing filter, respectively. Note that polishing filter included in T1 and T1N only.

(2)Hydraulic loading rate at peak hourly flow

3. Nutrient Upgrade Approaches

The following paragraphs provide details of the upgrade approaches as presented previously in Figure 3.

Tier 2 Phosphorus (A)

The effluent limit for Tier 2 alternatives is 1.0 mg/L total phosphorus. MWWTP can achieve 1.0 mg/L total phosphorus using a multi-point metal-salt addition approach. This approach dosed metal-salt upstream of the primary clarifiers and secondary clarifiers. A metal-salt storage building was required for housing both storage tanks and metering pumps. The process flow diagram for this approach is shown in Figure 4.

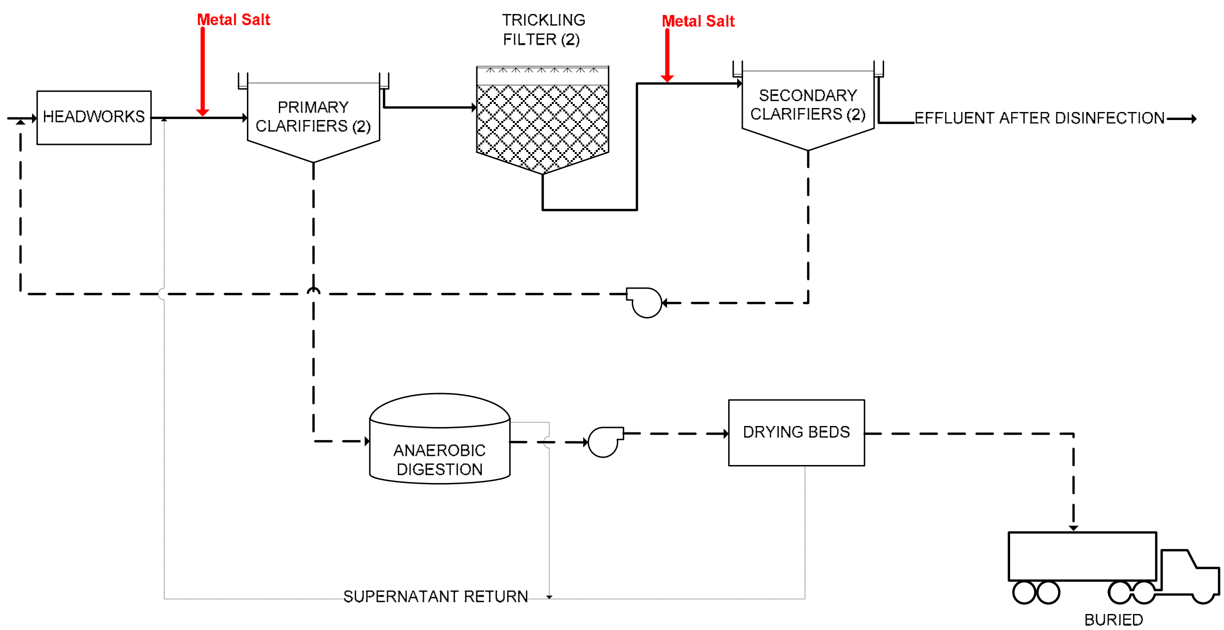

FIGURE 4
Modifications to POTW for Tier 2 Nutrient Control

Tier 2N – Phosphorus & Nitrogen (B)

The effluent limit for this alternative is 1.0 mg/L total phosphorus and 20 mg/L total nitrogen. Because of the favorable influent wastewater characteristics (i.e,. BOD: P = 40), a biological nutrient removal process was implemented to achieve nutrient control and to minimize the plants dependence on chemicals. Primary effluent was sent to an anaerobic basin prior to entering an oxidation ditch. Existing secondary clarifiers was replaced with larger 50-ft diameter units with a deeper SWD for enhanced settling of the mixed-liquor. The new clarifier underflow system provided adequate capacity to convey settled solids from the new activated sludge system. The metal-salt feed system remained from Tier 2 as a standby process. A process flow diagram for this Tier 2N approach is shown in Figure 5.

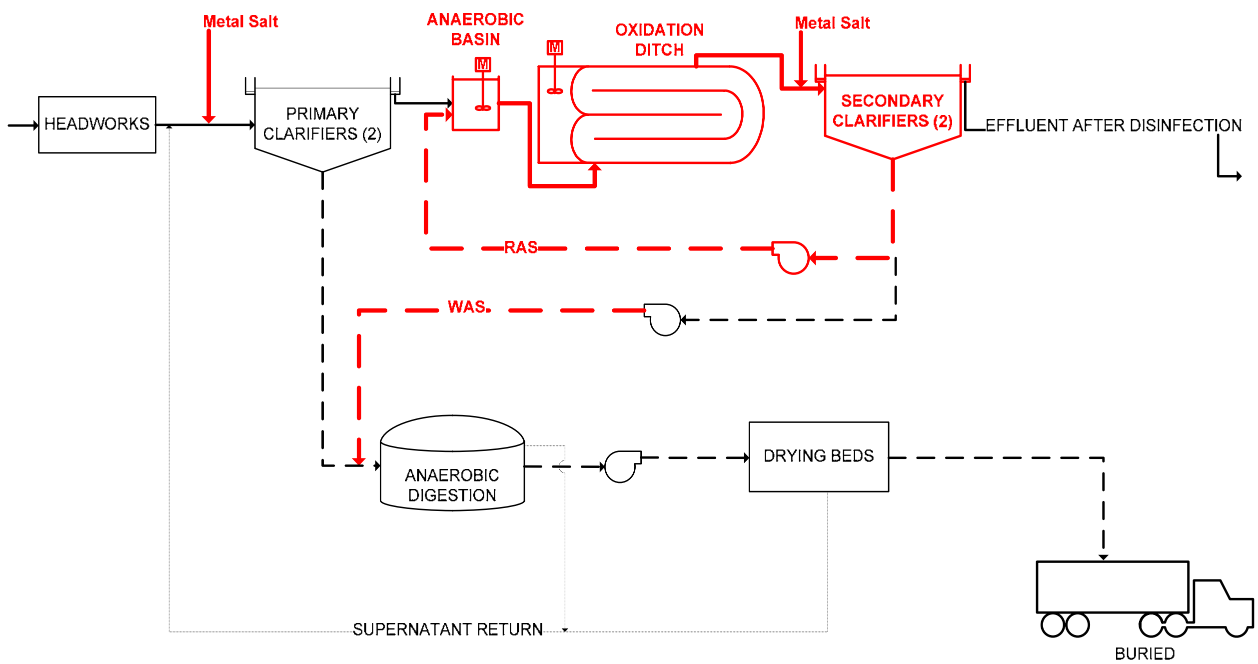

FIGURE 5
Modifications to POTW for Tier 2N Nutrient Goal

Tier 1 –Phosphorus (C)

The effluent limit for this alternative is 0.1 mg/L total phosphorus. This approach builds upon the Tier 2 approach for phosphorus control. The dosing rate of metal-salt was increased from Tier 2. In addition, new granular media filters with chemical feed were needed to remove particulate phosphorus from the liquid stream prior to final discharge. The filtration system required secondary effluent pumps to provide adequate head, as well as backwash pumps and other ancillary equipment. A process flow diagram for this chemical phosphorus approach is shown in Figure 6.

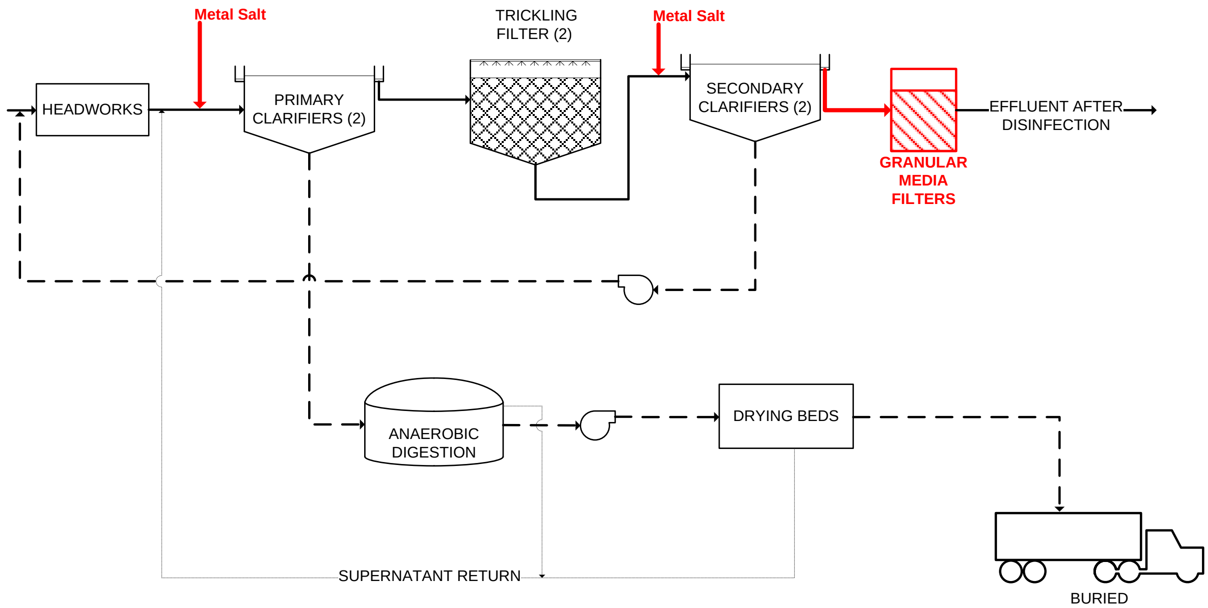

FIGURE 6
Modifications to POTW for Tier 1 Nutrient Goal

Tier 1N – Phosphorus & Nitrogen (D)

The effluent limit for this alternative is 0.1 mg/L total phosphorus and 10 mg/L total nitrogen. This approach combined the process elements proposed in both Tier 2N and Tier 1. First, this approach replaced the trickling filter system with oxidation ditches as described in Tier 2N. It also incorporated granular media filters as presented in T1. The multi-point chemical feed system remained as a redundant means of phosphorus removal. A process flow diagram is shown as Figure 7.

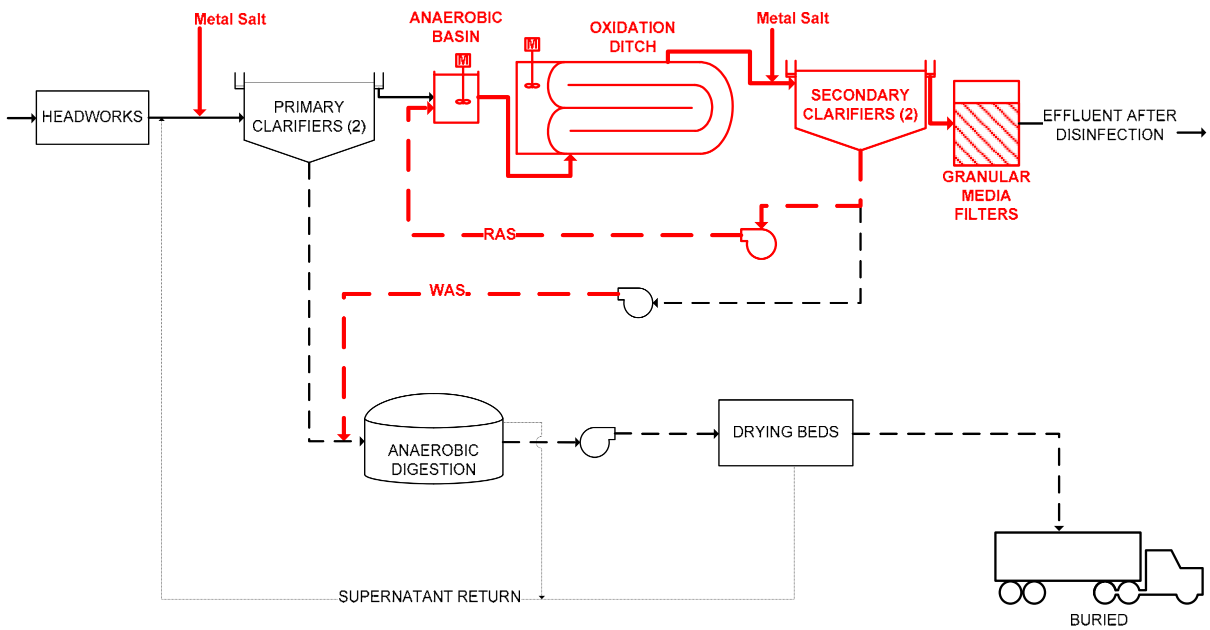

FIGURE 7
Modifications to POTW for Tier 1N Nutrient Goal

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

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

Table 5 presents a summary of the major facility upgrade components identified for meeting each tier of nutrient control. For all Tiers, a metal-salt feed and storage facility was required along with minor mechanical modification at the specific dosing points. Tier 1 also required the addition of a granular media filter system with upstream metal-salt feed. Tier 2N needed a BNR system using oxidation ditches with new secondary clarifiers and RAS/WAS pumping. Tier 1N incorporated a granular media filtration system to the new activated sludge treatment system.

TABLE 5

Major Facility Upgrade Summary

Processes	Tier 2	Tier 2N	Tier 1	Tier 1N
Metal-salt feed & storage system	X	X	X	X
Anaerobic basins		X		X
Oxidation Ditches (Basins, aerators, mixers)		X		X
Mixed-liquor distribution structure		X		X
Secondary clarifiers		X		X
RAS/WAS Pump Station		X		X
Granular media filtration system			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 ($ Million)

Unit Process Facility	Tier 2	Tier 2N	Tier 1	Tier 1N
Metal-Salt Feed Facility	$0.630	$0.340	$0.660	$0.340
Oxidation Ditches	$0.000	$3.630	$0.000	$3.630
Anaerobic Basin	$0.000	$0.920	$0.000	$0.920
Mixed-Liquor Splitting Structure	$0.000	$0.320	$0.000	$0.320
Secondary Clarifiers	$0.000	$3.100	$0.000	$3.100
RAS/WAS Pump Station	$0.000	$2.612	$0.000	$2.612
Secondary Effluent Pumps	$0.000	$0.000	$1.210	$1.210
Deep Bed Filters	$0.000	$0.000	$4.150	$4.150
TOTAL TIER COST	**$0.630**	**$10.922**	**$6.020**	**$16.282**

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 either provided by the POTW or 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 costs for each upgrade included the following components:

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

- Power costs for the major mechanized process equipment: aeration, secondary effluent pumps, backwash pumps and dewatering units

TABLE 7
Operating and Maintenance Unit Costs

Parameter	Value
Biosolids hauling	$20/wet ton
Biosolids tipping fee	$20/wet ton
Roundtrip biosolids hauling distance (1)	42 miles
Ferric chloride	$1000/ton
Polymer	$1/lb
Power	$0.07/kwh

(1) Provided by the POTW

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

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	$0.04	$0.06	$0.00	$0.00	$0.04	$0.06	$0.02	$0.02
Metal-salt	$0.05	$0.07	$0.00	$0.00	$0.04	$0.07	$0.01	$0.02
Polymer	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Power	$0.00	$0.00	$0.02	$0.03	$0.02	$0.02	$0.04	$0.05
Total O&M	**$0.09**	**$0.13**	**$0.02**	**$0.03**	**$0.10**	**$0.15**	**$0.07**	**$0.09**

Note: $ Million (US) in December 2009
Costs shown are the annual differential costs relative to the base line O&M cost of the POTW

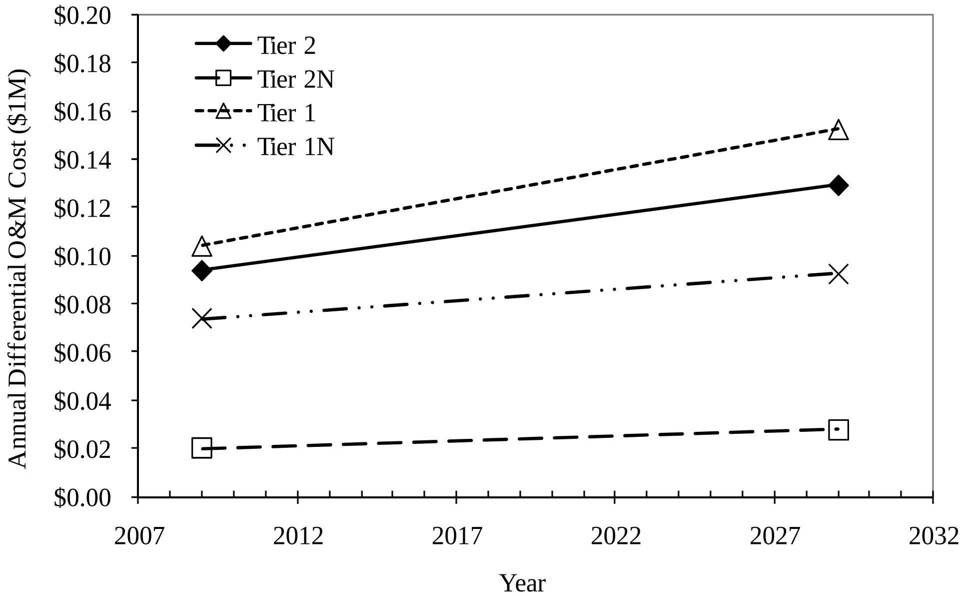

FIGURE 8
Impact of Nutrient Control on O&M Costs over 20 year evaluation period

5. Financial Impacts

This section presents the estimated financial impacts that will result from the implementation of nutrient discharge standards for MWWTP. Financial impacts were 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 sections.

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 MWWTP.

TABLE 9

Nutrient Removal: 20-Year Life Cycle Cost per Pound [1]

	Tier 2	Tier 2N	Tier 1	Tier 1N
Phosphorus Removal (pounds)[2]	166,285	166,285	225,697	225,697
Nitrogen Removal (pounds)[2]	-	1,122,213	-	1,782,338
Net Present Value of Removal Costs[3]	**$ 2,327,524**	**$ 11,263,061**	**$ 7,945,950**	**$ 17,518,681**
NPV: Phosphorus Allocation	2,327,524	2,327,524	7,945,950	7,945,950
NPV: Nitrogen Allocation[4]		8,935,538		9,572,731
TP Cost per Pound[5]	**$ 14.00**	**$ 14.00**	**$ 35.21**	**$ 35.21**
TN Cost per Pound[5]		**$ 7.96**		**$ 5.37**

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 those customers served by the POTW. The financial impact was 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 MWWTP are presented in Table 10.

TABLE 10

Projected Monthly Bill Impact per Equivalent Residential Unit (ERU) for Treatment Alternatives

	Tier 2	Tier 2N	Tier 1	Tier 1N
Initial Capital Expenditure	$ 629,000	$ 10,907,000	$ 5,998,000	$ 16,252,000
Estimated Annual Debt Service[1]	$ 50,500	$ 875,200	$ 481,300	$ 1,304,100
Incremental Operating Cost[2]	95,800	20,500	106,600	74,900
Total Annual Cost Increase	$ 146,300	$ 895,700	$ 587,900	$ 1,379,000
Number of ERUs	3,770	3,770	3,770	3,770
Annual Cost Increase per ERU	$38.81	$237.59	$155.94	$365.78
Monthly Cost Increase per ERU[3]	**$3.23**	**$19.80**	**$13.00**	**$30.48**
Current Average Monthly Bill[4]	$18.65	$18.65	$18.65	$18.65
Projected Average Monthly Bill[5]	**$21.88**	**$38.45**	**$31.65**	**$49.13**
Percent Increase	**17.3%**	**106.2%**	**69.7%**	**163.4%**

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 MWWTP is shown in Table 11.

TABLE 11

Community Financial Impacts: Affordability of Treatment Alternatives

	Tier 2	Tier 2N	Tier 1	Tier 1N
Median Annual Gross Income (MAGI)[1,2]	$ 28,700	$ 28,700	$ 28,700	$ 28,700
Affordability Threshold (% of MAGI)[3]	1.4%	1.4%	1.4%	1.4%
Monthly Affordability Criterion	**$33.48**	**$33.48**	**$33.48**	**$33.48**
Projected Average Monthly Bill	$21.88	$38.45	$31.65	$49.13
Meets State's Affordability Criterion?	Yes	No	Yes	No
Estimated Bill as % of State Criterion	**65%**	**115%**	**95%**	**147%**

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 energy consumption
- Changes in emissions from biosolids hauling, disposal and energy consumption

As per the data received from MWWTP and per process modeling of the base condition (Tier 3), MWWTP is able to achieve some nutrient removal with its existing infrastructure, but not enough to meet the effluent limits of the specified Tiers of nutrient standards. Table 12 summarizes the annual reduction in nutrient loads in MWWTP 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	6,500	6,500	8,965	8,965
Total nitrogen removed, lb/year	----	47,760	----	75,155

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 MWWTP to its receiving waters 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)

			Tier 3		Tier 2		Tier 2N		Tier 1		Tier 1N	
STORET LOCATION	**STORET ID**	**FLOW (cfs)**	**TP**	**TN**	**TP**	**TN**	**TP**	**TN**	**TP**	**TN**	**TP**	**TN**
MWWTP	----	1.39	3.37	37.00	1.0	N/A	1.0	20	0.1	N/A	0.1	10
Colorado River	4956540	6652.49	0.16	1.11	----	----	----	----	----	----	----	----
Combined Concentrations			**0.16**	**1.11**	**0.16**	**N/A**	**0.16**	**1.11**	**0.16**	**N/A**	**0.16**	**1.11**

The process upgrades established to meet the four tiers of nutrient standards require increased energy consumptions, chemical usage and biosolids production. Regular metal-salt addition would be required to meet the more stringent phosphorus limits. This would result in increased chemical sludge generation and consequently increased biosolids production. Process modifications to meet the total nitrogen limits would also result in increased energy consumption and biosolids productions. 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, for the current (2009) flow and load conditions and indicate a differential value relative to the base line condition.

TABLE 14
Estimated Environmental Impacts of Nutrient Control

		Tier 2	Tier 2N	Tier 1	Tier 1N
Chemical Use:					
Metal-salt use, lb/year		97,795	750	86,825	29,515
Polymers, lb/year		780	0	750	400
Biosolids Management:					
Biosolids produced, ton/year		78	0	75	40
Average yearly hauling distance[(1)]		150	0	145	76
Particulate emissions from hauling trucks, lb/year [(2)]		8	0	8	4
Tailpipe emissions from hauling trucks, lb/year[(3)]		19	0	18	10
CO_2 emissions from hauling trucks lb/year[(4)]		1895	0	1815	970
Energy Consumption:					
Annual energy consumption, kwh		0	327,359	284,909	609,016
Air pollutant emissions, lb/year [(5)]					
	CO_2	0	295,278	256,988	549,333
	NOx	0	458	399	853
	SOx	0	393	342	731
	CO	0	21	19	40
	VOC	0	3	2	5
	PM_{10}	0	6	6	12
	$PM_{2.5}$	0	3	3	6

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

[(1)] Roundtrip hauling distance of 42 miles, assuming the POTW uses 22 ton trucks for hauling biosolids to the landfill.

[(2)] Includes PM_{10} and $PM_{2.5}$ emissions in pounds per year. 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)*.

[(3)] Tailpipe emissions in pounds per year 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+.

[(4)] CO_2 emission factor in pounds per year for hauling trucks were derived from *Rosso and Chau, 2009, WEF Residuals and Biosolids Conference Proceedings.*

[(5)] Emission factors for electricity are based on EPA Clean Energy Power Profiler (http://www.epa.gov/cleanenergy/energy-and-you/how-clean.html) assuming PacifiCorp UT region commercial customer and *AP-42, Fifth Edition, Vol. I, Chapter 1, Section 1.1.: Bituminous and Sub bituminous coal Combustion (09/1998)*.