HDR

SROI | SUSTAINABLE RETURN ON INVESTMENT

CITY OF Springfield

# Integrated Planning Opportunities Alternatives Analysis – Enhanced Nutrient Removal at the Southwest Wastewater Treatment Plant

*Springfield, Missouri*

March 15, 2017

## Contents



## Tables



## Figures



## Appendixes

# 1. Introduction


Springfield's Southwest Wastewater Treatment Plant

The City of Springfield's (City) Southwest Wastewater Treatment Plant (SWTP) is designed and operated to effectively treat municipal wastewater. Effluent from the SWTP is discharged into Wilson's Creek, which flows to the James River and ultimately into Table Rock Lake. The level of treatment is based on technology- and water quality-based requirements. Water quality-based effluent limitations are tied to water quality standards, which are established to protect designated uses such as aquatic life protection and swimming. In part, because of karst topography and a phosphorus-based TMDL, extensive pollutant removal occurs at the SWTP; however, a certain amount of pollutants remains within treatment plant effluent. Common pollutants, including small amounts of metals, nutrients, bacteria, suspended solids and organics, are allowed to be discharged by Missouri regulations implementing the National Pollutant Discharge Elimination System (NPDES) permits.

Elevated levels of plant nutrients (nitrogen and phosphorus) can detrimentally impact surface water quality by leading to excessive algal growth, commonly referred to as cultural eutrophication. Several physical, chemical, and biological treatment processes may be used to remove nutrients to varying levels from municipal wastewater discharges. The SWTP includes nutrient treatment processes that produce effluent total nitrogen of about 20 mg/L and total phosphorus of about 0.5 mg/L. The primary nutrient removal processes include biological and chemical phosphorus removal and filtration. Upgrades to further enhanced nutrient removal include additional reliability and performance enhancements, larger biological reactors, and supplemental chemical addition. Incorporation of these processes typically produces effluent total nitrogen as low as 3 mg/L and total phosphorus as low as 0.3 mg/L. The limits of technology represent state-of-the-art processes and can typically achieve nutrient levels at or below these levels.

As part of the Integrated Planning strategy, the City of Springfield (City) selected enhanced nutrient removal at the SWTP as one of four environmental improvement opportunities to be evaluated as part of HDR's Sustainable Return on Investment (SROI) analytical framework. A detailed description of the SROI process is provided in *SROI Economic Business Case: Integrated Planning Opportunities Alternatives Analysis* (hereinafter referred to as SROI report). This report serves as a supplemental document to the SROI report, the purpose of which is to summarize the SROI process as it relates to enhanced nutrient removal at the SWTP.

# 2. Background

The SWTP is a tertiary treatment facility that began operations in 1959. It has a capacity to treat 42.5 million gallons per day (MGD) of Springfield's wastewater, but currently has an average daily flow of approximately 35 MGD. In the 1990s, increased algal blooms were observed in the James River along with a decline in clarity and increase in chlorophyll *a* (an indicator of the amount of algae that is suspended in water) in the James River arm of Table Rock Lake. Accelerated eutrophication issues in the James River were attributed in part to wastewater from the SWTP, which accounted for about 27% of the daily phosphorus loading to Table Rock Lake at that time (MDNR 2001). The SWTP is also the largest point source in the Table Rock Lake basin.

Beginning in the 1990s, multiple efforts were undertaken to address the nutrient impairment of the James River:

**Aerial photo of 1999 algae bloom in the James River arm of Table Rock Lake.**

- On August 21, 1995, the Springfield City Council approved a Phosphorus Ban Ordinance, which banned the sale of household laundry detergents which contain more than 0.5 percent of phosphorus and dishwashing detergents containing more than 8.7% phosphorus.
- In November 1999, the Missouri Department of Natural Resources (MDNR) approved a rule-making that required total phosphorus limits of 0.5 mg/L for all wastewater plants in the Table Rock basin with discharges ≥ 22,500 gallons per day.
- In March 2001, MDNR completed a Total Maximum Daily Load (TMDL) for the James River, which set an instream target of 0.075 mg/L total phosphorus and 1.5 mg/L total nitrogen.
- In 2001, the James River Basin Partnership was awarded the James River Watershed 319 Project grant with the object of addressing nutrient problems in the watershed by installing best management practices (BMPs) to reduce nonpoint sources of pollution.

Upgrades and improvements to the SWTP made during the 1990s and early 2000s have resulted in significant reductions in phosphorus loadings to Wilson's Creek and the James River. The SWTP currently has both biological and chemical phosphorus removal and biological nitrogen removal treatment processes. The additional removal of nitrogen and phosphorus is accompanied by a highly successful land application program of the residuals removed by the advanced treatment (MDNR 2014). The SWTP is now meeting its 0.5 mg/L total phosphorus limit and since 1992, phosphorus loadings from the SWTP have significantly decreased resulting in reduced instream phosphorus levels (Figure 1).

While the City's efforts have yielded significant nutrient reductions to Wilson's Creek, James River, and Table Rock Lake, nutrient enrichment remains a concern. Table Rock Lake has been identified as impaired for chlorophyll, nitrogen, and eutrophication issues on Missouri's Clean Water Act 303(d) List since 2002. Additionally, MDNR nutrient reduction strategy seeks to reduce the State's overall nutrient contribution to the Gulf of Mexico through a combination of point and nonpoint source controls. Upgrades to enhanced nutrient removal at the SWTP would result in further nutrient load reductions, potentially resulting in improved conditions at Table Rock Lake and helping the State achieve its goal of reducing its nutrient contribution to the Gulf of Mexico.

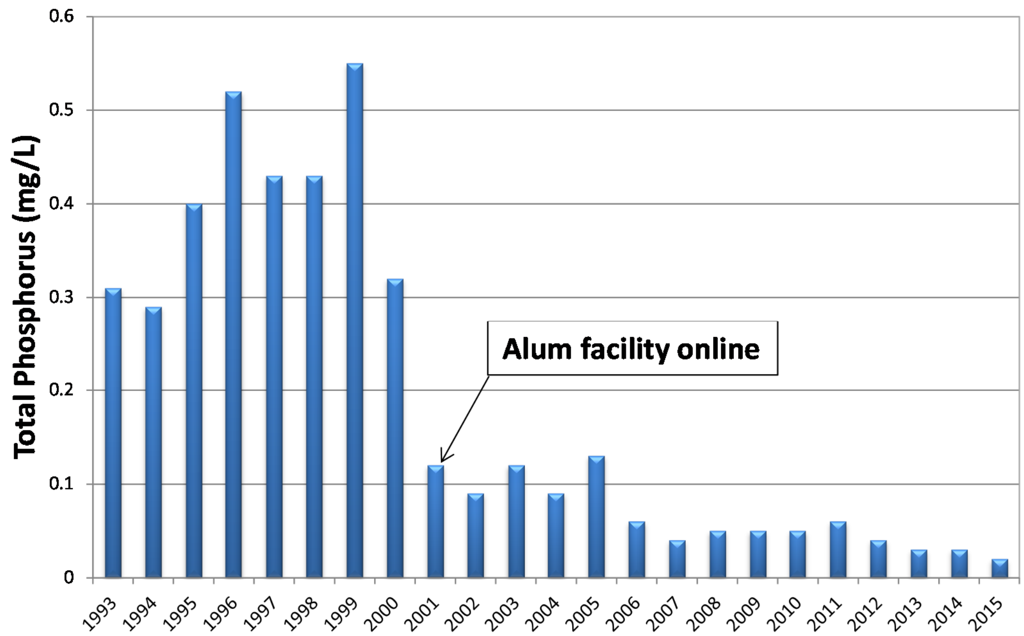


**Figure 1. Annual Geometric Phosphorus Levels in the James River at Galena (1992-2014)**

# 3. Alternatives

The City of Springfield and stakeholder members requested HDR evaluate the relative costs and benefits of upgrading the SWTP to enhanced nutrient removal. As previously discussed, the SWTP already has both biological and chemical phosphorus removal and biological nitrogen removal treatment processes. Two distinctly different biological treatment trains (Plants 1 and 2) are operated at the SWTP. Plant 1 has four pure oxygen activated sludge basins for carbonaceous treatment followed by intermediate clarification and ten aerated activated sludge basins for nitrification. After clarification, nitrified wastewater is filtered through deep bed denitrification filters prior to ozonation for disinfection. The City currently adds a supplemental carbon source prior to denitrification as available and accommodated without impacting the ozone disinfection process. Plant 2 uses a more conventional activated sludge process for biological phosphorus removal and nitrification followed by clarification and media filtration. Aluminum sulfate (alum) is used within both treatment trains for additional phosphorus removal, as needed.

For the SROI analysis, capital costs for further enhanced nutrient removal were based on installation of additional anaerobic and anoxic reactors for biological phosphorus removal and denitrification. These process improvements were recommended during previous planning efforts to implement further nutrient removal at the SWTP and would need to be studied in more detail prior to implementation. Supplemental chemical addition of alum and methanol (carbon source) was also included in the evaluation. With these additional processes, reduction of total phosphorus (TP) effluent levels from approximately 0.5 to 0.1 mg/L was assumed. Similarly, total nitrogen (TN) levels would be anticipated to decrease from approximately 20 to 3 mg/L. No process modeling was conducted to project these assumed effluent nutrient levels. Therefore, in-depth process evaluation is needed for implementation of additional enhanced nutrient treatment investments at the SWTP.

# 4. Water Quality Improvements

Water quality improvements associated with enhanced nutrient removal at SWTP were estimated based on nutrient load reductions. Methods used to estimate pollutant loadings, reductions and associated impacts to the water quality index (WQI) are described below.

## 4.1 Pollutant Loading

Average annual pollutant loadings of TP and TN were calculated for the SWTP for both existing conditions and anticipated improvements associated with enhanced nutrient removal. The pollutant loadings are based on an estimated actual flow rate of 36.2 million gallons per day (MGD) and estimated average annual effluent nutrient concentrations. Upgrades to enhanced nutrient removal are anticipated to decrease TP levels from 0.5 to 0.1 mg/L. Likewise, average TN levels are estimated to decrease from 20 to 3 mg/L (Table 1).

**Table 1. Nutrient Loading at the SWTP**

| Nutrient | Existing Conditions | | Enhanced Nutrient Removal | |
|---|---|---|---|---|
| | Average Effluent Concentration (mg/L) | Annual Loading (lbs/yr) | Average Effluent Concentration (mg/L) | Annual Loading (lbs/yr) |
| TP | 0.5 | 55,132 | 0.1 | 11,026 |
| TN | 20 | 2,205,262 | 3 | 330,789 |

Notes: Loadings based on an estimated actual flow rate of 36.2 MGD.

## 4.2 Pollutant Reductions

Reductions in nutrient loading associated with upgrades to enhanced nutrient removal at the SWTP were estimated as a percentage of total nutrient loading in Wilson's Creek below SWTP, James River below Wilson's Creek and for Table Rock Lake. This was determined by multiplying the following two factors: 1) the percent reduction in nutrient loading from the SWTP, and 2) the percent contribution of nutrient loading from the SWTP at the three aforementioned waterbodies. Based on information presented in Table 1, upgrades to enhanced nutrient removal will result in an 80% reduction in TP and an 85% reduction in TN relative to existing nutrient loadings from the SWTP. The SWTP's percent contribution to stream nutrient loading was estimated from the USGS SPAtially Referenced Regressions On Watershed attributes (SPARROW) model as described below.

USGS's SPARROW model is a source-transport model that provides the capability to predict constituent loads, concentration, and yield in streams over regional and continental spatial scales (Booth 2011). Results from the 2002 SPARROW Decision Support System Mississippi/Atchafalaya Basin Total Nitrogen and Phosphorus Models indicate that point source loadings diminish as a percentage of total nutrient loading downstream of the SWTP (Table 2). Assuming 100% of the point source loading within the

SPARROW model is from the SWTP, the reduction to total instream nutrient loading can be estimated by factoring in the percent reduction in loading from the SWTP (Table 3).

**Table 2. Percent Contribution to Total Instream Nutrient Loading from Point Sources**

| Location | Point Source Contribution | |
|---|---|---|
| | TP | TN |
| Wilson's Creek below SWTP | 74.9% | 88.3% |
| James River below Wilson's Creek | 30.5% | 34.7% |
| Table Rock Lake | 18.1% | 17.8% |

Source: USGS 2002a, USGS 2002b

**Table 3. Percent Reduction in Total Instream Nutrient Loading Based on Upgrades to Enhanced Nutrient Removal**

| Location | Percent Reduction | |
|---|---|---|
| | TP | TN |
| Wilson's Creek below SWTP | 60% | 75% |
| James River below Wilson's Creek | 24% | 29% |
| Table Rock Lake | 14% | 15% |

Note: The percent reduction was calculated as product of the percent reduction in loading from the SWTP and the percent point source contribution.

## 4.3 Water Quality Index

A 10-point water quality index (WQI) was used to quantify impacts of water quality improvement opportunities on different receiving waters in the Springfield area. The WQI provides a single metric that expresses overall water quality as a composite of weighted use condition scores. Weighted use condition scores are similarly calculated based on a composite of weighted criteria scores. (Note: A detailed description of the WQI is provided for in the SROI report.)

Criteria score changes associated with enhanced nutrient reduction were estimated for in-stream aesthetics and nutrients, which are linked to aesthetics, aquatic life, and drinking water supplies in the WQI. While other benefits likely exist, enhanced nutrient reduction will likely have the largest impact with respect to these criteria. Impacts on aesthetics criteria scores were estimated based on anticipated improvements to instream nutrient levels. Changes to nutrient criteria scores were based on estimated improvements to instream nutrient levels as calculated from loading reductions presented above in Table 3. Based on these estimated changes, WQI scores for enhanced nutrient reduction are presented in Table 4, Table 5, and Table 6 below. Use condition calculations are provided for in Appendix A.

### Table 4. WQI Changes to Wilson's Creek below SWTP

| Beneficial Use | Weight (W) | Current | | Enhanced Nutrient Removal at SWTP | |
|---|---|---|---|---|---|
| | | Use Condition (U) | Subindex (W*U) | Use Condition (U) | Subindex (W*U) |
| *Aesthetics* | *2.0* | *0.630* | *1.260* | *0.679* | *1.358* |
| Secondary Contact Recreation | 1.5 | 0.993 | 1.490 | 0.993 | 1.490 |
| Whole Body Contact Recreation | 1.0 | 0.917 | 0.917 | 0.917 | 0.917 |
| Aquatic Life Protection – Habitat | 0.5 | 0.250 | 0.125 | 0.250 | 0.125 |
| *Aquatic Life Protection – Water Quality* | *2.5* | *0.605* | *1.513* | *0.666* | *1.665* |
| Livestock & Wildlife Watering | 1.0 | 1.000 | 1.000 | 1.000 | 1.000 |
| Industrial Water Supply | 0.0 | -- | -- | -- | -- |
| Hydrologic Cycle Maintenance | 0.0 | -- | -- | -- | -- |
| Human Health – Fish Consumption | 0.5 | 0.632 | 0.316 | 0.632 | 0.316 |
| Irrigation | 0.0 | 0.000 | 0.000 | 0.000 | 0.000 |
| *Drinking Water Supply* | *1.0* | *0.775* | *0.775* | *0.975* | *0.975* |
| | | **WQI** | **7.395** | | **7.845** |

*Note*: Shaded rows with italicized text denote those beneficial uses impacted by the water quality improvement opportunity.

### Table 5. WQI Changes to James River below Wilson's Creek

| Beneficial Use | Weight (W) | Current | | Enhanced Nutrient Removal at SWTP | |
|---|---|---|---|---|---|
| | | Use Condition (U) | Subindex (W*U) | Use Condition (U) | Subindex (W*U) |
| *Aesthetics* | *0.5* | *0.676* | *0.338* | *0.694* | *0.347* |
| Secondary Contact Recreation | 2.0 | 0.999 | 1.998 | 0.999 | 1.998 |
| Whole Body Contact Recreation | 2.0 | 0.963 | 1.926 | 0.963 | 1.926 |
| Aquatic Life Protection – Habitat | 0.5 | 0.300 | 0.150 | 0.300 | 0.150 |
| *Aquatic Life Protection – Water Quality* | *3.0* | *0.821* | *2.462* | *0.842* | *2.527* |
| Livestock & Wildlife Watering | 1.5 | 1.000 | 1.500 | 1.000 | 1.500 |
| Industrial Water Supply | 0.0 | -- | -- | -- | -- |
| Hydrologic Cycle Maintenance | 0.0 | -- | -- | -- | -- |
| Human Health – Fish Consumption | 0.5 | 0.649 | 0.324 | 0.649 | 0.324 |
| Irrigation | 0.0 | -- | -- | -- | -- |
| Drinking Water Supply | 0.0 | -- | -- | -- | -- |
| | | **WQI** | **8.698** | | **8.772** |

*Note*: Shaded rows with italicized text denote those beneficial uses impacted by the water quality improvement opportunity.

## Table 6. WQI Changes to Table Rock Lake

| Beneficial Use | Weight (W) | Current | | Enhanced Nutrient Removal at SWTP | |
|---|---|---|---|---|---|
| | | Use Condition (U) | Subindex (W*U) | Use Condition (U) | Subindex (W*U) |
| *Aesthetics* | *2.5* | *0.900* | *2.250* | *0.926* | *2.315* |
| Secondary Contact Recreation | 1.0 | 1.000 | 1.000 | 1.000 | 1.000 |
| Whole Body Contact Recreation | 3.0 | 1.000 | 3.000 | 1.000 | 3.000 |
| Aquatic Life Protection – Habitat | 0.5 | 1.000 | 0.500 | 1.000 | 0.500 |
| *Aquatic Life Protection – Water Quality* | *2.0* | *0.994* | *1.988* | *0.997* | *1.994* |
| Livestock & Wildlife Watering | 0.0 | -- | -- | -- | -- |
| Industrial Water Supply | 0.0 | -- | -- | -- | -- |
| Hydrologic Cycle Maintenance | 0.0 | -- | -- | -- | -- |
| Human Health – Fish Consumption | 0.5 | 0.665 | 0.333 | 0.670 | 0.333 |
| Irrigation | 0.0 | 0.000 | 0.000 | 0.000 | 0.000 |
| Drinking Water Supply | 0.5 | 1.000 | 0.500 | 1.000 | 0.500 |
| | | **WQI** | **9.570** | | **9.642** |

*Note*: Shaded rows with italicized text denote those beneficial uses impacted by the water quality improvement opportunity.

# 5. Costs

This opportunity considers the impact of wastewater treatment plant upgrades to remove nutrients. Capital costs for enhanced nutrient removal came from feasibility level engineering estimates performed Black & Veatch during development of the City's Overflow Control Plan. The total cost is projected to be $28 Million.

Operation and maintenance costs for phosphorus removal were estimated based upon projected increased cost for operations, chemicals, and biosolids management. Increased operations costs were estimated to be a 5% increase over the current cost of operation of the SWTP not including power plus a 15% increase of current power costs. Operations costs were obtained from data provided by the City through Black & Veatch. Power costs were based on 2013 power usage records provided by the City.

Chemical costs were based on estimated costs for the incremental increase in alum required for phosphorus removal and the cost for methanol to needed for enhanced nitrogen removal. It should be noted that the SWTP currently has denitrification filters in one train, but their operation has not been optimized. The City also currently has a source of free methanol. For the purpose of this evaluation, it was assumed that methanol would no longer be free. Alum and methanol dosing was based on preliminary process calculations and costs were based on current market values. Alum usage was based upon reducing TP effluent quality from 0.5 to 0.1 mg/L, while methanol usage was estimated on the carbon needed to reduce TN effluent quality from 33 to 3 mg/L. The methanol estimate is quite conservative since it assumes that minimal denitrification occurs prior to the final denitrification processes.

Biosolids management costs were based upon an increase in biosolids production of 20%. This is based upon literature values for chemical phosphorus removal. In addition to other operation and maintenance costs, additional truck hauling would be required for biosolids handling. Truck hauling for biosolids management and chemical hauling is measured in terms of vehicles miles travelled (VMT). An increase in VMT has an environmental impact beyond the monetary costs incurred by the City which are captured in the operation and maintenance costs discussed above. The increase in VMT for biosolids management was based upon increasing the current VMT by 20%. Actual VMT were not available and were estimated based upon fuel usage. VMT for chemical costs were based upon the increased number of loads required for the increased dosages multiplied by the travel distance from the supplier. The size of a delivery and the location of the supplier were provided by the City.

Additional cost savings arise from cost savings in administrative and legal cost from lower TMDL impairment impacts. This category relates to internal costs related to TMDL regulatory impacts, specifically attributed to administrative time and/or legal costs. The inputs, which vary for each alternative, were determined in a workshop with the City.

A summary of capital and annual costs is presented below in Table 7. Detailed cost estimate calculations are included in Appendix B.

**Table 7. Summary of Capital and Annual Costs**

| Category | Capital Costs ($2014, Millions) |
|---|---|
| Initial Capital Costs – Year 2015 ($M) | $28.0 |
| 20-year Capital Replacement Cost – Year 2036 ($M) | $14.0 |
| Residual Value of Initial Capital Cost – Year 2040 ($M) | $27.5 |
| **Category** | **Annual Costs ($2014, Millions / Year)** |
| Annual operating costs ($M / year) | $2.9 |
| Annual Trucking Costs for Biosolids Removal ($M / year) | $0.05 |
| Reduced Annual Impairment Costs ($M / year) | $0.01 |

# 6. Analytical Methods

The methodology for estimating the sustainability value of these options, including social and environmental benefits and financial costs, entails projecting the value of impacts over a 25-year planning horizon and applying a discount rate to bring future values into today's dollars. Figure 2 is a "structure and logic model" that aims to graphically illustrate how various inputs are combined to determine benefits and costs. They are intended to provide a transparent record of how each benefit and cost is calculated. With respect to treatment plant upgrades, the main environmental benefits relate to water quality improvements (shown as a change in the WQI). At the same time, the plant will require additional energy and chemicals in its higher treatment standard and it will produce addition biosolids, the additional trucking of which would increase a variety of social and environmental impacts. These benefits are compared against costs that include higher capital costs for upgrades, maintenance of facilities, and additional administrative costs. Residual capital costs at the end of the project planning horizon are also accounted for in the lifecycle of the projects.

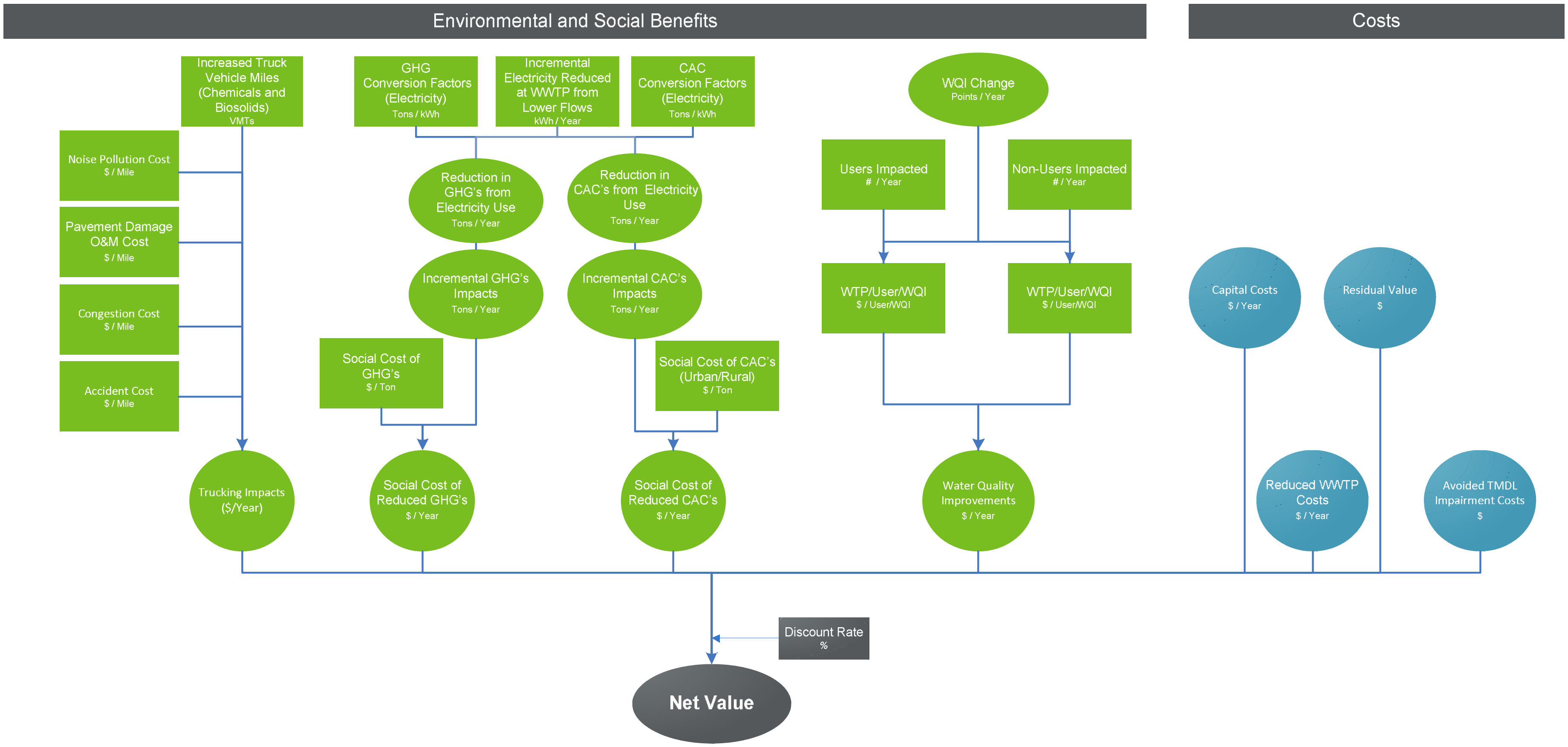


**Figure 2: Structure and Logic Diagram of Benefits and Costs: Enhanced Nutrient Removal at SWTP.**

# 7. Results

Table 8 presents final results of costs and benefits of the treatment plant upgrades. The present value capital costs amount to about $21.8 million, including long-term residual value at the end of the analytical period. The total present value of O&M costs are more than twice that amount, at over $48 million in present value terms. In addition, costs for covering truck hauling service add nearly $1 million in present value terms over 25 years. A small amount of cost savings may be realized for reduced TMDL impairment responses, but these are relatively insignificant.

The social and environmental impacts of nutrient removal, and specifically for water quality improvements, could be substantial. The estimated value of water quality improvements is $59.8 million in present value terms. This value nearly offsets the capital and O&M costs to achieve the improvements. At the same time, the addition treatment leads to energy emissions and trucking impacts along the route to biosolids disposal sites, which lower the net benefits of the project by a combined amount of about $2.2 million in present value terms. The combined positive and negative benefits total $57.6 million in present value terms.

Overall, the total net value of treatment plant improvements would cost about $13.4 million more in lifecycle costs than it generates in benefits. The benefit-cost ratio of 0.81; however, is relatively close to a breakeven point of 1.0, which indicates that additional analysis should be conducted in an attempt to lower costs or optimize water quality impacts further. In particular, capital and operational cost estimates of enhanced nutrient removal should be further evaluated. The additional costs are largely driven by the infrastructure and chemical usage needed to provide enhanced nitrogen removal. In addition, the calculation of water quality benefits should be more refined since the estimated benefit is so large. Therefore, the return on investment of enhanced nutrient removal could be further refined to balance projected costs and benefits.

**Table 8: Summary of Present Value Costs of Upgrading to Enhanced Nutrient Removal at the SWTP ($2014 million)**

| Types of Benefits and Costs | Present Value of Impact |
|---|---|
| **Environmental Benefits** | |
| Water Quality Improvements | $59.8 |
| GHG emissions (Reduced Benefits) | ($1.4) |
| **Social Benefits** | |
| Air pollution impacts on health (Reduced Benefits) | ($0.3) |
| Trucking Externalities (Reduced Benefits) | ($0.5) |
| **Costs** | |
| Capital Expenditures (including residual value in year 2040) | $21.8 |
| O&M Costs | $48.5 |
| Truck hauling direct costs | $1.0 |
| TMDL Impairment (Reduced Costs) | ($0.2) |
| **Totals** | |
| Financial Lifecycle Cost | ($71.0) |

| | |
|---|---|
| Total Social, Environmental Benefits | $57.6 |
| Total Value - All Costs and Benefits | ($13.4) |
| Benefit-Cost Ratio | 0.81 |

Figure 3 provides the best estimate of value created relative to cost and accounting for several uncertainties in drivers of cost and benefit that can raise or lower the perspective on total value. The graphs are standard box-and-whisker charts that show in the colored boxes the values that extend between the 25th and 50th percentiles and 50th and 75th percentiles, respectively. The 50th percentile can be interpreted as the best estimate. The 'whisker lines' that extend beyond the boxes indicate benefit cost ratios that reach to the 10th and 90th percentiles of possible values – both of which are relatively unlikely to occur.

Figure 3 presents the range of benefit-cost ratios for the treatment plant upgrades. The results indicate that while the expected net value for the improvements is around 0.81, as shown in Table 8, there is a large upside and downside range for this investment. The downside indicates that there is a chance that costs could be higher and water quality improvements are lower. The benefits per cost value of this investment could be less than 0.4 (with a 10 percent chance of occurring). But, on the upside, nutrient removal upgrades could generate as much as 35 cents more for every dollar spent above the breakeven point of the investment.

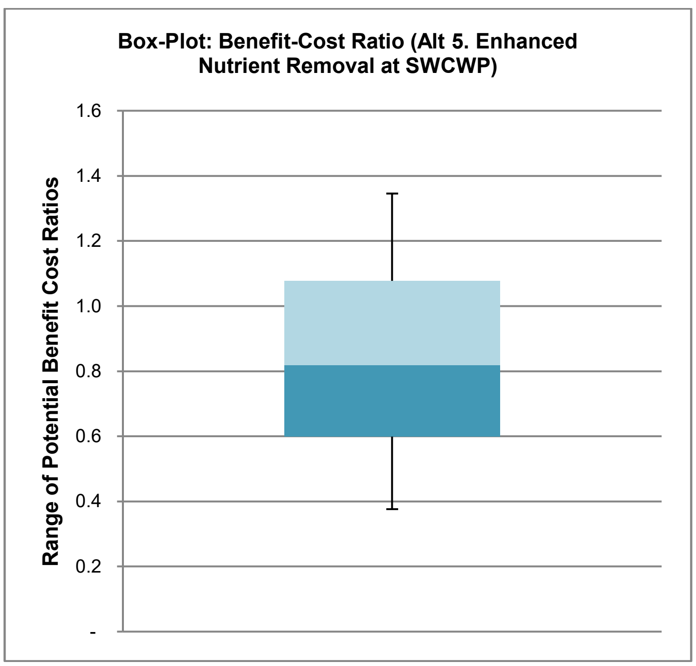


**Figure 3: Box-Whisker Plots – Benefit Cost Ratios.**

# 8. Summary of Results

The SROI pilot analysis suggests that the benefits of implementing additional enhanced nutrient removal at the SWTP may be marginally less than the costs. However, these analyses are based upon relatively conservative cost assumptions, which could be significantly less than current assumptions. In addition, treatment strategies could be used to optimize the benefits compared to costs. For example, more cost-effective nitrogen removal without the additional cost of supplemental carbon could be implemented to balance costs and benefits. The estimated water quality benefits for this Integrated Planning Opportunity are very large (over $60 million) and also need additional refinement before implementation. These findings show that additional nutrient removal at the SWTP warrants further evaluation as benefits could very well outweigh costs, particularly with an optimized strategy.

# 9. References

Booth, N.L., E.J. Everman, I.L. Kuo, L. Sprague, and L. Murphy. 2011. A Web-Based Decision Support System for Assessing Regional Water-Quality Conditions and Management Actions. Journal of the American Water Resources Association, v.47, n.5, 1136-1150.

Clark, D.L., T. Dupuis, H. Falconer, L. Hatch, M.S. Kasch, P.J. Lemonds and JB Neethling. 2016. Nutrient Management Volume III: Development of Nutrient Permitting Frameworks. Water Environment & Reuse Foundation. NUTR1R06z.

MDNR (Missouri Department of Natural Resources). 2014. Missouri Nutrient Loss Reduction Strategy. December 16, 2014.

MDNR (Missouri Department of Natural Resources). 2001. Total Maximum Daily Load for James River. Approved May 7, 2001.

USGS. 2002a. SPARROW Decision Support System Mississippi/Atchafalaya Basin Total Nitrogen Model – 2002. U.S. Geological Survey, Reston, VA. Available at http://cida.usgs.gov/sparrow/map.jsp?model=35

USGS. 2002b. SPARROW Decision Support System Mississippi/Atchafalaya Basin Total Phosphorus Model – 2002. U.S. Geological Survey, Reston, VA. Available at http://cida.usgs.gov/sparrow/map.jsp?model=38.

# APPENDIX A: Use Condition Score Calculations

### Aesthetics Use Condition Scores for Wilsons Creek below SWTP

| Criteria | Weight (w) | Current | | Enhanced Nutrient Removal at SWTP | |
|---|---|---|---|---|---|
| | | Criteria Condition (C) | Subindex (w*C) | Criteria Condition (C) | Subindex (w*C) |
| % of stream miles that are generally considered attractive to the public | 0.50 | 0.800 | 0.400 | 0.800 | 0.400 |
| Aesthetic condition of selected "highly visible" areas within the watershed (selected by number of "views") | 0.20 | 0.800 | 0.160 | 0.800 | 0.160 |
| *Nutrient impacts to aesthetics* | *0.20* | *0.100* | *0.020* | *0.344* | *0.069* |
| Economic value of aesthetic improvements (as a % of economic improvements available) | 0.10 | 0.500 | 0.050 | 0.500 | 0.050 |
| | | **Use Condition (U)** | **0.630** | | **0.679** |

*Note*: Shaded rows with italicized text denote those criteria impacted by the water quality improvement opportunity.

### Aesthetics Use Condition Scores for James River below Wilsons

| Criteria | Weight (w) | Current | | Enhanced Nutrient Removal at SWTP | |
|---|---|---|---|---|---|
| | | Criteria Condition (C) | Subindex (w*C) | Criteria Condition (C) | Subindex (w*C) |
| % of stream miles that are generally considered attractive to the public | 0.50 | 0.700 | 0.350 | 0.700 | 0.350 |
| Aesthetic condition of selected "highly visible" areas within the watershed (selected by number of "views") | 0.20 | 0.700 | 0.140 | 0.700 | 0.140 |
| *Nutrient impacts to aesthetics* | *0.20* | *0.582* | *0.116* | *0.670* | *0.134* |
| Economic value of aesthetic improvements (as a % of economic improvements available) | 0.10 | 0.700 | 0.070 | 0.700 | 0.070 |
| | | **Use Condition (U)** | **0.676** | | **0.694** |

*Note*: Shaded rows with italicized text denote those criteria impacted by the water quality improvement opportunity.

**Aesthetics Use Condition Scores for Table Rock Lake**

| Criteria | Weight (w) | Current | | Enhanced Nutrient Removal at SWTP | |
|---|---|---|---|---|---|
| | | Criteria Condition (C) | Subindex (w*C) | Criteria Condition (C) | Subindex (w*C) |
| % of stream miles that are generally considered attractive to the public | 0.40 | 0.900 | 0.360 | 0.900 | 0.360 |
| Aesthetic condition of selected "highly visible" areas within the watershed (selected by number of "views") | 0.00 | -- | -- | -- | -- |
| *Nutrient impacts to aesthetics* | *0.30* | *0.900* | *0.270* | *0.987* | *0.296* |
| Economic value of aesthetic improvements (as a % of economic improvements available) | 0.30 | 0.900 | 0.270 | 0.900 | 0.270 |
| | | **Use Condition (U)** | **0.900** | | **0.926** |

*Note*: Shaded rows with italicized text denote those criteria impacted by the water quality improvement opportunity.

**Aquatic Life Protections – Water Quality Factors Use Condition Scores for Wilsons Creek below SWTP**

| Criteria | Weight (w) | Current | | Enhanced Nutrient Removal at SWTP | |
|---|---|---|---|---|---|
| | | Criteria Condition (C) | Subindex (w*C) | Criteria Condition (C) | Subindex (w*C) |
| Total Suspended Solids or Sediment | 0.20 | 0.600 | 0.120 | 0.600 | 0.120 |
| *Total Phosphorus* | *0.15* | *0.100* | *0.015* | *0.331* | *0.050* |
| *Total Nitrogen* | *0.10* | *0.100* | *0.010* | *0.363* | *0.036* |
| Dissolved Oxygen | 0.20 | 0.900 | 0.180 | 0.900 | 0.180 |
| Toxics - Metals, Organics (PAH) | 0.35 | 0.800 | 0.280 | 0.800 | 0.280 |
| | | **Use Condition (U)** | **0.605** | | **0.666** |

*Note*: Shaded rows with italicized text denote those criteria impacted by the water quality improvement opportunity.

**Aquatic Life Protections – Water Quality Factors Use Condition Scores for James River below Wilsons Creek**

| Criteria | Weight (w) | Current | | Enhanced Nutrient Removal at SWTP | |
|---|---|---|---|---|---|
| | | Criteria Condition (C) | Subindex (w*C) | Criteria Condition (C) | Subindex (w*C) |
| Total Suspended Solids or Sediment | 0.20 | 0.800 | 0.160 | 0.800 | 0.160 |
| *Total Phosphorus* | *0.15* | *0.704* | *0.106* | *0.790* | *0.119* |
| *Total Nitrogen* | *0.10* | *0.400* | *0.040* | *0.488* | *0.049* |
| Dissolved Oxygen | 0.20 | 1.000 | 0.200 | 1.000 | 0.200 |
| Toxics - Metals, Organics (PAH) | 0.35 | 0.900 | 0.315 | 0.900 | 0.315 |
| | | **Use Condition (U)** | **0.821** | | **0.842** |

*Note*: Shaded rows with italicized text denote those criteria impacted by the water quality improvement opportunity.

**Aquatic Life Protections – Water Quality Factors Use Condition Scores for Table Rock Lake**

| Criteria | Weight (w) | Current | | Enhanced Nutrient Removal at SWTP | |
|---|---|---|---|---|---|
| | | Criteria Condition (C) | Subindex (w*C) | Criteria Condition (C) | Subindex (w*C) |
| Total Suspended Solids or Sediment | 0.20 | 1.000 | 0.200 | 1.000 | 0.200 |
| *Total Phosphorus* | *0.15* | *1.000* | *0.150* | *1.000* | *0.150* |
| *Total Nitrogen* | *0.10* | *0.939* | *0.094* | *0.968* | *0.097* |
| Dissolved Oxygen | 0.20 | 1.000 | 0.200 | 1.000 | 0.200 |
| Toxics - Metals, Organics (PAH) | 0.35 | 1.000 | 0.350 | 1.000 | 0.350 |
| | | **Use Condition (U)** | **0.994** | | **0.997** |

*Note*: Shaded rows with italicized text denote those criteria impacted by the water quality improvement opportunity.

**Drinking Water Supply Use Condition Scores for Wilsons Creek below SWTP**

| Criteria | Weight (w) | Current | | Enhanced Nutrient Removal at SWTP | |
|---|---|---|---|---|---|
| | | Criteria Condition (C) | Subindex (w*C) | Criteria Condition (C) | Subindex (w*C) |
| *Nitrate* | *0.20* | *0.000* | *0.000* | *1.000* | *0.200* |
| Odor and Taste | 0.20 | 1.000 | 0.200 | 1.000 | 0.200 |
| Bacteria/Pathogens | 0.30 | 0.917 | 0.275 | 0.917 | 0.275 |
| Carcinogens | 0.30 | 1.000 | 0.300 | 1.000 | 0.300 |
| | | **Use Condition (U)** | **0.775** | | **0.975** |

*Note*: Shaded rows with italicized text denote those criteria impacted by the water quality improvement opportunity.

# APPENDIX B: Model Inputs – Costs and Benefits

## Model Inputs – Costs

| Category | Inputs Needed | Unit | Enhanced Nutrient Removal at SWTP |
|---|---|---|---|
| Capital Costs | Capital Costs | $ | $28,000,000 |
| Annual Incremental O&M Cost Total | Annual O&M Costs | $/Year | $2,866,00 |
| Major Ongoing Maintenance Expenditures - Reoccurring | Ongoing Maintenance Expenditure | $ | |
| | Frequency of Expenditure | Frequency in Years | |
| Sinkhole Repair Costs | Sinkhole Repair Costs - Small | $/Sinkhole | |
| | Sinkhole Repair Costs - Large | $/Sinkhole | |
| | Estimated Number of Years to Form Sinkhole (how many years until the sinkhole occurs) | Years | |
| | Number of Basins Impacted - Small | # | |
| | Number of Basins Impacted - Large | # | |
| Reduced Water at SWTP/NWTP from SSO Reduction | Reduction in Water Treated at SWTP/NWTP | MG/Year | |
| Increased Electricity Consumption at WWTP | Electricity Used in WW Treatment at SWTP/NWTP - current | kWh/MG | |
| | Incremental electricity Used in WW Treatment at SWTP - higher level of treatment | kWh/MG | 111 |
| Reduced WWTP O&M Costs from SSO Reduction | Total Treatment O&M Costs at SWTP and/or NWTP - current | $/MG | $623.76 |
| GHGs Produced from Additional Chemicals Use at SWTP | Increased Tons of Alum | Tons/Year | 743 |
| | Increased Tons of Ferric | Tons/Year | 0 |
| Increased VMTs (Chemicals Trucking) | Increased Truck Hauling Miles of Shipping Chemicals to SWTP | Miles/Year | 12,524 |
| Increased VMTs (Additional Biosolids Hauling) | Increased Truck Hauling Miles for Transport of Additional Biosolids | Miles/Year | 64,000 |
| Additional Sealant Costs to Private Property | Cost of Coal Tar Based Sealant | $/Sq Yard | |
| | Cost of Asphalt Sealant | $/Sq Yard | |
| | Gross Area Sealed | Sq Yards | |
| | Useful Life Between Applications - Coal Tar Based Sealant | Years | |
| | Useful Life Between Applications - Asphalt Sealant | Years | |
| Replacement Costs | Dollar Value of Replacement Costs (Current) | $ | $14,000,000 |
| | Year of Replacement Cost Incurred | Year | 20 |

## Model Inputs – Non-Water Quality Benefits

| Category | Inputs Needed | Unit | Enhanced Nutrient Removal at SWTP |
|---|---|---|---|
| Avoided TMDL Impairment Costs (Administrative or Legal Costs Only) | Avoided Annual TMDL Costs Related to Administrative or Legal Costs | $/Year | 10,000 |
| Avoided Regulatory Compliance Costs (Permit Violation Costs) | Number of Years Incurred (could be annual or for a fixed period) | Incurred Year | |
| | Number of Days per Year | Days/Year | |
| | Permit Violation Costs | $/Day | |
| Public and Stakeholder Relations Benefit | Reduction in Public Outreach Costs | $/Year | 0 |
| | Reduction in Time Dealing with Customer Complaints | Hours/Year | |
| | Hourly Wage of a Customer Service Employee | $/Hour | |
| | Number of Years of Benefits (if shorter duration than study period) | Years | study period |
| Tree Benefits | # of Trees Planted Around Detention Basin Retrofits | # | |
| Avoided Private Property Costs | Incremental Decrease in Number of Overflows | #/Year | |
| | Cost of Overflow Event to Private Owner | $/Event | |
| Residual Value - 1 | Useful Life of the Major Capital Components | Years | 60 |
| Residual Value - 2 | Useful Life of the Replacement Capital Components | Years | 20 |

## Model Inputs – Water Quality Benefits

| Water body | Users | Non-Users | Average WQI Improvement |
|---|---|---|---|
| | | | Enhanced Nutrient Removal at SWTP |
| Wilsons Creek below SWTP | 11,200 | 5,958 | 0.450 |
| James River below Wilsons Creek | 18,720 | 181,782 | 0.074 |
| Table Rock Lake | 1,069,500 | 315,391 | 0.071 |