Lower Boise River Phosphorus Model Trade

CONCEPTUAL DESIGN OF A COMBINED SEDIMENT BASIN/WETLAND SYSTEM

TECHNICAL MEMORANDUM

PREPARED FOR

The City of Boise

PREPARED BY

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November 9, 1999

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INTRODUCTION

Purpose and Scope

Purpose. As part of the pilot trading program framework development for the Lower Boise River Watershed, a conceptual design for a combined sediment basin/wetland system was prepared. The design was developed utilizing actual data from the proposed site to better understand performance and associated costs. Information provided by the design was used as a point source-non point source phosphorus model trade for the trading program framework.

Scope. Three tasks were identified as part of the scope:

- Task 1 – Data collection and evaluation

  The objective of this task was to evaluate and analyze existing data pertaining to the proposed site.

- Task 2 – Design Calculations

  The objective of this task was to perform calculations to size the combined sediment basin/wetland system and to estimate phosphorus removal by various components of the system.

- Task 3 – Conceptual Design Plans

  The objective of this task was to develop conceptual plans for the combined sediment basin/wetland system. As part of this task, an estimate of the associated probable costs was prepared based on quantities calculated from the design plans and unit prices for materials, equipment, and labor.

Site Description and Basis for Selection

Site Descriptions. Four sites were considered as possible locations for the phosphorus model trade project. These sites were identified by Dave Ferguson of the Soil Conservation Commission (SCC). Three of these locations were potential retention basin sites with some small areas for wetlands, "A" Drain, Noble Drain, and Solomon Drain. The fourth location, Mason Creek, was evaluated as a potential wetland site. Each site had advantages or limitations, which are described briefly below. Appendix D includes photos and a map for the location of these sites.

- "A" Drain

  The "A" Drain site has a relatively small tributary drainage area and, therefore, requires a smaller facility to convey a flood through the site. The area, however, has limited storage capacity, requiring a relatively high embankment, which would provide limited phosphorus treatment. The area for wetland creation is also limited by topography.

- Noble Drain

  The Noble Drain site has a larger tributary area than "A" Drain and the same site limitations. It is possible that Noble Drain could provide a larger area for wetland creation than "A" Drain, which may improve phosphorus removal. The valley area is broader than the "A" Drain, which would require longer embankments and increase costs, but could increase storage volume.

- Solomon Drain

  The Solomon Drain site also has a larger tributary area than "A" Drain and the same site limitations. It is possible than Solomon Drain could provide a larger area for wetland creation than "A" Drain, which may improve phosphorus removal. The valley area is broader than the "A" Drain, which would require longer embankments and increase costs, but could increase storage volume.

- Mason Creek

  Mason Creek was selected as the preferred site for the conceptual design. First, since the site is off-channel, there is an opportunity to optimize treatment based on available area for wetlands creation. Second, an off-channel facility requires fewer facilities for flood control, which reduces costs. Third, the site is close to the Lower Boise River and phosphorus removal will have a more direct impact on reducing the phosphorus concentrations in the River. Fourth, there is limited topographic relief, due to past farming practices, which allowed a conceptual design without detailed survey information. Technically, wetland systems are the best "natural system" method to remove phosphorus and this site provides the largest area for wetland creation.

  The site, however, has limitations. First, it is subject to seasonal backwater flooding from the Lower Boise River. Aerial photographs from the Bureau of Reclamation in Boise, Idaho, suggest this area has been relatively minor in the past, but a floodplain analysis was not available to better assess the risks. Second, the soil mantle is relatively shallow (less than 3 feet), with pervious soils or bedrock below. This limits the depth of excavation for emergent wetlands or retention basins. Finally, most of the soils at the site are classified as sandy-silty loams, which are less desirable for wetland creation and may require soil amendments to facilitate plant growth.

Site Selection and Basis. The possibility of selecting one of these four sites for the model trade, was discussed at a July 29, 1999 Agricultural Work Group

Meeting. Based on recommendations by Brown and Caldwell and the Agricultural Work Group, the Mason Creek site was chosen for the conceptual design.

Due to the limitations specified above, some preliminary analysis was performed in regard to the flooding and existing wetlands. These preliminary findings, limited potential for flooding and no existing wetlands (per the National Wetlands Inventory) assisted selection of this site for the conceptual design.

Data Collection and Evaluation

Water Quality. Water quality, specifically total phosphorus (TP), total suspended solids (TSS), and flow information, was obtained from USGS at the Mason Creek (at Mouth near Caldwell site) confluence with the Lower Boise River for the years 1994 – 1998 (provisional) (USGS, 1997).

Total phosphorus concentrations ranged from 0.16 mg/L (minimum) to 0.93 mg/L (maximum) with an average concentration of 0.32 mg/L. Total suspended solids concentrations ranged from 12 mg/L (minimum) to 525 mg/L (maximum) with an average concentration of 142 mg/L. The average daily flow was 100 cfs.

Watershed Characteristics. Several aerial photos provided by the Bureau of Reclamation in Boise, Idaho were reviewed to assess flooding potential. National Wetland Inventory maps were reviewed to assess the possibility of existing wetlands.

DESIGN APPROACH

As part of the conceptual design process for the wetland system (system), two approaches were evaluated, the Natural Resources Conservation Service (NRCS) five-component constructed wetlands approach and the conventional wastewater treatment (WWT)system approach. These approaches are described below. As a result of this evaluation, Brown and Caldwell determined that a hybrid design based on a combination of the two approaches would be best for the selected site.

NRCS Constructed Wetland System

The NRCS five-component system (NRCS, 1999b) was designed for treatment of attached and soluble nutrients in urban storm runoff and agricultural irrigation return flows. The breakdown includes a) sediment basin (3%), b) primary grass-filter area (23%), c) vegetated wetlands (23%), d) deep-water pond (41%), and e) polishing filter (10%). These components are proportioned on a percentage basis based on the total surface area (i.e., facility size) and the system is sized for a minimum four-day hydraulic retention time (HRT). Different recommendations are provided for treatment of continuous runoff agricultural return flows versus intermittent stormwater runoff and for phosphorus removal versus the removal of other pollutants. The maximum loading rate for optimum phosphorus removal recommended by the NRCS is 3 g/m^2/yr.

Conventional Wastewater System

The conventional wastewater treatment system utilizes wetlands for tertiary treatment and for "polishing" municipal or industrial effluent to meet discharge limits. The effluent has already received primary (i.e., sediment removal) and secondary treatment prior to being discharged to the wetland cells. The constructed wetland is designed to optimize natural physical, chemical, and biological treatment processes. The essential role of vegetation is believed to be a facilitator for microbial growth, for transmission of oxygen to the root system (Reed, 1991) and for nutrient uptake and transformation, where pollutants are transformed into basic elements, compost, and plant biomass.

Two basic types of constructed wetlands are used (Reed, 1991) for wastewater effluent treatment. The first includes emergent vegetation and a water surface exposed to the atmosphere ("free water surface" wetland). The bottom is carefully graded to ensure uniform flow and inlet/outlet structures provide even distribution and control of water depth. The "free water surface" wetland cells are finely graded, uniformly shaped basins with controlled flow rates and water depths in the individual cells. Relatively consistent phosphorus removal can be achieved by closely controlled flows, depths, plant species, surface area, and hydraulic retention times. The same components are present in the second type of wetland, but also contain a media (i.e., soil) and the water level is designed to remain below the surface of the media ("subsurface flow" wetland).

Proposed Wetland System

Two objectives of this conceptual design were to optimize phosphorus removal and minimize operation and maintenance costs while providing flexibility.

The proposed wetland system for the Mason Creek site is located in Caldwell, Idaho just above the confluence with the Lower Boise River (Appendix D). The design approach used is a hybrid of the NRCS approach and conventional WWT system. Due to the site limitations, a deep-water pond is not practical; excavations are limited to 2-feet to avoid pervious sub-soils and shallow groundwater; and fills for berms are limited to 3-feet to minimize impacts on flood storage of the Lower Boise River. In addition, the area of the site (i.e., approximately 54 acres for actual wetlands) limits treatment of flow from Mason Creek to about 6 to 7 cfs, based on a recommended minimum HRT of four days. Therefore, the conventional treatment approach was investigated further by analyzing the effect of flow rate on pounds of phosphorus removed annually.

Optimize Phosphorus Removal. Using equations developed by Kadlec and Knight (1996), the amount of phosphorus removed by 54 acres of wetlands

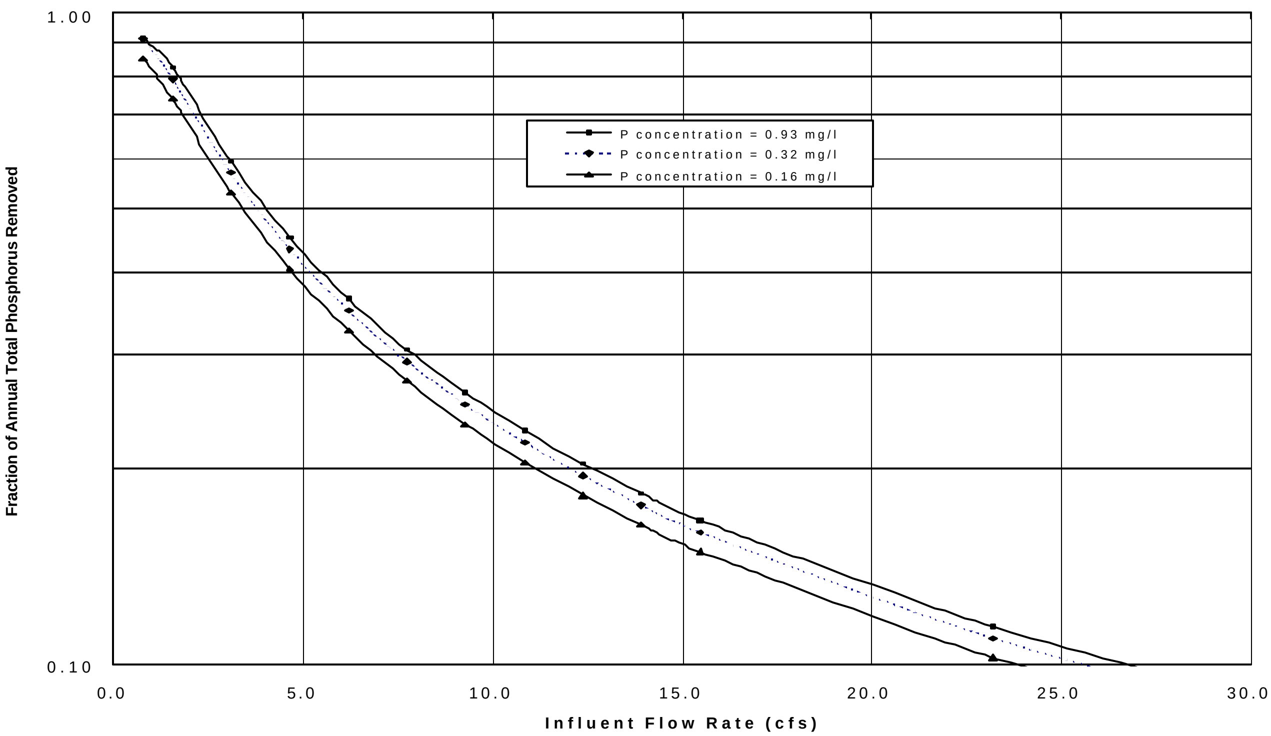

Figure 1. Fraction of Total Phosphorus removed as a function of influent flow rate.

was calculated for flows ranging from 1 to 20 cfs and for the minimum (0.16 mg/L), average (0.32 mg/L), and maximum total phosphorus (0.93 mg/L) influent concentrations (see Appendix B). A 200 day (April 15 – October 31) growing season was assumed.

Figure 1 shows the fraction of TP removed (in pounds) as a function of flow rate and demonstrates that the "efficiency" of the wetlands, as measured by the fraction of TP removed, drops from 90% at 1 cfs to 15% at 15 cfs. If flow rates through the wetlands were limited to 7 cfs or less, as suggested by the NRCS approach, the efficiency to remove TP would be 30% or better. This is considerably less than results reported by the NRCS (NRCS, 1999a). The difference in the efficiency for these two approaches may be due to design modifications (i.e., not using a deep water pond) and that the Kadlec and Knight (1996) equations are based on organic phosphorus (as opposed to inorganic phosphorus) and may under predict total phosphorus removal.

Figure 2 shows the amount of TP removed (in pounds) as a function of flow rate. An important trend is observed. As the flow rate through the wetlands increases, the mass of TP removed increases, but with diminishing results. At an average influent concentration (0.32 mg/L), an increase in flow from 1 to 6 cfs will increase the pounds total P removed from 616 to 813, or by 32%. However, increasing flow rate from 10 cfs to 15 cfs, the pounds removed only increases from 864 to 890, or by 3%. This analysis demonstrates that the amount of TP removed can be optimized for this site by increasing flow rate, without regards to the efficiency of the removal process (i.e., the fraction of TP removed).

For the purpose of design, 15 cfs was used, due to practical limitations of facility size (i.e., pipes, structures), velocity of flow through the system, and the unknown effects of operating a wetland system at higher flow rates. Based on an average phosphorus concentration of 0.32 mg/l, the design flow rate represents a loading rate of 11 g/m^2, which is 3.6 times greater than recommended by the NRCS approach.

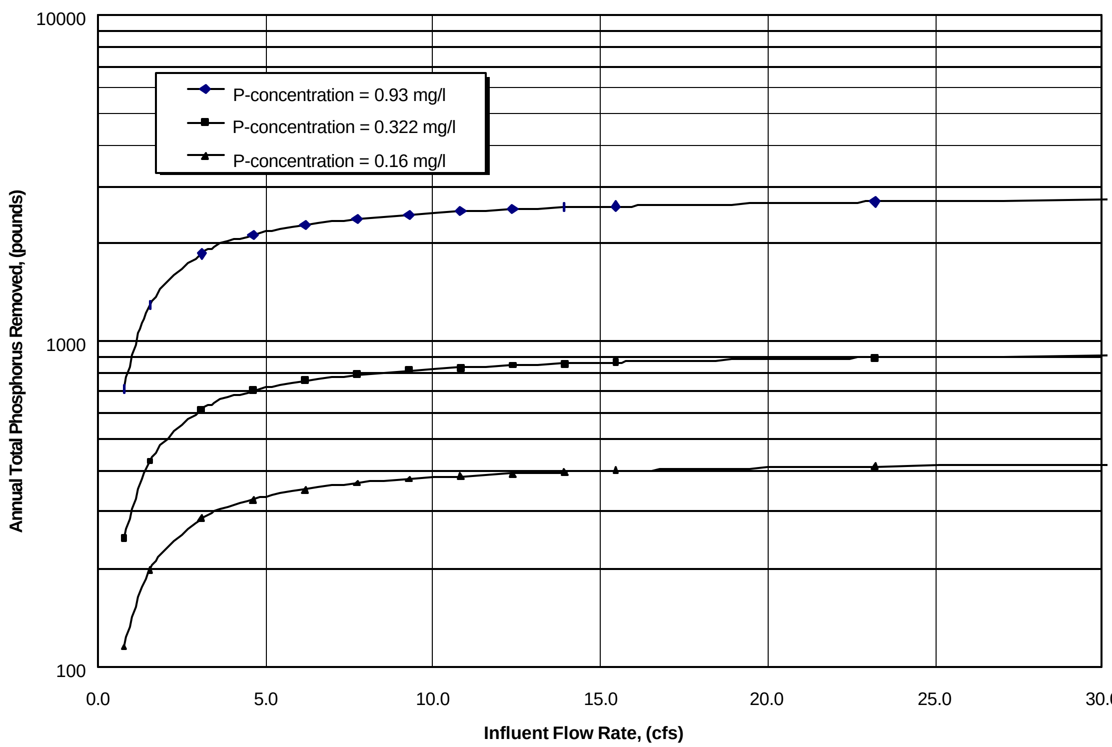

Figure 2. Total Phosphorus removed as a function of influent flow rate.

Operation and Maintenance Considerations. Since the performance of the treatment wetlands is dependent on the ability to control flow rates and flow depths, design elements were included to improve and simplify operation and maintenance of the wetland design and flow distribution system. The elements of the distribution system include:

- The intake structure allows relatively precise controls of flows directed through the system, and thereby enhances phosphorus removal efficiencies.

- The structures that control flows between wetland cells also allow for a wide range of flow rates and flow depths to account for changing conditions in the wetland cells and to optimize plant growth and nutrient removal.

- The ability to bypass portions of the system is provided by two parallel systems and separate piping with valves that allows portions of the system to be shut down for maintenance activities or repairs. This minimizes "downtime" for the entire system, thus allowing some level continuous phosphorus removal.

- The depth of the wetland cells allows for accumulation of biomass for up to 30-years, based on accumulation rates of 1-inch per year (Hammer 1989, NRCS 1999). This will minimize frequency of cleaning the entire system.

- The sediment basin provided storage for up to 6-years, while maintaining an optimum removal efficiency, before sediment must be removed. For estimating costs (see below), however, annual sediment removal was assumed.

- Each sediment basin can be shutdown for sediment removal while allowing design flows to pass through the remaining sediment basin, although at a lower efficiency.

- The system is designed to operate with minimal flows during off-season. This will help keep plants alive and minimize decay, which can lead to the remobilization of phosphorus.

CONCEPTUAL DESIGN

Description of Features

Drawings of the proposed system have been prepared (see Appendix A). The drawings include an overall conceptual site plan, site plans for the intake facilities, sediment basin, and outlet area, a typical profile through the wetland system, and the associated details.

1. The conceptual plan (drawing 1) shows two parallel systems, each with a sediment basin, primary filter, vegetated wetlands, and polishing filter. Water quality monitoring stations are provided at the inlet and outlet areas.

2. The intake structure (drawing 2) consistS of a weir in Mason Creek to create backwater at the twin gated diversion structure. The flow rate through the intake is controlled by changing the gates to achieve the required differential head in the measuring wells. Equipment for flow rate monitoring and automated

sampling is housed in the monitoring structure. After passing through the intake, flows are distributed to the sediment basins in an open channel. A separate bypass is provided to sluice sediment that may accumulate in the structure.

3. Two separate sediment basins are provided one for each system (drawing 3). Flows from the intake facilities are split and discharged into each sediment basin, allowing one cell to be closed for maintenance (i.e., sediment removal) while the other continues to operate. Flow baffle structures (i.e., wood fences) minimize short-circuiting of flow through the cell, improving sediment removal. Concrete ramps provide vehicle access for sediment removal. Both basins provide a total of up to 6-years of sediment storage at two feet of depth. Bypass piping and gates allow design flows to be distributed to either or both wetland systems when one sediment basin is closed for maintenance.

4. All flows that pass through the wetland cells are discharged through level control structures (drawing 6) into the bypass channel and conveyed to the flow measurement structure (drawing 4). These structures are consistent for all cells (i.e. A1-A2-A3 and B1-B2-B3). Flow rates are measured and recorded and samples taken automatically for analysis. Any flows that bypass the wetland cells are combined with flows that are treated prior to sampling, which facilitates a mass-balance analysis of flow and total phosphorus.

5. A general profile of the wetland system is provided on drawing 5. Wetland cell A-2, the vegetated wetland area, includes 2-feet of excavation, which provides storage for biomass accumulation. The sediment basin is also excavated two feet for sediment storage. Cost of the system can be reduced by eliminating or reducing the excavation, but the system life span (i.e., maximum time between installation and replacement of wetland vegetation) will be reduced.

6. Details of the level control structure and embankment between cells are provided on drawing 6. The berm increases the depth of each cell and provides vehicle access throughout the system. The level control structures are designed for 7.5 cfs, or half of the total design flow. One structure required for each cell, which improves uniform distribution of flows across the wetland cell. A level spreader ditch is recommended at the downstream end of the level control structures to improve even distribution of flows (drawing 3). Control gates allow level control structure to be shutdown for maintenance or for "throttling" flows for lower design-flow rates.

Projected System Performance

The ability of the system to remove phosphorus from flows diverted from Mason Creek was estimated separately for the sediment basin and for the wetland portion of the system.

Using the average measured TSS concentration of 142 mg/l (USGS, 1997) and a flow rate of 15 cfs, the sediment basin was calculated to remove up to 32,000 cubic feet of sediment during the 200 day irrigation season (see Appendix B). Using a ratio of 1 pound of phosphorus removed for each ton of sediment removed (Ferguson 1999b), the amount of TP removed by both of the sediment basins is approximately 1,040 pounds TP per season.

The anticipated amount of TP removed by the wetland cells was calculated using the Kadlec and Knight (1996) equations. At a flow rate of 15 cfs and average phosphorus concentration of 0.32 mg/l, 54 acres of wetlands will remove approximately 860 pounds of TP per season. The total amount of TP removed by the sediment basin and wetlands system is approximately 1,900 pounds per season.

To demonstrate the variability of phosphorus removal for the proposed system, Shop Creek, a retention/wetland system in the Cherry Creek reservoir watershed in Denver, Colorado was used for comparison purposes (Chadwick, 1998). The seasonal variation in phosphorus removed was estimated based on an 8-year monitoring study of the Shop Creek facility. Analysis of the data shows that the standard deviation in annual average phosphorus removal varies from 22% for the total system to 25% for the wetlands (see Appendix B).

The projected performance variation for the Mason Creek wetlands is from 15 to 20% (130 – 170 pounds), which is better than Shop Creek. Shop Creek is subject to regular storm events, which reduces HRT and increases flow variability, thereby reducing TP removal. In addition, flows through the Mason Creek wetlands will be more constant and controlled, which results in more consistent removal of TP and less variability.

Estimate of Probable Costs

An estimate of probable costs was prepared for this conceptual design based on calculation of quantities and estimate of unit prices for materials, equipment, and labor. Quantities were calculated using the proposed grades shown on the drawings (Appendix C). Unit prices were obtained from the Means Heavy Construction Cost Data (R. S. Means, 1993) and adjusted for inflation, experience on other projects, and best professional judgement. Unit prices include profit and reflect local market for this type of construction. Therefore, probable costs reflect a public bid process and do not assume price reductions for in-kind or donated labor and materials. Calculations of quantities and probable costs are included in Appendix C.

Table 1 presents a summary of probable costs. Costs are presented as capital costs, optional capital costs, operations and maintenance, and the outcome of a present worth and annual cost analysis.

Table 1. Mason Creek Wetlands Summary of Probable Costs

ITEM	DESCRIPTION	CAPITAL COST
Capital Costs		
Intake Facilities	Diversion at Mason Creek, flow measurement and monitoring station, and distribution to sediment basin	$56,000
Sediment Basin	Two 1.5 acre basins with baffles and maintenance access.	$121,000
Bypass	Control structures, channel, and outlet measuring and monitoring station	$60,000
Water Level Control Structures	6 concrete structures with 5 - 12" diameter outlet pipes for water surface control	$139,000
Wetland Cells	Berms, water control structures and wetland plants	$1,405,000
	Sub-Total	**$1,781,000**
	Contingencies (20%)	**$356,000**
	Engineering (15%)	**$267,000**
	Land Acquisition (60-acres)	**$600,000**
	Grand Total	**$3,004,000**
Optional	Concrete Lining for sediment basin to improve sediment excavation and disposal removal	$203,000
Optional	Liner to minimize interaction with groundwater	$1,921,000
Operations and Maintenance		
	Annual O&M	$71,800
	Harvest wetland plants at 5-year intervals	$74,000
Annualized Costs (I=interest= 7%, n = 30-years)		**$326,000**
	Phosphorus removed by wetlands (pounds/season):	860
	Phosphorus removed by sediment basin (pounds/season):	1040
	Annual cost per pound of phosphorus removed:	**$172**
Annualized Costs (I = 3%, n =30-years)		**$238,600**
	Phosphorus removed by wetlands (pounds/season):	860
	Phosphorus removed by sediment basin (pounds/season):	1040
	Annual cost per pound of phosphorus removed:	**$126**

Capital Costs. Costs are shown for the intake facilities, sediment basin, spillway, water level control structures, and wetland cells. Capital costs include a 20% contingency and 15% for engineering. Land costs were based on $10,000 per acre, as directed by the Effluent Trading Group on August 31, 1999.

Optional Costs. Costs for optional concrete lining of the sediment basin and synthetic liner for the wetland cells are also shown, but are not included in the total or in the calculation of annualized costs (see below).

Operations and Maintenance. Operations and maintenance costs were estimated based on a percentage of capital costs (Hammer, 1989a). Harvesting and disposal of wetland plants at a 5-year interval was also included in operations and maintenance costs.

Present Worth Analysis. A present worth and annual cost analysis was performed using a 30-year life span and interest rates of 3% and 7%. The 30-year life span is consistent with values reported by Hammer (1989a) and accumulation of biomass at the rate of 1-inch per year. The 7% interest rate reflects a public project based on borrowing money by issuing bonds. The 3% rate reflects only inflation and no costs to borrow money. At 7% the annualized costs are $326,000 and at 3% annualized costs are $238,600.

Based on projected annual phosphorus removal of 1,900 pounds, the annual cost to remove phosphorus ranges from $126 per pound to $172 per pound, for 3% and 7% interest rates, respectively.

Cost Comparison

Costs for construction of wetland systems for treatment of stormwater are reported to range from $10,000 per acre to over $30,000 per acre (Zentner, 1995 and Reed, 1991). The average cost for 79 surface flow constructed wetlands for municipal wastewater treatment is reported to be almost $24,000 per acre with a maximum value of $135,000 per acre (Arizona DEQ, 1995). It is important to note that many constructed wetland systems for wastewater do not include the costs of pre-treatment (i.e., primary treatment to remove sediment).

Based on a project area of 60-acres and a present worth of capital and O&M costs, the costs per acre for the Mason Creek wetlands at 7% interest rate is over $67,000.

Plant Selection

The sediment basin, for proper functioning, will have no plants. The primary filter zone is an irrigated pasture that could include wetland grasses such as Red Top. The shallow wetland cells will support emergent wetland plants such as Bulrush and Pond Weed. The final filter would support herbaceous and woody wetland species such as Willows. It is assumed that the initial plant density will be two-foot centers.

Monitoring

The level of effort for monitoring can vary depending on the strength of the data (i.e., confidence, interval, error). Standard statistical methods exist for determination of the number of samples needed to characterize the central tendency (mean or median) given a desired confidence interval and measure of variation (Gilbert, 1987). The general method assumes data are normally distributed and not correlated, however environmental data are generally log normally distributed. Transformed log normal data are generally necessary for use with methods based on normal distributions. Table 2 below shows that for a 30% error and 90 % confidence interval, 8 samples need to be obtained.

Table 2. Samples Required to Estimate Mean at Specified Percent Error and Confidence Interval

	Samples Required at Various Confidence Intervals		
% Error	.70	.80	.90
10	10	25	48
20	3	8	16
30	1	4	8

SUMMARY AND RECOMMENDATIONS

A conceptual design was prepared for the Mason Creek wetlands, which was the selected site for a facility to reduce phosphorus loads to the Lower Boise River to support a model point source-non point source phosphorus trade. By monitoring the phosphorus loading to and from the system, non-point source phosphorus reduction credits can be obtained. The ability of this system to remove phosphorus was estimated using Kadlac and Knight (1996) equations and data provided by USGS (1997) for Mason Creek. In addition, probable capital and operations and maintenance costs were calculated. Significant findings and recommendations are presented below.

Phosphorus Removal Projections

Pounds of phosphorus removed by the wetlands were calculated as a function of flow rate (Figure 1). The analysis shows that phosphorus removed can be optimized for the site by increasing flow rate, without regards to efficiency of the removal process (i.e., fraction of the phosphorus removed). This approach is unique because often the design basis is based on meeting certain effluent limitations, which requires a relatively high level of treatment efficiency. However, since the objective of the Mason Creek wetlands is to maximize pounds of phosphorus removal, effluent concentration is not a primary consideration.

For this analysis, the proposed system was designed for a flow rate of 15 cfs, which was projected to remove 860 pounds of phosphorus per season by the wetlands. The sediment basin was calculated to remove 1,040 pounds of phosphorus, based on phosphorus to sediment ratio of 1 pound of TP removed per ton of sediment removed. The combination of wetlands and sediment basin was projected to remove 1,900 pounds of TP per year. Based on long-term performance measurements of Shop Creek retention/wetland system in Colorado, the annual variation in performance for the Mason Creek wetlands is expected to be from 15 to 20% (130 – 170 pounds removed).

Conceptual Design

Conceptual design plans were prepared for the proposed system and are presented in Appendix A. The drawings provide an overview of the entire project and include plans for the intake, sediment basin, and outlet area, details and a profile through the wetland system. The plans provide the basis for calculating quantities to estimate probable cost.

Estimate of Probable Costs

A detailed estimate of probable costs was prepared for the proposed system. The estimate includes capital, operation and maintenance costs, which are summarized in Table 1 (see Appendix C for details). Capital and O&M costs were estimated to be $3,004,000 and $145,800, respectively. Annualized costs for phosphorus removal of $126 and $172 per pound were calculated based on interest rates of 3% and 7%, respectively.

Recommendations

Before proceeding with a more detailed design, Brown and Caldwell recommends that several considerations be addressed.

1. Obtain and test soil samples for engineering properties and suitability for plant growth. The cost estimate assumes a nominal cost for soil amendments to facilitate growth. Due to the large area involved, the quantity of materials and labor costs for amendments could significantly increase annualized costs.

2. Determine depth to groundwater and nature of the subsoils (i.e., classification and infiltration rates). The depth to groundwater will help determine if surface flows through the wetlands system will interact with groundwater flows. Investigate if interaction with groundwater is a concern. The cost estimate identifies the probable cost of a synthetic liner for the wetland cells, but does not include the amount in the total or the annualized costs. If required, the liner costs will substantially increase annualized costs. Note that the liner may be needed for only one, two, or perhaps all three cells. A cost breakdown for all three scenarios should be performed.

3. Investigate the need to line the sediment basins with concrete to facilitate sediment excavation and removal on a regular basis. Currently, the design allows one basin to be shutdown and dried out for sediment removal, while still operating the system. If the subsoils are pervious and the groundwater levels are sufficiently below the bottom of the sediment basins, it is possible that a concrete liner would not be necessary. Costs for the liner are provided, but not included in the total or annualized costs.

4. Investigate the need to excavate to increase operation and maintenance flexibility. Currently, the design includes two feet of excavation in the vegetated wetland cell (cells A-2 and B-2) and the sediment basins. This excavation represents approximately 18% of the capital costs for the facilities. This cost for additional sediment and biomass storage provided by the excavation should be compared to the increase in operating and long-term maintenance costs if excavation were eliminated.

5. Investigate the short and long-term effects of maximizing the flow through the system on the ability to remove phosphorus to determine best design flow rate. This design is based on maximizing pounds of phosphorus removed on an annual basis, which requires relatively high loading rates (i.e., short hydraulic residence times).

6. Identify requirements for permitting and include additional facilities and other costs, if required, in the annualized cost comparison.

7. Review cost estimate for the project based on construction under the direction of the Pioneer Irrigation District. This will provide a range of costs upon which the decision to proceed with design and construction can be

made. A range of costs is particularly appropriate in this instance, because the ability of the wetlands to remove phosphorus will vary by season.

8. Perform a site evaluation to confirm that wetlands do not exist. National Wetland Inventory maps were reviewed to assess the possibility of existing wetlands for this conceptual design.

9. Acquire additional data on flood storage function of site under existing conditions. Aerial photographs from the Bureau of Reclamation in Boise, Idaho, suggest this area has been relatively minor in the past, but a floodplain analysis was not available to better assess the risks.

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