

ATTACHMENT C
MOORHEN MARSH LOW ENERGY AQUATIC PLANT SYSTEM
ALTERNATIVES ANALYSIS

ALTERNATIVES ANALYSIS SUMMARY

Three alternatives were compared to Moorhen Marsh and they are discussed herein along with pertinent Moorhen Marsh information. The three alternatives (options) are generally summarized below and a detailed description of each follows this Section.

- Option 1 – Use a super long reach excavator to harvest water lettuce directly from specific locations in the North and South Relief Canals.
- Option 2 – Construct a basic water lettuce scrubber system on the Moorhen Marsh property.
- Option 3 – Combine Options 1 and 2.

In the alternatives analysis, yearly nutrient removal quantities were estimated for each option and were compared with each other and with Moorhen Marsh’s anticipated yearly removals. The results are shown in Table 1.

Table 1 – Estimated Yearly Nitrogen and Phosphorus Removals

	Moorhen Marsh (as bid)	Option 1 – Long Reach Excavator Harvesting Canals	Option 2 – Basic Water Lettuce System on Existing Site	Option 3 – Combined Option 1 and Option 2
TN Removed (pounds/year)	7,600	6,000	4,700	10,700
TP Removed (pounds/year)	1,200	730	800	1,530

As seen in Table 1, Option 3 has the greatest estimated yearly nitrogen and phosphorus removals, followed by Moorhen Marsh, Option 1, and Option 2 for nitrogen. Option 3 is followed by Moorhen Marsh, Option 2, and Option 1 for phosphorus removal.

Using a simplified economic analysis that estimates the cost per pound to remove total nitrogen (TN) and total phosphorus (TP) from the canal water, the estimated yearly cost to achieve the nutrient reductions were compared with each other and with Moorhen Marsh’s estimated yearly costs. The analysis spreadsheets are presented in Exhibit C-1 and results are summarized in Table 2.

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Table 2 - Simplified Economic Analysis Results: Cost per Pound of Nutrient Removed

	Moorhen Marsh (as bid)	Option 1 – Long Reach Excavator Harvesting Canals	Option 2 – Basic Water Lettuce System on Existing Site	Option 3 – Combined Option 1 and Option 2
TN Removal Cost (\$/year)	51.66	22.13	46.91	34.82
TP Removal Cost (\$/year)	327.21	181.91	275.57	243.52

Table 2 indicates that Option 1 has the lowest yearly estimated nitrogen removal cost and Option 2 has the lowest yearly estimated phosphorus removal cost. Moorhen Marsh has the highest nitrogen removal cost and the second lowest phosphorus removal cost. Note that Options 2 and 3 are predicated on a pre-design Option 2 construction cost estimate of \$5 million. As construction costs decrease, the dollars per pound of nutrient removed will decrease. For example, if the actual Option 2 cost were \$4,000,000 then the estimated removal cost for Option 2 reduces to \$42.65/pound for nitrogen and \$250.57/pound for phosphorus. Likewise, Option 3’s removal costs reduce to \$32.95/pound for nitrogen and \$230.45/pound for phosphorus.

DISCUSSION OF OPTIONS AND ESTIMATED OPERATIONAL COSTS

OPTION 1 – USE A SUPER LONG REACH EXCAVATOR TO HARVEST WATER LETTUCE FROM IRFWCD’S NORTH AND SOUTH RELIEF CANALS

In this alternative, which can be quickly implemented with minimal design and permitting effort, a super long reach excavator will be used to remove water lettuce from certain locations in IRFWCD’s North and South Relief Canals. To accomplish this, floating debris booms will be strung across the canals, trapping water lettuce as it is carried downstream by canal flow. When a sufficient quantity of water lettuce has been captured, perhaps sixty to seventy percent of it will be removed by the super long reach excavator (long reach), loaded into a dump truck and transported to the County landfill for disposal. The remaining water lettuce will be used as a “mother crop” to grow new water lettuce plants to be harvested later, for continual canal water nutrient removal. The long reach can be stationed at the Moorhen Marsh property. Harvest times are estimated to be at least once per week in the rainy season and perhaps every two to three weeks in the slower growing dry season. If not being used for harvesting water lettuce, the long reach machine may also be utilized by Road & Bridge Division.

Per a conversation with IRFWCD Superintendent Mr. David Gunter, we can expect to remove approximately 2,000 wet tons of water lettuce each year from the North and South Relief Canals (estimated removal for both canals ~ 1,000 wet tons per location). The most appropriate removal locations are:

- North Relief Canal – just west of the 58th Avenue bridge with the long reach located on the south side of the canal bank;
- North Relief Canal – a short distance west of the northeast corner of the County Moorhen Marsh property, harvesting from the south side of the canal bank; and

- South Relief Canal – just west of the 43rd Avenue bridge with the long reach located on the south side of the canal bank.

It is advantageous to provide two canal water lettuce harvesting locations along the NRC between 66th Avenue and 58th Avenue. This will allow alternate harvesting between the two locations, wherein sixty to seventy percent of the water lettuce at each location is harvested every other week during the wet season, allowing the non-harvested location two week’s growing time between harvests. In the dry season, the harvesting may be alternated every three to four weeks. This operational scenario will provide for more efficient nutrient removal as opposed to harvesting in a single location, and also result in greater water lettuce reproduction.

Pounds of Nutrients represented by 2,000 wet tons (4,000,000 pounds) of water lettuce based on the year-long Moorhen Marsh pilot plant study are estimated to be approximately¹:

- Total Nitrogen Removed: ~ 6,000 pounds/year
- Total Phosphorus Removed: ~ 730 pounds/year

Additional nutrients can be removed if passive sediment traps are constructed across the canal bottoms slightly upstream of the floating boom systems. These installations would be rectangular earthen bottom traps constructed with steel sheet piling, perhaps twenty feet wide and reaching from toe-of-slope to toe-of-slope with the interior dug to an eight-foot to six-foot depth. When the basins are full, a long reach will remove the collected sediment and debris to the design depth, and the material transported to the landfill for disposal unless IRFWCD wishes to reuse it on its property. The sediment will be analyzed for its nutrient load which will be included in yearly removal totals.

Required Equipment and Personnel:

- One super long reach excavator
- Two sets of TuffBooms, 10 booms per set
- One dump truck
- One long reach operator
- One dump truck operator

Estimated Capital Costs:

(2) Sets of TuffBooms, 10 booms per set = \$48,000

Estimated Equipment Costs:

Super Long Reach Excavator = \$280,000
 Eighteen cubic yard dump truck = \$180,600
 Total Equipment Cost = \$460,600

¹ From the Moorhen Marsh year-long pilot study report (Pilot Plant Study for Full-Scale Managed Aquatic Plant Pollutant Removal System – Final Project Report for Stages 1, 2 and 3, Van Ert, Nemoto and Associates, LLC, February 8, 2018), page 22, water lettuce has an average of 5.70 percent dry solids. From Table 2.2, page 23, the dry solids are comprised of 2.63 percent nitrogen and 0.32 percent phosphorus. These numbers represent average water lettuce values taken over a one-year period. For 2,000 tons of water lettuce, this corresponds to 228,000 pounds dry weight, which equals approximately 6,000 pounds nitrogen and 730 pounds of phosphorus. Note this does not include nitrogen and phosphorus present in the precipitate from the water lettuce root system, which will not be present in water lettuce harvested with a super long reach excavator.

Estimated Yearly Operating Costs:

Super Long Reach Excavator Maintenance = \$3,200²
Super Long Reach Excavator Fuel and Lubricants = \$5,472³
Dump Truck Maintenance = \$2,000
Dump Truck Fuel and Lubricants = \$3,000
Total Equipment Operating Costs = \$13,672 ~ 14,000/year

OPTION 2 –CONSTRUCT A BASIC WATER LETTUCE SCRUBBER SYSTEM ON THE MOORHEN MARSH PROPERTY

This option consists of constructing and operating a very basic (low-tech) water lettuce scrubber system on the Moorhen Marsh property. It will be much less complex than the Moorhen Marsh design but will remove fewer pounds of nitrogen and phosphorus per year. However, operation and maintenance will be much simpler. This basic water lettuce scrubber system will incorporate the currently designed Moorhen Marsh headworks screening and pumping station, followed by several parallel high-density polyethylene (HDPE) lined water lettuce scrubber systems, each capable of collecting a precipitate from microorganisms growing on water lettuce roots.⁴ The water lettuce scrubbers will be followed by a simple reoxygenation area flowing into a lined channel that returns the treated water to the NRC. Captured precipitate will be pumped to a designated area for dewatering and landfill disposal or perhaps beneficially recycled as a soil amendment.

Because this system is not designed, presentation of an estimated cost may be premature. However, the system's low-tech concept means that except for the headworks structure, most of the construction can be performed by a standard earth-moving type contractor, with the additional exception of a specialty company for HDPE installation. The design will contain only a small fraction of the concrete structures included in the very concrete intense Moorhen Marsh design, which represents a tremendous cost savings. Nor will the basic design have Moorhen Marsh's settling basins or wetland systems, various flumes, complex buried piping systems, or other "hard" appurtenances; the deletion of these all representing another significant cost reduction. It is reasonable to assume a conservative construction cost for this facility will be \$5,000,000 and perhaps less. An estimated \$5,000,000 construction cost was used in the simplified economic analysis to compare the various options.

The portion of the site not used for treatment processes will contain a pole barn for equipment storage and perhaps a large compost pad to compost harvested water lettuce along with harvested algae from the County's two large algal treatment systems. The property will also be the stationing point for the long reach. This long reach will also be used to harvest the water lettuce in the scrubbers, negating the need to purchase other expensive harvesting equipment, resulting in a much more efficient use of the long reach machine. The site could also serve as a research facility and perhaps generate cash flow through the receipt of research grants from the state or universities. These are just a few of its potential benefits.

² Caterpillar publication

³ Assume equipment operates for 38 weeks/year: 4 gallons/hour (from Caterpillar publication) * 6 hours/day * 2 days/week * 38 weeks/year * \$3/gallon

⁴ During its year-long Moorhen Marsh pilot plant study, Van Ert, Nemoto and Associated discovered a precipitate originating from organisms growing on water lettuce roots. The study found that the precipitate accounted for significant amounts of the nitrogen and phosphorus removed in the pilot plant's water lettuce scrubber units.

Major equipment required for system operation and other mechanical costs are assumed to be the same as for Moorhen Marsh. Assume only one laborer and facilities manager are required due to less intense treatment system.

Based on data from the Moorhen Marsh pilot plant, estimated predesign removals for a basic water lettuce treatment system are:⁵

- Total Nitrogen Removed: ~ 4,700 pounds/year
- Total Phosphorus Removed: ~ 800 pounds/year

OPTION 3 – USE A SUPER LONG REACH EXCAVATOR TO HARVEST WATER LETTUCE FROM IRFWCD’S NORTH AND SOUTH RELIEF CANALS AND CONSTRUCT A BASIC WATER LETTUCE SCRUBBER SYSTEM ON THE MOORHEN MARSH PROPERTY (COMBINE OPTIONS 1 AND 2)

Combining a basic water lettuce scrubber system constructed on Moorhen Marsh property (Option 2) with the in situ long reach canal harvesting system (Option 1), should exceed projected Moorhen Marsh nutrient removals. The long reach canal harvesting system can be implemented quickly, followed about two years later with an operating basic water lettuce scrubber system.

If Options 1 and 2 are combined, the total estimated removals when both options are operational are:

- Total Nitrogen Removed: 10,700 pounds/year
- Total Phosphorus Removed: 1,530 pounds/year

ESTIMATED NUTRIENTS REMOVED PER YEAR BY MOORHEN MARSH LOW ENERGY AQUATIC PLANT SYSTEM AND ESTIMATED OPERATIONAL COSTS

From prior design work based on the year-long Moorhen Marsh pilot plant study, Moorhen Marsh is estimated to remove 7,600 pounds of Total Nitrogen and 1,200 pounds of Total Phosphorus per year from the North Relief Canal.

Construction bids for Moorhen Marsh were received on July 14, 2020 and the apparent low bid is \$11,966,000.

Major Equipment Costs:

- Water Lettuce grinder/compactor (if the water lettuce is composted onsite) = \$100,000
- (2) Tractors = 2*\$25,000 = \$50,000
- (1) Compact Loader (existing) = \$83,000
- (1) Dump Trailer = \$7,500
- Total Major Equipment Cost = \$240,500*

Estimated Yearly Operating Costs:

- Dump Trailer Maintenance = \$80
- Dump Trailer Fuel and Lubricants = \$300

⁵ TN and TP removals are based on the assumption that the combined water surface areas of the proposed basic water lettuce system will be approximately 4 acres.

Tractor Maintenance = $2 * \$1,000 = \$2,000$
Tractor Fuel and Lubricants = $2 * \$1,340 = \$2,680$
Tractor Tubes and Tires = $2 * \$800 = \$1,600$
Compact Loader Maintenance = $\$1,000$
Compact Loader Fuel and Lubricants = $\$1,200$
Compact Loader Tires = $\$800$
Electricity = $\$10,800^6$
Total Operating Costs = $\$20,460/\text{year}$

See Exhibit C-1 for the spreadsheet economic analysis regarding estimated yearly costs for nutrient removals.

⁶ Assume Moorhen Marsh's yearly electric pump costs are 1/2 of Egret Marsh's yearly pump electric cost.

EXHIBIT C-1 - OPTION 2 SIMPLIFIED ECONOMIC ANALYSIS

Blue = Automatically Calculated

ESTIMATED NUTRIENT REMOVAL COSTS (\$/Pound) FOR BASIC WATER LETTUCE SYSTEM ONSITE

INPUT DATA AND ASSUMPTIONS

7/17/2020

- 1 Date facility placed into service = 7/17/2020
- 2 **END DATE FOR THIS ANALYSIS = 7/17/2021**
- 3 This input item deleted
- 4 Number of years the facility has been operating = 1.00 years
- 5 Use Straight Line Depreciation
- 6 Assume the Capital Costs are spread over a period of 50 years (= Design Life)
- 7 Estimated Total Nitrogen Removed from startup through date of this analysis = 4,700 pounds
- 8 Average TN removed per year = 4,700 pounds
- 9 Estimated Total Phosphorus Removed during total operational period = 800 pounds
- 10 Average TP removed per year = 800 pounds
- 11 Assume estimated average yearly labor costs have been consistent throughout the operational period

CAPITAL COST (Grant money not included)

Item	Cost
Construction Estimate	5,000,000.00
TOTAL CAPITAL COST	5,000,000.00

ESTIMATED AVERAGE STAFF YEARLY LABOR COST

Staff Member	Hours/Week dry season	Hours/Week wet season	Amount
Facilities Operations Manager	25	25	47,814.00
Maintenance Worker 1	30	30	32,869.20
			0.00
			0.00
TOTAL LABOR			80,683.20

\$36.78/hour
\$21.07/hour including benefits
\$21.07/hour including benefits

MAJOR EQUIPMENT COSTS

Assume replacement cost = original cost * 1.06

Item	Description	Date Placed into Service	Age of Original Equipment at Time of Analysis (Years)	Equipment Life Span (years)	Remaining Life Span (Years)	Number of Replacements During Facility's Design Life	Original Cost	Salvage Value	Replacement Cost (not including salvage value)	Total Cost in Design Life	Cost per Year	
1	Dump Trailer	7/17/2020	1.00	10	9.00	4.10	7,500.00	0.00	8,000.00	40,300.00	806.00	
2	Two Tractors	7/17/2020	1.00	10	9.00	4.10	50,000.00	0.00	53,000.00	267,300.00	5,346.00	
3	Compact Loader	7/17/2020	1.00	15	14.00	2.40	83,000.00	0.00	88,000.00	294,200.00	5,884.00	
4	Water lettuce grinder/compactor	7/17/2020	1.00	15	14.00	2.40	100,000.00	0.00	110,000.00	364,000.00	7,280.00	
5		N/A	N/A		N/A	N/A				0.00	0.00	
6		N/A	N/A		N/A	N/A				0.00	0.00	
7		N/A	N/A		N/A	N/A				0.00	0.00	
8		N/A	N/A		N/A	N/A				0.00	0.00	
9		N/A	N/A		N/A	N/A				0.00	0.00	
10		N/A	N/A		N/A	N/A				0.00	0.00	
										TOTAL	965,800.00	19,316.00

AVERAGE YEARLY OPERATION AND MAINTENANCE COSTS

(Does not include labor)

Fiscal Year Costs	O&M Cost	Count
Yearly Costs from Attachment C	20,460.00	1
		0
		0
		0
		0
		0
		0
		0
		0
TOTAL	20,460.00	1
AVERAGE COST PER YEAR	20,460.00	

TOTAL COSTS ON A YEARLY BASIS

Item	Cost per Year
Capital Costs	100,000.00
Staff Labor Costs	80,683.20
Major Equipment Costs	19,316.00
Operation and Maintenance Costs	20,460.00
TOTAL COST PER YEAR	220,459.20

COST PER POUND OF NUTRIENT REMOVED

Nitrogen Removal =	\$46.91	per pound
Phosphorus Removal =	\$275.57	per pound

