3.3 Using Illinois River Floodplains for Nitrate Removal: TWI's Hennepin Levee District Example

Section 2.2.3 outlined the conventional methods for reducing excess nitrate pollution in the Illinois River. These methods include agricultural best management practices (BMPs) and tertiary treatment at publicly owned waste treatment facilities. Section 2.2.3 also discussed restoring floodplains and their wetlands as another opportunity for tertiary treatment to reduce excess nitrate.

The choice of which alternative to use for nitrogen pollution reduction requires some measure of comparison. This section provides a cost comparison of reducing the pollution for each alternative in addition to an analysis of the possible nitrogen reduction from restoring the Hennepin Levee District (HLD) floodplain. Furthermore, this section examines the economic feasibility of watershed-based trading between the restored HLD and the sources of nitrate pollution.

3.3.1 Costs of Nutrient Reduction: Conventional Methods

The sources of nitrate that most logically should be targeted for reductions include edge-of-field losses in agricultural production and sewage effluent, as these are the most prevalent and manageable sources. To reduce edge-of-field nitrate losses by 20%, using a combination of BMPs to achieve the lowest cost, would cost $0.40 per pound of reduction. However, these costs increase as the target reductions are increased. A 40% reduction in edge-of-field nitrate losses would cost $3.37 per pound of reduction whereas a 60% reduction would cost $7.48. In contrast, to achieve a 20% reduction by exclusively reducing fertilizer use requires an overall 45% reduction in fertilizer use at a cost of $1.29 per pound of reduction.

These estimates are in terms of marginal social costs as determined by the United States National Oceanic and Atmospheric Administration (NOAA). NOAA economists, using an U.S. Department of Agriculture (USDA) economic modeling program, examined the change in producer and consumer surpluses resulting from removing high quality cropland from production.[1] They focused on the opportunity costs of removing land from production including expected increases in the prices of agricultural goods and the loss of jobs in the region. However, the NOAA analysts do not consider the associated benefits of floodplain restoration such as flood control, recreational opportunities, quality habitat creation, and overall water quality improvement. Furthermore, TWI's Hennepin project encompasses lower quality farmland. Therefore, the estimates for the cost of nitrogen removal from the Mississippi River Basin are likely to be higher than if these estimates were for restoring floodplains to achieve the nitrate removal goals. The estimates for the cost of removing nitrogen at wastewater treatment plants are based on infrastructure and technology costs.

Tertiary treatment of urban point source effluent using biological nitrogen removal could be used to remove the excess nitrogen. NOAA economists estimated the annualized capital and O&M (operation and maintenance) costs to retrofit a treatment facility for nitrate removal equals $36,000 per ton ($18 per pound) of reduction.[2] This cost is distilled from NOAA estimates that ranged from $1.79 to $22,976.81 per pound of nitrogen removed.[3] NOAA accumulated this cost information from "cost equations developed originally by Hazen and Sawyer and Smith Associates (1988), as modified and reported in Camacho (1992) for the Chesapeake Bay Program."[4]

3.3.2 Capacity for Nitrogen Removal

As detailed in Section 2.1.1, *Rhizobium* bacteria possess the ability to convert water-borne nitrates into nitrogen gas and release it into the atmosphere. The sum of the original floodplain and other wetland areas in Illinois and in the Upper Mississippi River Basin would easily have been enough to control the existing nitrate pollution.[5] However, due to human alteration of the landscape, much of the original wetland acreage no longer functions as wetlands.

Theoretically, using only restored wetlands with bacteria-mediated denitrification could remove the excess nitrate. Hey suggests this would require 407,000 acres of restored wetlands and riparian buffers in the Illinois River Basin. This level of restoration would remove an estimated 101,000 tons of nitrate from the Illinois River, achieving an 80%

reduction. This equals a reduction of roughly 0.25 tons of nitrate per acre. The estimated annualized cost for this restoration equals $55 million, with the cost per pound of nitrate reduced equaling $0.27 ($540 per ton).[6] In contrast, NOAA economists estimate that through the restoration of 1 million acres of wetlands in the Mississippi River Basin, the annualized cost of nitrate reduction is $2.75 per pound ($5,500 per ton).[7] Again the NOAA economists consider the change in producers and consumers surpluses in their calculations. What impact can the restored HLD floodplain individually make towards reducing the nitrate load of the Illinois River? This is explored below.

Fertilizer Reduction

Simply removing agricultural land from production will result in reduced nitrogen loading to the Illinois River. The capacity of the restored HLD to reduce nitrogen pollution through removing this land from agricultural production is calculated by determining the arable acreage, the agricultural use (i.e., type of crop), and the fertilizer use based on Illinois averages. Table 3.3.2-1 shows the land use in the Hennepin Levee District (HLD) before its acquisition by TWI. By far the most prominent land use in the HLD was row crops, grown on every property except for a natural area and the land owned collectively by the Drainage and Levee District. This land use is consistent with the Putnam County statistics.

Table 3.3.2-1 Previous owners and land usage in the Hennepin Levee District.[8]

Owner	Acres	Land Use
Village of Hennepin	577	Row Crop
Smith	559	Row Crop
Jones	381	Row Crop
Roberts	370	Row Crop
Lee	200	Row Crop
Grant	182	Row Crop
Johnson	155	Pasture/Row Crop
Drainage & Levee District	85	Drainage Structures
Smith	37	Natural Area
Jackson	40	Row Crop
Jefferson	38	Row Crop

Next, we estimated the amount of fertilizer leaching from agricultural fields based on studies conducted in Illinois. These estimates were used to calculate the reduction in nitrogen pollution to the Illinois River as a consequence of removing HLD lands from agricultural production.[9]

Arable acreage in HLD = **2500** acres +/-[10]

Land usage = row crops, we estimate 50% in corn and 50% in soybeans

Corn acreage = **1250** acres

Soybean acreage = **1250** acres

Nitrogen fertilizer application[11]

Corn = **156.9** lbs/acre

Soybeans = 22.1lbs/acre (only applied to 11% of soybean fields) = **2.51** lbs/acre adjusted

Estimated total fertilizer usage

Corn = 1250 acres x 156.9lbs/acre = **196,125** lbs nitrogen

Soybeans = 1250 acres x 2.51lbs/acre = **3,137.5** lbs nitrogen

Total nitrogen fertilizer = **199,262.5** lbs nitrogen

Nitrogen pollution reduced

Estimated amount lost to leaching = **20%** of fertilizer applied[12]

20% x 199,262.5lbs nitrogen = **39,852.5** lbs nitrogen = **19.9** tons nitrogen

Removing the land in the HLD from agricultural production will result in an estimated reduction of 200,000 lbs of nitrogen fertilizer use in Illinois. Using an estimate of 20% leaching, a reduction of 40,000 lbs (20 tons) of nitrogen pollution in the Illinois River should result.

This estimate considers the removal of nitrogen fertilizer from the system. The real target of reductions is nitrate. A strict determination of the amount of nitrate reduced by removing the land from production is beyond the scope of this paper. However, since most of the nitrogen fertilizer applied to agricultural fields is in the form of nitrate or other nitrogen molecules that readily convert to nitrate, these estimates may serve as a surrogate for nitrate removal.

These results do not account for the amount of nitrogen introduced into the soil by soybean production or contributions from residual soil nitrogen pools built up over years of agricultural activities. Soybean production likely results in a roughly equivalent amount of nitrogen loading as corn production. Furthermore, the residual soil nitrogen is subject to leaching from the floodplain soil. However, for these factors there was an insufficient amount of information to make an estimate. Regardless, these estimates do indicate that removing the land in floodplains from agricultural production achieves some level of pollution amelioration.

Denitrification

In addition to reductions from removing land from production, bacteria in the restored floodplain will remove nitrogen from the river water through denitrification. The denitrification rate, nitrate concentration, the inflow and outflow of Illinois River water, the amount of water in the HLD, and uncontrollable factors such as climate and precipitation will influence denitrification. We calculate the amount of nitrate removed by denitrification at the restored HLD floodplain.

Research shows that anaerobic bacteria, under optimal conditions, can remove between 70-80% of the nitrate that enters into wetlands.[13] The calculations herein use the average of the research estimates (75%) for the denitrification rate. The concentration of nitrate ions used in the computation is an average of the concentration in the Illinois River at Ottawa, Illinois as shown in Figure 2.2.1-1. The Ottawa gauging station was the nearest upstream station to the HLD. Data from the gauging station is useful but not optimal for estimating the nitrate levels of the Illinois River as it flows past the HLD. Between Ottawa and the HLD, an Illinois River tributary, the Fox River, joins the system. Therefore, estimates of the nitrate concentrations in the Illinois River at the HLD should include this additional source. However, data for the Illinois River south of Ottawa is not available until the Valley City, Illinois gauging station, which is at the southern end of the Lower Illinois River Basin.

While the actual Illinois River nitrate concentration varies considerably from year to year based on factors such as fertilizer application amounts, temperature and precipitation, the average will suffice for this demonstration. TWI plans an input flow of 300 cubic feet per second (cfs), which can input approximately 733,000,000 liters of river water per day into the HLD.[14] TWI plans for the maximum daily inflow and outflow of water to the HLD from March through June, comprising 122 days. TWI does not expect that this level of water input and output will negatively influence the habitat quality in the floodplain. During this time of year, the level of nitrate in the Illinois River Basin reaches its greatest concentration (Figure 2.2.1-1). This time of year also coincides with the flood stage of the river, when the HLD will experience elevated water levels. However, artificially elevated water levels at other times may constrain the restoration effort. Finally, as the bacteria require 6-8 days to achieve the 75% denitrification rate, the designed system will retain water in the system for that period before it flows out into the Illinois River

Design flow =	**300** cfs
300 cf/sec x 1hl/3.532cf x 100 l/hl x 60sec/min x 60min/hr x 24hr/day =	
	733,861,834 l/day
Average nitrite-nitrate ion concentration =	**6.67** mg/l
6.67 mg/l x 733,861,834 l/day = 4,894,858,433 mg/day = 4,895 kg/day =	
4895 kg/day x 122 days of the year =	**597,190** kg/year
597,190 kg/year x 2.205lbs/kg	**1,316,804** lbs/year
Denitrification rate =	**75** %
1,316,804 kg/year x 0.75 =	**987,602** lbs/year
Tonnage	
987,602 lbs/year x 1 ton/2000lbs =	**494** tons

By actively pumping water through the HLD in the spring (March-June), TWI captures the river water at its highest nitrate concentration, while maintaining inundation of the floodplain during the flood season. With a constant inflow and outflow and with an average nitrate concentration of 6.67 mg per liter, the HLD can process some 1,320,000 lbs of nitrate per year.[15] Assuming a denitrification rate of 75%, a reduction of 494 tons (988,000 pounds) of nitrate pollution is possible.[16]

Of the 2,500 acres of land in the HLD, probably 2,100 will be inundated during the flood season and active in denitrification. The other acreage consists of uplands and the levees. The removal of 494 tons of nitrate from 2,100 acres equals a removal rate of 0.235 tons per acre. This estimate approximates Hey's 0.25 ton per acre estimate discussed above.

Total Nitrogen Reductions

The total estimated nitrogen reduction at the HLD is 19.9 tons of nitrogen per year through taking the land out of production and 494 tons of nitrates per year from denitrification. The restored Hennepin floodplain can achieve 513.9 tons of nitrate reduction when we consider nitrate as a portion of the total nitrogen in the system. These estimates provide an indication of the potential of nitrogen removal through restoration of Illinois River floodplains. Of the nitrogen pollution created by municipal and industrial sources (36,600 tons) in Illinois, our estimate demonstrates that the HLD can remove 1.4% of the total nitrogen. The total nitrogen estimate includes nitrates and other inorganic and organic nitrogen molecules. Estimates of the quantity of nitrate produced by municipal and industrial sources were unavailable so a direct comparison of nitrate production vs. nitrate removal was infeasible. However, wastewater treatment facilities mostly receive ammonia and organic nitrogen and very little nitrate in their influent streams. These facilities oxidize the ammonia and organic nitrogen into nitrate and then release it as effluent. Therefore, nitrate effluent should account for a high percentage of the total nitrogen effluent leaving wastewater treatment facilities.

Why should we compare the nitrogen production of wastewater treatment plants with the removal capacity of restored floodplains? Why, for example, not include a more direct comparison between agricultural effluent and floodplain removal capacity? The pollution produced at a wastewater treatment facility is directly measurable. Government agents can much more easily determine the effluent levels emanating from these sources than from the more diffuse effluent streams leaving agricultural lands. Other reasons for this comparison are considered in the discussion of watershed-based trading below.

While these calculations are only estimates, once the restoration and levee breaches are completed, TWI will monitor the inflow and outflow concentrations of nitrates to and from the project area. This will provide exact measurements of the denitrifying capacity of the floodplain. The existing pump will permit easy manipulation of water depth (critical both to denitrification and to competing wildlife functions-Section 4.1.2).

3.3.3 Economics of Reducing Nitrate

HLD Acquisition and Restoration Costs

The 2,490-acre HLD was purchased in 2001 for $2,100/acre at a total cost of over $5.2 million.[17] The current average price for agricultural land and buildings in Putnam County is $2,428 per acre.[18] However, agricultural land in levee districts is usually less productive and therefore less expensive. TWI's financial contributors generously agreed to back bank issued bonds issued to the previous owners of the HLD.

To repay its debt, TWI will use monies generated from Federal and State programs aimed at wetland and land conservation, including the Conservation Reserve and Enhancement Program (CREP), the North American Wetland Conservation Act (NAWCA), and the Wetland Reserve Program (WRP) (Section 2.2 and Appendix 1). TWI will enroll 1,456.8 acres into the CREP, thereby ensuring $152.72 per acre per year for the fifteen years enrollment period. In addition, TWI will enroll 865.7 acres into the WRP, which provides a one-time payment of $1,200 per acre. Finally, TWI will enroll 240 acres into the NAWCA for a one-time payment of $2,083 per acre. The State of Illinois will pay TWI an upfront sum based on a percentage of the total Federal CREP money accrued over the 15-year enrollment period.

TWI partitioned the land into seven nonprofit [501(c) 3] corporations (called ducks) named after resident waterfowl species to maximize the payments from the CREP.[19] CREP sets a cap at $50,000/yr for a given parcel of land. Two of the ducks not enrolled in the CREP program are the Pintail Foundation, enrolled in the WRP, and the Wigeon Foundation, enrolled in the WRP and the NAWCA. An eighth duck is a donated natural preserve area.

Watershed-Based Trading

One hypothetical way to fund floodplain restoration is through nitrogen farming. Nitrogen farming is a combination of using floodplain wetlands for denitrification and watershed-based trading (Section 2.2.3). Donald Hey of TWI considers nitrogen farming as "an efficient, self sustaining solution that could significantly reduce nitrogen with only minimal government intervention and cost."[20] "Nitrogen farming requires five components: polluted water, a parcel of land, adequate hydric soils, energy to achieve and maintain inundation, and a nitrogen credit market. This solution involves using the wetlands to remove nitrate pollution and then selling the resulting nitrogen removal credits to those individuals or organizations that are seeking an economical means to compensate for their release of nitrogen."[21]

If a nitrogen farm were set up in a manner where the amount of reduction for nitrogen can be accurately quantified, then it would be possible for a nitrogen farm to trade credits directly. A nitrogen farm would be considered a point source in this case. In contrast, if there is some question about the true level of reduction, then a nitrogen farm might more appropriately fall into the category of providing NPS reductions.

The HLD is here considered a point source because it will include a discrete, measurable discharge to the Illinois River. Potential trades between wastewater treatment facilities and the HLD nitrogen farm would be a point/point trade (Section 2.2.3).

Nitrate Reduction Cost Scenarios

These scenarios consider the economics of restoring the Hennepin floodplain for nitrate removal (Scenarios 1 and 2) and the economics of a theoretical watershed-based trading market (Scenario 3). Hey makes the argument that the removal of nitrate at the restored HLD may create new economic opportunities through nutrient credit trading. TWI's HLD restoration project may serve as an example of using restored floodplains for nitrate removal. The quantity of nitrate removed from the river establishes the nitrogen farmer's yield. Each standardized quantity (e.g., one pound or one ton) of nitrate removed equals one credit generated by the farmer. TWI's idea is that, "credits, in turn, would be sold to industries, municipalities, and farmers discharging excessive amounts of nitrogen, and, presumably, to the highest bidder among these groups."[22]

Scenario 1: Costs of Using Restored Floodplains for Nitrate Reductions With Federal and State Monies. Table 3.3.3-1 provides the present value income and expenses for the project, including contributions from Federal and State programs (Appendix 4).[23] Before considering income from the sale of nitrogen credits, the HLD project operates at a deficit of $4,139,207 in present value terms (over twenty years) or $278,219 in annualized costs. A discount rate of 0.03 was used in the calculations.[24]

Table 3.3.3-1 TWI's HLD restoration project present value (PV) income and expenses.

Source of Income	PV Income	Source of Expense	PV Expenses
Single Federal and State Payments	*$2,265,311*	*Restoration Costs*	*$2,076,490*
CREP	*$2,661,470*	*O&M and Adminstration*	*$1,826,561*
Other Federal and State Payments	*$2,311,215*	*Bond Property Purchase*	*$4,569,460*
Bond Proceeds	*$5,000,000*	*Bond Interest*	*$2,253,286*
Residual Fund Interest	*$2,703,173*	*Letter of Credit*	*$395,478*
		Purchases	*$717,873*
		Debt Service	*$3,588,000*
		Bond Repayment	*$3,638,862*
Totals	***$14,941,170***		***$19,080,377***

Through denitrification, the restored HLD can reduce 494 tons (988,000 pounds) of nitrate effluent per year. The annualized cost of reducing nitrate at the HLD equals $563 per ton removed. Therefore, an investment in nitrogen farming would require returns of $563 per ton of reduction over twenty years to offset the cost of purchasing and operating the farm.

Scenario 2: Costs of Using Restored Floodplains for Nitrate Reduction Without Federal and State Monies. The Federal and State programs TWI will use to generate additional funding for its restoration efforts may not always be available. Therefore, it is useful to consider the costs of nitrate removal without using these programs. The cost of purchasing, restoring and operating the 2,500-acre levee district equals roughly $19,100,000 in present value or $1,284,000 in annualized costs as shown in Scenario 1. The annualized cost of nitrate reductions in this scenario equals approximately $2596 per ton (Appendix 4).

Scenario 3: Nitrogen Watershed-Based Trading.

As previously established, the cost of nitrate removal by a wastewater treatment facility is $18 per pound or $36,000 per ton. TWI, in contrast, can remove a ton of nitrate for $2596 without government subsidies, with an estimated 494 ton per year capacity. Suppose a trade occurred between TWI and a wastewater treatment facility for those 494 tons. The wastewater treatment facility might pay TWI $16,702 per ton of reduction (halfway between the restored floodplain price and the wastewater treatment price). Therefore, TWI could net almost $7.0 million annually from the sale of nitrate reduction credits. This example shows that even without Federal and State monies, TWI would greatly exceed its original investment within a few years. The present value of this revenue stream over the twenty years of the investment equals over $100 million (~$10,500 per ton) (Appendix 4). Furthermore, the wastewater treatment facility could save over $9.5 million annually in nitrate pollution reduction costs (Table 3.3.3-2).

Table 3.3.3-2. Annualized cost comparison for hypothetical nitrate credit trading between TWI and a wastewater treatment facility.

	TWI		**Treatment Facility**
Cost per ton reduced	*$2596*	*Cost per ton reduced*	*$36,000*
Tons reduced	*494*	*Tons reduced*	*494*
Net costs	*$1,282,424*	*Cost of nitrate reduction without trade*	*$17,784,000*
Tons sold	*494*	*Tons purchased*	*494*
Sale price	*$16,702*	*Purchase price*	*$16,702*
Gross revenue	*$8,250,788*	*Cost of nitrate reduction with trade*	*$8,250,788*
Net revenue	*$6,968,364*	*Net savings*	*$9,533,212*

The creation of a trading market along with an information distribution system to provide the credit buyers and sellers access to one another requires economic (and also political) development. For example, a state agency may create the market and information distribution system to stimulate trading. However, the development costs will likely be passed on to the buyers and sellers of the credits. This will reduce the net revenue for the nitrogen farm and the net savings for the treatment facility.

[1] NOAA used the U.S. Mathematical Programming Model (USMPM)
[2] CENR. 2000.
[3] Doering, O.C. et al. 1999. p53.
[4] Ibid. p53., Hazen and Sawyer Engineers and J.M. Smith Associates. 1988., and Camacho, R. 1992.
[5] Hey, D. L. 1999.
[6] Ibid.
[7] CENR. 2000.
[8] TWI. 2001. The names were changed to protect the identity of the previous owners.
[9] David, M. B. and L. E. Gentry. 2000.
[10] TWI. 2001.
[11] Illinois agricultural statistics 1999 annual summary.
[12] David, M. B. and L. E. Gentry. 2000.
[13] Hey, D. L. 1999., and Hey, D. L. 4/2001.
[14] Hey, D. L. 4/2001. Personal communication.
[15] USGS. 2000.
[16] Hey, D. L. 4/2001. Personal communication.
[17] Although TWI will gain control over 2,654 acres of land, they will only purchase 2,490 acres at the outset. Of the remaining 164 acres, 84 acres formerly belonged to the HLD legal entity (e.g., drainage ditches, the pump site, and portions of the levee). 51 acres were donated as a nature preserve and a 28-acre homestead comprise the rest.
[18] Illinois Department of Agriculture and the U.S. Department of Agriculture. 2000.
[19] These are the Wigeon, Pintail, Mallard, Blue-Wing Teal, Ringbill (sic), Wood Duck, and Gadwall corporations.
[20] Hey, D. L. 1999.
[21] Ibid.
[22] Ibid.
[23] Hey, D. L. 4/2001. Personal communication.
[24] Discount rate calculations show the present value of benefits and costs received at some time in the future. The 0.03 rate was chosen because it approximates the real discount rate, the rate used by financial corporations.