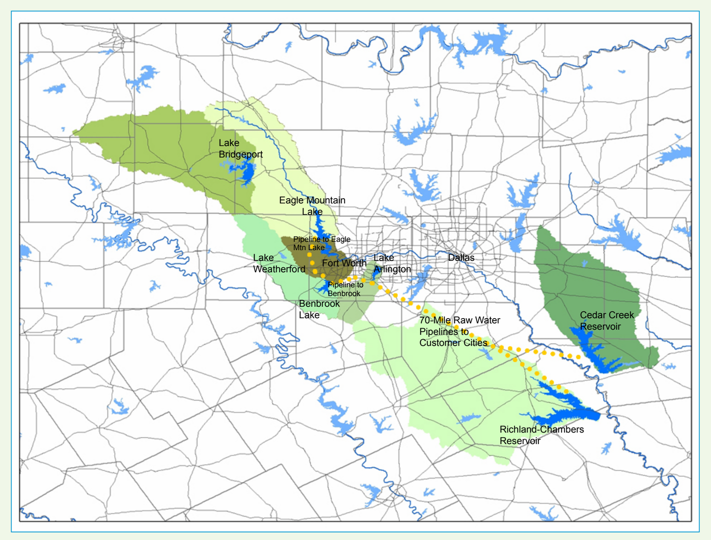
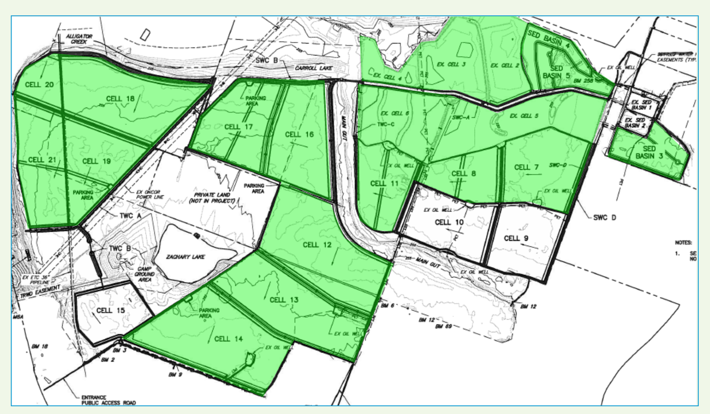
Tarrant Regional Water District

George W. Shannon Wetlands Water Recycling Facility – From Research to Reality

Introduction

The mission of the Tarrant Regional Water District (TRWD), a political subdivision of the State of Texas created in 1924, is to provide raw water to its customers located within Tarrant and adjacent counties. As one of the largest water suppliers in the state, the TRWD provides raw water from surface water sources to over 1.6 million people in its service area that currently spans across ten counties in North Central Texas. To meet the raw water supply needs, the District has constructed and operates four major surface water reservoirs. Pipeline connections have been constructed to further link these reservoirs to other existing reservoirs. Based on conservative projections, the population within the current service area will swell to over 3.8 million by the year 2060. In order to meet this future water supply requirement, the District is pursuing several options. One of the options is to supplement the yield of two of the District's downstream water supply reservoirs (Richland-Chambers and Cedar Creek Reservoirs) by diverting Trinity River water, which is largely made up of return flows, polish the diverted river water in constructed wetlands, and then pump the wetland-treated water to the reservoirs. The TRWD's plan, designated the George W. Shannon Wetlands Water Recycling Facility (GWSWWRF), should provide about 115,500 acre-feet/year (103 MGD average) of additional raw water supply from these two reservoirs. The TRWD's existing water supply and the operating concept for the GWSWWRF is shown below.





Research Program

TRWD formulated a staged program to research and examine the financial aspects, operation and maintenance issues, and treatment performance of constructed wetlands. As the Richland-Chambers Wetland is being constructed within the Trinity River flood plain in the Richland Wildlife Management Area operated by the Texas Parks and Wildlife Department (TPWD), study of operational issues related to wetland system management and recovery after flood events were important. The staged research program was conducted for almost 18 years and involved the following:

- An initial 2.5 acre Pilot-Scale Wetland operated from 1992 to 2000;
- A Field-Scale Wetland (243 acres), constructed as the first train of the Richland-Chambers Wetland, which began operation in Spring 2003;
- A second wetland train (Phase I Expansion) totaling 187 acres, completed in 2009; and
- Concurrent operation of the Field-Scale and Phase I Expansion wetland trains from October 13, 2010 through January 11, 2011 following moist soil drawdown operations for the Field Scale Wetland from May through August 2010 and continuous flow operations for the Phase I Expansion train.

Construction was initiated in January 2011 for the Phase II Expansion which includes the full-build-out of the Richland-Chambers Wetland. Upon completion, the project will have a footprint of approximately 2500 acres to treat an average flow of 91 MGD. This project will supplement the yield of Richland-Chambers Reservoir by 63,000 acre-feet per year.

The TRWD's GWSWWRF will eventually also include a project to polish diverted Trinity River flows to supplement the yield of Cedar Creek Reservoir. Although the Cedar Creek Wetland is on a longer time line, the water right permit has been acquired and preliminary assessment and site selection studies have been completed. The Cedar Creek Wetland project will encompass approximately 2,000 acres and ultimately supplement the yield of the reservoir by 52,500 acre-feet per year.

Design criteria have been refined at each phase of the wetland system design based on the operational and management data gathered from the preceding phases. The continuing operation of the Field-Scale Wetland and the initial operation of the Phase I Expansion train, which incorporated improved design criteria based on the initial 3.5-year operational period of the Field-Scale Wetland, provided opportunities to evaluate the revised design criteria as well as comparison of operational and management strategies. Operating conditions for the Field-Scale Wetland included a major scouring flood during July 2007 as well as other river flooding events and long periods of relatively dry conditions including significant drought periods. Concurrent operation of the Field-Scale Wetland and the Phase I Expansion train provided opportunity for direct comparison of performance following moist soil management drawdown activities versus continuous flow-through conditions. Specific observations and conclusions regarding system performance, water level management, responses of the wetland system to adverse conditions, and vegetation are summarized below.

System Performance

The mass balance analyses provide important insights regarding the removal efficiencies achieved under the varying conditions. The following table presents the efficiency results achieved for Total Suspended Solids (TSS), Total Nitrogen (TN), and Total Phosphorus (TP) removal overall for the Field-Scale Wetland and the Phase I Expansion train.

PERFORMANCE SUMMARY FOR FIELD-SCALE AND PHASE I EXPANSION

Period	Unit	Percent Mass Removed			Percent Concentration Reduction		
		TSS	TN	TP	TSS	TN	TP
6/3/03 to 1/11/11	PS-SB	66	6	9	67	5	7
	SB-WC4	86	61	42	82	61	40
	PS-WC4	95	64	48	94	63	44
5/13/10 to 1/11/11	PS-SB2	70	2	4	75	4	6
	SB2-WC6	87	64	66	88	66	64
	PS-WC6	96	65	67	97	67	67
10/13/10 to 1/11/11	PS-SB2	68	-1	0	74	0	0
	SB2-WC4	97	71	45	96	72	33
	PS-WC4	99	70	45	99	72	34
10/13/10 to 1/11/11	PS-SB2	68	-1	0	74	0	0
	SB2-WC6	84	45	54	87	51	57
	PS-WC6	95	44	54	97	52	58

PS = River Pump Station; SB = Sedimentation Basin; SB 2 = Sedimentation Basin No. 2 (constructed with the Phase I Expansion Train and used to feed both Field-Scale Wetland and Phase I Expansion Train during 2010); WC4 = Wetland Cell 4 Outfall (end of Field-Scale Wetland train); WC6 = Wetland Cell 6 Outfall (end of Phase I Expansion Train)

The wetland system demonstrated effective removals of TSS, TN, and TP, but the calculated removals were influenced by hydraulic and mass loading to available wetland treatment area as well as the different operational conditions. The modified design criteria used for the Phase I Expansion train improved treatment efficiency so that it out-performed the Field-Scale Wetland for TP removal even with the higher loading rates experienced for the Phase I Expansion train. Also apparent was that although the extensive growth of annual wetland plant species promoted by several months of moist soil management activities conducted in the Field-Scale Wetland provided effective total nitrogen removal, it did not provide improved TP removal efficiency relative to the continuous flow operations conducted in the Phase I Expansion train. Since the Phase I Expansion train out-performed the Field-Scale Wetland despite the higher hydraulic and TP mass loading, the continuous flow operations for this train provided both more wetland-treated water supply as well as higher water quality.

Design Components

The design criteria changes for wetland cells 5 and 6 of the Phase I Expansion train including the centrally located inflow control structure and inlet deep water zone with concrete curb across the width of the cell at the upstream end of Cell 5 and the location of the three flow control structures in conjunction with the outlet deep water zone at the downstream end of Cells 5 and 6 functioned well to distribute and collect flows across the entire width of the wetland cells. No short-circuiting flow currents were observable within either Cell 5 or Cell 6.

However the multiple weir structures at the outflow of Cell 6 increased the error inherent in the outflow measurement. A single flow control structure centrally located in conjunction with inlet and outlet deep water zones has been demonstrated to provide comparable flow distribution and collection comparable to multiple structures.

The inclusion of stop logs with the gated flow control structures between Cells 5 and 6 were effective in managing water levels under low flow during vegetation establishment.

A 12 to 18-inch elevation drop along the profile of the cells made it difficult to back flood an entire cell to facilitate initial vegetation establishment without creating excessive water depths at the lower end of the cell for newly planted area. Future wetland cells should be designed as flat bottom or with a maximum of 6 inches of elevation drop along the profile of the cell.

Internal deep water zones, if included, should be designed to meet flow distribution criteria only rather than incorporating habitat elements. No shallow shoals or islands should be incorporated into the deep water zones.

Natural colonization of wetland plants from available seed bank can be utilized to minimize planting requirements. However, critical areas such as bordering deep water zones should be planted with appropriate emergent vegetation to enhance flow distribution functions of these areas.

Water Level Management

Precision grading during construction of the cells promoted better flow distribution and minimized short-circuiting flows. The grading also provided an even grade for flow through the train so that backwater effects did not produce areas of water too deep for development of emergent vegetative cover. Water depths in the upper portion of the wetland cells are controlled by hydraulic loading, cell slope, and density of emergent vegetation, but weir controlled in the lower portion of the cell. During the 2010 operations, management of water depths through the entire length of the Phase I Expansion train met the design goal of averaging 12 inches or less.

Adverse Conditions

FLOODING

Both flood events resulting in backwater flows into the wetland cells and a major scouring flood event that overtopped the perimeter levees (July 2007) were experienced. The reverse spillways incorporated into the perimeter levees of the wetland cells provided levee protection so that no levee washouts were produced by the flood flows.

Multiple impacts to the vegetative cover resulting from the 2007 major flood event were observed. First, several new plant species as well as early colonizing species observed only during the first 1-2 years of operation were identified within the wetland cells following the flood event indicating the flood waters provided seed source. Second, although tall emergent plants were physically "laid down" by the flood flows, new shoots were observed in abundance a month after the flood water receded. Third, growth stimulation of all emergent plants was apparent. Fourth, submerged aquatic vegetation was stripped from the marsh areas and left hanging from woody vegetation (trees and shrubs) within the wetland cells or piled upon the perimeter levees. However, small residual patches of submerged aquatics were still observed within the wetland cells which provided rapid regrowth and colonization of the deeper marsh areas within 3 months following the flood event.

BIOTURBATION

Wildlife impacts to vegetation and suspended sediments were observed from several sources including feral hogs, nutria, and carp. However, impacts from ducks and other waterfowl were negligible. Management techniques to control bioturbation including removal of targeted wildlife, drawdown of water level for natural harvesting of fish by waterfowl, and increase in human activity (hunting) to shift animal populations from outfall areas appeared to be effective in reducing adverse impacts within the wetland cells. Draining to control carp and other bottom-foraging fish was less effective due to the ability of the fish to find refuge in the deep water zones, the slow drawdown rate possible when draining, and the inability to fully drain the cells. Periodic draining of sedimentation basins should also be employed to facilitate removal of fish when data indicate reduced sediment removal efficiency. Where incomplete draining of cells or basins is not possible, reduction of the flooded area may still facilitate other physical or chemical removal methods.

VEGETATIVE COVER

Development of dense emergent vegetation across the marsh zones of the Phase I Expansion cells was not achieved prior to the interruption of operation on January 11, 2011. Although substantial growth of the planted vegetation was achieved as well as colonization from the seedbank, open water within the marsh zones still represented over 10 percent of Cell 5 and 15 percent of Cell 6 based on the TPWD's October 2010 survey. Also, the cover represented by undesirable plants species identified during this survey represented over 19 percent of Cell 5 and 16 percent of Cell 6. Additional management activities will be required to target the identified undesirable species. The ability to manage initial water levels within future cells should be facilitated by the change in design criteria to flat bottom cells or less than 6 inch elevation change along cell profile so that exposure of less bare moist soil is available for colonization of the undesirable species. However, more extensive plantings of desired perennial species can also be employed to compete with invading undesirable species.

Although moist soil management activities conducted within the Field-Scale Wetland cells promoted establishment of vegetative cover, the majority of the vegetative cover was provided by annual species rather than perennial species. Therefore, additional water level draw downs are required for seed germination the following spring to reproduce the vegetative cover. Also, a functioning litter layer was not observed in areas dominated by annual species. A plant detritus litter layer is important for maintaining populations of microbes which are critical for nutrient removal.

Conclusions

Both the Field-Scale and Phase I Expansion Wetland trains exhibited effective removal of suspended sediments and nutrients. However, design criteria modifications and continuous flow operations provided greater TP removal efficiency within the Phase I Expansion train than for the Field-Scale Wetland. Lower hydraulic and TN mass loadings and the significant plant biomass produced during moist soil management drawdown in the Field-Scale Wetland resulted in higher TN percent mass removed and percent concentration reduction than in the Phase I Expansion train during Fall 2010 operations.

Moist soil management activities conducted in the Field-Scale Wetland during 2009 and 2010 resulted in increased vegetative cover especially within some marsh zones where water depths had inhibited establishment during flow-through conditions. However, occurrence of submerged aquatic species which had previously colonized the lower marsh zone of Cell 3 were lost as these species were not documented during the TPWD 2009 and 2010 surveys. Also, the vegetative community documented within the Phase I Expansion wetland cells operated under continuous flow-through conditions exhibited comparable species diversity with several desirable waterfowl flood species represented.

Growth of annual wetland plant species does not result in development of a sustained litter layer needed to support microbial populations critical for biological removal of nutrients from the water column through winter and early spring months. Hydraulic and mass loadings to wetland treatment areas should be managed to facilitate achieving nutrient concentration reduction goals.

Wildlife bioturbation can substantially impact establishment of aquatic vegetation as well as removal efficiency for suspended solids and nutrients. Management plans for carp and nutria populations should be developed and implemented. Feral hog populations should also be addressed, but may be less damaging over the long term due to migratory habits.

As population growth continues to exert increasing demands upon limited water resources, indirect reuse of return flows of highly treated effluents can be effectively utilized to supplement the yield of existing water supplies. The multiple benefits achieved with constructed wetland systems enable society to achieve more efficient use of limited water supplies while protecting receiving waters and preserving natural resources. Capitalizing on the multiple benefits of constructed wetland systems enables society to fulfill multiple goals and objectives that balance the needs of an increasing human population with conserving the ecological integrity of our environment.

From Research to Reality Timeline

Pilot-Scale Wetland System

OPERATED FROM 1992-2000

SYSTEM DIMENSIONS	
Sedimentation Basin 1	0.1 acre
Sedimentation Basin 2	0.2 acre
Nine Wetland Cells	0.25 acre each
Total	**About 2.5 acres**

Determined that a wetland system could achieve target levels for nutrient and sediment that would protect water quality within the reservoir

Field-Scale Wetland System

FIRST TRAIN (243 ACRES)
BEGAN- OPERATIONS IN SPRING 2003

SYSTEM DIMENSIONS	
Field-Scale Wetland	243 acres
Phase 1 Expansion	187 acres
Phase 2 Expansion	1,362 acres
Total Footprint	**~2,500 acres**

- Sedimentation Basins (five) = 100 acres
- Wetland Treatment Area (20 wetland cells) = 1792 acres

Phase 1 Expansion

SECOND TRAIN (187 ACRES)
COMPLETED IN 2009

Phase 2 Expansion

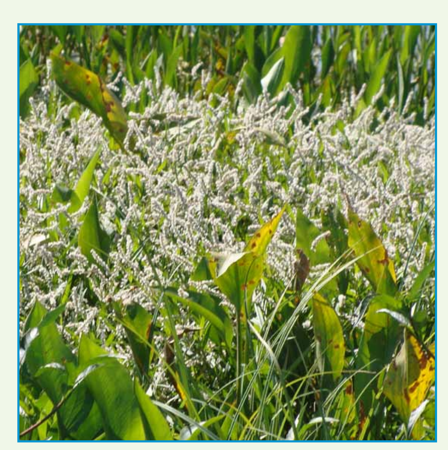
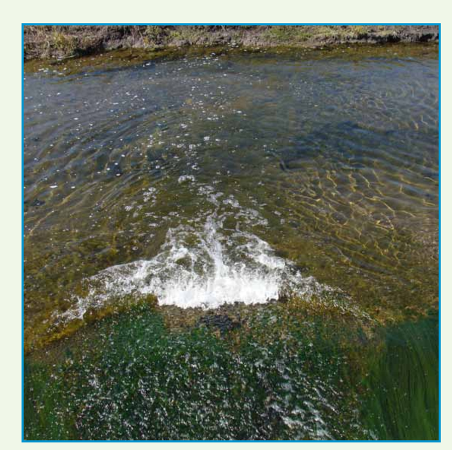
CONSTRUCTION BEGAN IN 2011

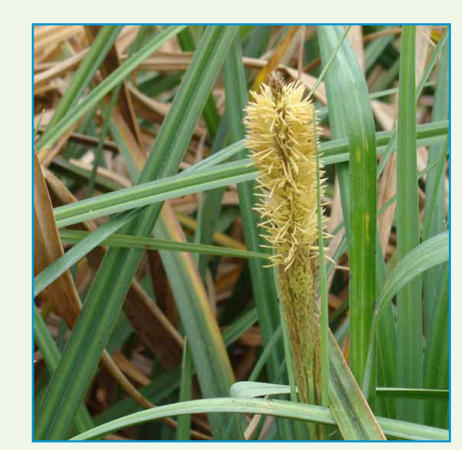
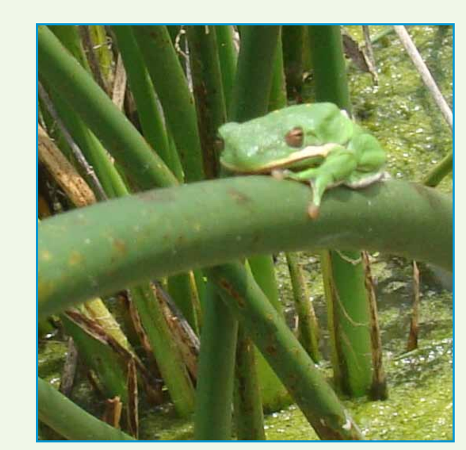
COMPLETE SYSTEM WILL BE ABOUT OF 2,500 ACRES AND WILL TREAT AN AVERAGE FLOW OF 91 MGD.

1992 2000 2003 2009 2011



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