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The Prairie Crossing Project: Attaining Water Quality and Stormwater Management Goals in A Conservation Development

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Written

Abstract

Relative to undeveloped lands, typical urban developments generate increased stormwater runoff rates and volumes, as well as associated contaminants. Sediments, heavy metals, fertilizers, de-icing materials, and many other chemical constituents are found in runoff from residential and commercial developments.

The Prairie Crossing project, a large residential development, has taken a series of measures to reduce runoff volumes and pollutant loads. These measures include source controls and integration of large-scale restored landscapes into the development to serve as the stormwater management system. The landscape stormwater management system is composed of upland prairie biofiltration, natural swale conveyance systems, wetlands, and a lake. Combined, these increase lag time, increase opportunities for pollutant removal through settling and biofiltration, and reduce the rate and volume of runoff through enhanced infiltration opportunities.

This paper is a preliminary and brief analysis of the expected water quality and stormwater management benefits provided by this project, designed as a "conservation development." Proposals are currently being prepared to monitor the project's water management benefits and performance.

Introduction

Typically, residential developments maximize the building density (for a given zoning classification) and incorporate potential open space into individual lots. Public open space is only provided where required by municipal ordinance for use as parks or for stormwater detention purposes. These lands usually are grassed and used for playgrounds, ball fields, and other active uses. Stormwater detention basins are usually grassed or rip-rap ringed open water areas used to temporarily detain stormwater.

Stormwater management for urban development is typically concerned only with the prevention of onsite and downstream flooding and the nuisance aspects of stormwater runoff. Consequently, stormwater systems consist of a storm sewer system to convey runoff to a detention basin. The sewer system eliminates the nuisance aspects of stormwater and detention basins control the very large stormwater runoff events from developments which would cause downstream flooding.

Historically, detention basins designed for flood control have provided only limited water quality improvement by capturing some suspended solids. This improvement has been incidental and only for storm events for which detention time is significant. Only recently have detention basins begun to be designed to provide water quality benefits in addition to flood control. However, this has created problems for wet detention basins also intended to serve as recreational and aesthetic amenities since accumulating sediments and nutrients cause hypereutrophic conditions.

This papers presents the stormwater management system developed for the Prairie Crossing project in Grayslake, Illinois. The Prairie Crossing system is designed to manage stormwater runoff rates,

and additionally, to improve stormwater quality and reduce runoff volumes. The project attempts to offer an alternative stormwater management system to conventional land development by using large, restored landscapes as a "stormwater treatment train system."

Background

Prairie Crossing occupies 667 acres in central Lake County, 40 miles northwest of Chicago, Illinois. The site has been farmed under an annual crop rotation and has deep silt and clay loam soils from glacial till parent materials. The land has been modified by drainage improvements including an extensive tile system, agricultural tillage for perhaps 150 years, herbicide and pesticide use since the 1950s, and the elimination of native biological communities.

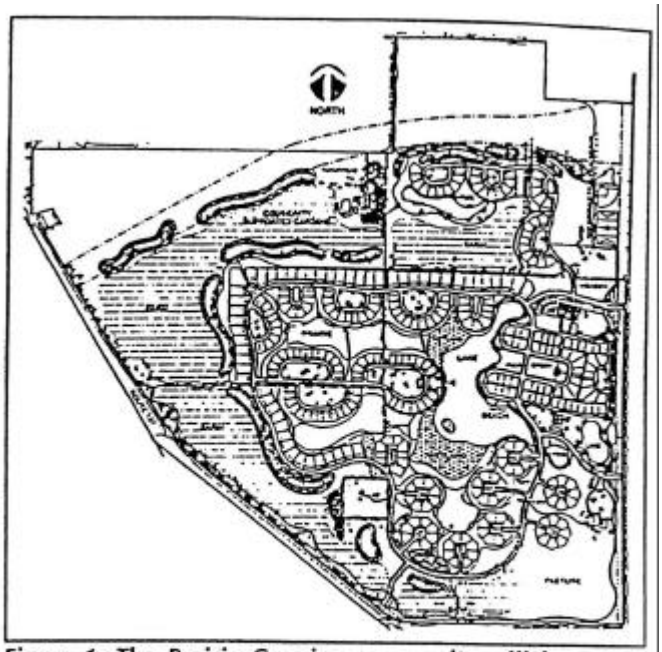

Figure 1. The Prairie Crossing community will have 317 single-family homes on 667 acres of gently rolling countryside. More than 350 acres are devoted to natural prairies, marshes, lakes, gardens, pastures, and farm fields.

The Prairie Crossing project will include 317 homes on 132 acres of the site with a high density "village center" and an outer area of cluster homes surrounded by open lands (Figure 1). The remainder of the site will be retained as open space and agricultural lands integrated with the residential development. The open space in and around the residential area is being restored to emulate historic functions and the aesthetics of presettlement prairies, wetlands, wet prairies, and savanna communities that occupied the site prior to and during the initial settlement by Indo-European immigrants in the 1830s. This restored landscape will provide a unique living environment for the residents of Prairie Crossing. The project includes the development of a 22-acre lake, 13 acres of wetlands and 160 acres of created prairies. An additional 150 acres of agricultural lands (protected by conservation easement held by The Conservation Fund) are integrated to protect the rural agricultural landscapes that, until recently, typified this area of Lake County.

Stormwater Management "Treatment Train System"

The open space in the Prairie Crossing project is designed to provide stormwater management functions of the project. The stormwater system has been designed as a treatment train with several components that each perform in sequence to treat the water before it enters the central lake and then leaves the site (Figure 2). Stormwater runoff from residential areas outside the village center is routed into swales planted with native prairie and wetland vegetation. These swales are the initial component of the treatment train and convey runoff from roadways and residential lots into expansive prairies while providing a modest amount of infiltration and settling of solids. The prairies are the second component of the treatment

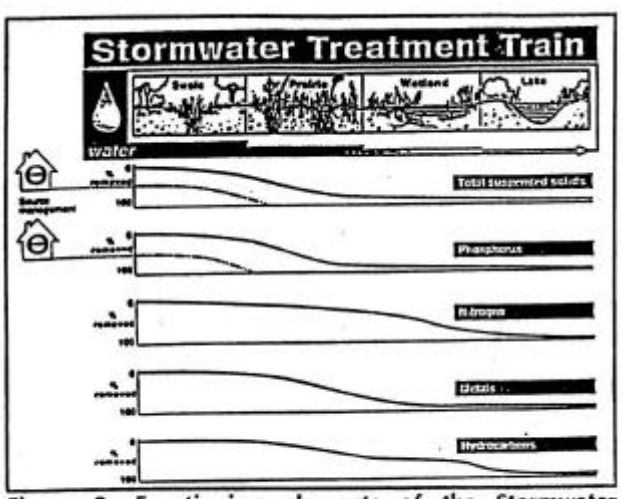

Figure 2. Functioning elements of the Stormwater Treatment Train and the anticipated general stormwater management and water quality benefits in each element.

train. The prairies slowly convey stormwater as diffuse overland flow to the wetland systems bordering the lake. The prairies are expected to infiltrate a substantial portion of the annual surface runoff volume due to their very deep root systems and provide for additional solids settling as well as biological treatment. The wetlands are the third component of the treatment system and provide both stormwater detention and biological treatment prior to the runoff entering the lake. The final treatment component is the lake. The lake will provide stormwater detention as well as further solids settling and biological treatment. The components of this stormwater treatment train management system are designed to treat the stormwater runoff and reduce the stormwater runoff peaks and volumes.

Landscape Management

Over 50 percent of the development will be native restored prairie and wetland landscape. This landscape requires minimum maintenance. Mowing will occur during the first several years of plant community establishment and then prescribed burning will replace mowing. Fertilizers will not be used in the prairies or wetlands. Herbicides will only be used by direct wick application to treat any target noxious weeds as may be required during the initial establishment years. Irrigation will not be required to establish or culture the native plant communities.

Effectiveness of the Stormwater Management Treatment Train©

The purpose of this paper is to present the Stormwater Treatment Train© concept as a viable method of managing stormwater that also provides an excellent living environment; not to present an exhaustive analysis of the effectiveness of the treatment train. The authors intend to collect hydrologic and water quality data over several years to better quantify those benefits. However, to provide some indication of the expected benefits of the Prairie Crossing treatment train, a preliminary analysis is presented here.

The potential effectiveness of the Stormwater Treatment Train© as applied to Prairie Crossing was estimated using published information (Schueler 1987, Horner et al. 1994, Moshiri 1993) regarding expected pollutant removal of the various treatment train components combined with continuous hydrologic modeling using HSPF (USEPA 1993). The hydrologic modeling was used to evaluate the influence of local climatic, soil, and site conditions that are difficult to account for based solely on published data.

Figure 3 illustrates the influence of the Prairie Crossing treatment train on the hydrology of the site. Figure 3 shows simulated hydrographs (using HSPF) for Prairie Crossing and for a more typical development with similar gross density. The hydrographs are for a typical summer. As can be seen from the figure, stormwater runoff volumes are reduced dramatically, particularly for smaller events. Prairie Crossing produces only minor rises in stormflow during smaller storm events while significantly increasing baseflows between events. Prairie Crossing produces larger increases in stormflow during large events. However, both the maximum daily flow and the storm event runoff volume are substantially reduced relative to a more typical development.

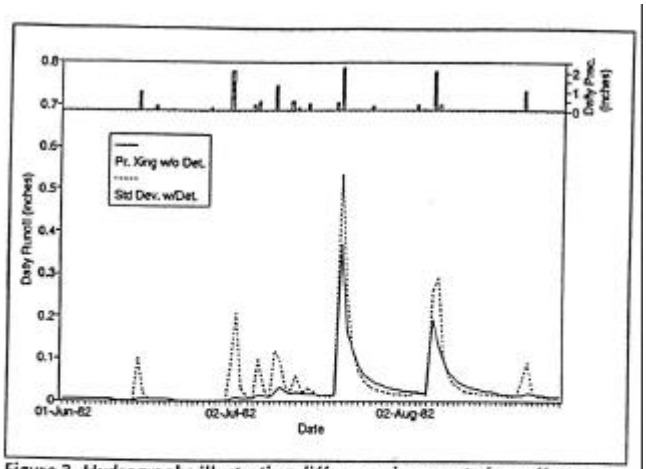

Figure 3. Hydrographs illustrating difference in expected runoff response between Prairie Crossing development and standard development of similar gross density. Prairie Crossing produces a more natural hydrograph with lower peak flows and higher baseflows relative to the hydrograph from the typical development. Even without detention, Prairie Crossing produces lower peak daily runoff rates and substantially lower event runoff volumes than standard developments with detention. The effect is particularly dramatic for smaller events and for events occurring after dry periods.

Overall, the modeling indicates that Prairie Crossing should produce average annual surface runoff volumes that are 65 percent less than a more typical development.

Table 1 presents the estimated annual pollutant removal effectiveness and runoff volume reduction of the individual components along with the cumulative removal rate of the treatment train. The values in the table assume that sediments, nitrogen, phosphorous, and metals that settle in the swales and prairies are removed from the system. Phosphorous and nitrogen that settle within the wetlands and lake are assumed to remain available to the nutrient cycle and not removed from the system. The table shows that only the swales and prairie filters reduce runoff volumes to any significant degree. Because of both settling and the significant runoff volume reduction, the prairie is expected to be quite effective in removing all of the constituents. The wetland and lake are expected to be quite effective in removing solids. However, because of nutrient cycling that occurs within these types of waterbodies, the expected removal rates for nutrients (particularly phosphorous) are not expected to be high.

Table 1: Estimated Effectiveness of Individual Treatment Train Components

Constituent	Percent Reduction				
	Swales	Prairies	Wetlands	Lake	Total
Surface Runoff Volume[1]	20%	55%	0	0	65%
Total Suspended Solids[2]	25%	80%	50%	80%	98%
Total Nitrogen	20%[3]	60%[3]	25%[4]	40%[4]	85%
Total Phosphorous	20%[3]	70%[3]	10%[4]	20%[4]	85%
Metals[3]	25%	75%	35%	60%	95%

[1] Based on HSPF modeling
[2] Based on removal rates suggested in "Fundamentals of Urban Runoff Management" (Horner et al., 1994) and "Controlling Urban Runoff" (Schueler, 1987) for Swale, Wetland and Lake. Work by Tollner (1975) on filter strips used for Prairie.
[3] Assumes that 25% of total nitrogen, 50% of total phosphorus, and 75% of metals are settlable and removed at same rate as total suspended solids and that soluble fractions are removed at same rate as surface runoff volume.
[4] Based on Moshiri (1993)

Table 2 shows the percent of the total site load leaving each of the treatment train components. The table shows that most of the constituents are expected to accumulate in the prairie, where they will be incorporated into the soil and thereby present little concern. The table also shows that only a small fraction of the total site load will enter or accumulate in the lake, significantly enhancing its ability to support recreational and aquatic life uses.

Table 2: Percent of Site Runoff Volume and Pollutant Load Leaving Treatment Train Components

Constituent	Percent Leaving Treatment Train Component[1]			
	Swales	Prairies	Wetlands	Lake
Surface Runoff Volume	80%	35%	35%	35%
Total Suspended Solids	75%	15%	8%	2%
Total Nitrogen	80%	30%	25%	15%
Total Phosphorous	80%	25%	20%	15%
Metals	75%	20%	10%	5%

[1] Based on removal rates in Table 1.

Water Quality Improvement Through Source Management

In addition to the Stormwater Treatment Train system in the Prairie Crossing project, the stormwater runoff quality will be enhanced through reduction strategies to manage the sources of pollutants. The project has many design features that specifically target enhancement opportunities with a focus on water quality. Key design features include the following:

1) Over 60 percent of the lake shorelines have very shallow water entry angles and a littoral vegetation zone. This will offer protection to shorelines and reduce shoreline destabilization from water-wave action and burrowing mammals; both of which contribute to in-lake sediment loading.

2) A strict development covenant and "Guidebook Living with Nature" articulate management policies governing open space and developed lots, the lake environment, roadways, and other aspects of the development. Example requirements include:

   a. Use of organic and osmocote slow release fertilizers applied twice per year on residential lawns at the most appropriate time for immediate assimilation by the cool season lawn grasses,
   b. Community composting facility associated with a community supported garden and agricultural programs will alleviate fly-dumping of landscape wastes, and
   c. Landscaping plans for residential yards which include extensive use of native wildflower plantings and other low maintenance vegetation systems.

3) Educational opportunities for residents to learn about the native landscapes, to infuse homeowners with a sense of place, encourage their support of environmentally-friendly living and stewardship, and to instill a self-policing system of covenant enforcement.

4) Employment of an environmental director to oversee all activities, to work closely with homeowners, to understand alternatives, and to implement land management.

Conclusions

The Prairie Crossing development is unique in northeastern Illinois and probably most other parts of the country. Although it utilizes concepts (namely cluster development and stormwater best management practices) that are not unique, it combines them into a management system that minimizes the need for stormwater structures, enhances the living environment, and minimizes the negative impacts of urban development. This not only reduces costs to the developer, but it also reduces maintenance costs such as catch basin cleaning and lake dredging for the municipality.

The created prairies will provide habitat heterogeneity and opportunities for a variety of plant species and communities to exist. They will also result in substantial reduction in stormwater runoff volumes and water quality enhancement. Based on published BMP effectiveness information and hydrologic modeling, the Prairie Crossing development is expected to reduce surface runoff volumes by 65 percent and reduce solids, nutrients, and heavy metals loads by 85 percent to nearly 100 percent. Source controls will minimize the impacts of the development even further. These removal rates will be verified, contingent upon funding, through site monitoring and further modeling calibrated to collected site data.

While most developments rely on detention basins to provide pollutant removal, much of the removal for the Prairie Crossing development is expected to occur within the prairie. This will

significantly enhance the lake/detention basin's ability to serve as a recreational and aesthetic amenity and reduce lake maintenance.

Acknowledgements

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