Stormwater Retrofit of Existing Detention Basins

NCD employee. Shows erosion of the stream channel.

Our current approach to conventional stormwater management often leads to unintended consequences. This is especially true in those communities where there is a high reliance on structural drainage systems and standard detention basins. Standard detention basins only focus on reducing the peak rate of runoff of post-development conditions to those of pre-development conditions. A significant drawback to this approach is that it encourages directly connected impervious areas as well as the use of structural drainage systems.

This case study focuses on a 2008 watershed plan prepared by Sean Hayden, Soil Scientist of the Northwest Conservation District (NCD) for Northfield Brook in northwest

Connecticut. Sean Hayden applied for and received Section 319 funding from the Connecticut Department of Energy and Environmental Protection to perform this Watershed Plan. This plan identified several issues that contributed to the impairment of water quality in Northfield Lake.

Northfield Brook is an impaired stream that flows south through the Northfield section of Litchfield into Thomaston where it creates Northfield Lake behind a flood control dam operated by the Department of Army Corps of Engineers (DOACE). The DOACE is experiencing problems of sediment build-up as well as elevated levels of nutrient concentration and bacteria within Northfield Lake. As a result of these water quality-degrading influences, the DOACE has been forced to close the swimming beach on the lake many times during most summers. The agency has even considered eliminating the pond altogether and allowing the stream to course through the project uncontrolled because of the unresolved water quality problems.

Inlet and outlet of small basin.

Identifying the problem

The watershed is approximately 4 miles long and 2 miles wide at the widest point between the headwaters of the watershed and the Northfield Flood Control Dam. The watershed above the Northfield Lake Dam is approximately 3,700 acres and has about 10 miles of associated perennial and intermittent streams. The area of Northfield Lake is eight acres. The dam was built in 1965 by the DOACE. Most of the watershed is

Sediment deposit in Northfield Lake.

forested, with the balance being agricultural and residential development. Agricultural land use is mostly pasture with hay fields being the dominant crop. Highwood Estates, consisting of 150 single-family residences on half-acre lots, is located just east of Northfield Lake. The subdivision is served by two detention basins which discharge into a tributary watercourse of Northfield Lake.

Regulatory rules required that the basins be designed to provide a zero increase in the peak rate of runoff for a twenty-five-year storm. In this part of Connecticut, the twenty-five-year event is defined at 5.7" of rain in a 24-hour period. During the watershed survey, Hayden determined that the basins were not functioning properly. The outlet control structures were very large, which resulted in both basins not detaining any runoff and thus no reduction in the peak rate of runoff was provided. The increased runoff rates and volumetric increases had a detrimental effect on the receiving stream system. The existing stream experienced significant erosion, which contributed to the deposition of approximately 2,000 cubic yards of eroded material into Northfield Lake. Hayden's assessment was confirmed by Trinkaus Engineering during a subsequent inspection of the basins.

Water Quality Status

Currently the Northfield Brook is on the Connecticut 2008 Impaired Waters List because at least one designated use cannot be supported, or at least one designated use is impaired. Its impairment is for recreational use because of excessive E. Coli concentrations.

The DOACE has been continuously sampling for E. Coli in Northfield Lake since 1995. The single sample maximum allowable E. coli concentration for a designated swimming area is 235 col/100ml. E. coli concentrations routinely exceed 235 col/100ml at the swimming area throughout most summers, resulting is frequent beach closures. Some samples have contained well over 1000 col/100ml.

The DOACE has also been sampling for total phosphorus (ug/l) in Northfield Lake since 1995. Lake water quality is quickly degraded with algae blooms when phosphorus concentrations exceed 20 ug/l. Lake water sampling indicates that total phosphorus concentrations regularly exceed 20 ug/l with a few lake water samples exceeding 50 ug/l. High phosphorus concentrations have been evidenced by serious algae bloom problems during the summer and early fall.

Design of Retrofits for Existing Stormwater Basins

The NCD applied for and received Section 319 funding from the Connecticut Department of Energy and Environmental Protection to address the impairment issues by hiring a consultant to design retrofits for the failing Highwood Estates stormwater basins. The goals of the retrofits were to increase the removal of coarse and fine sediments, on which E. coli is commonly attached, and to reduce peak rates of runoff.

While the Town of Thomaston owned the land surrounding both basins, the focus of the retrofits was to work within the existing footprint of the basins to develop a retrofit that would provide a practical solution, yet minimize the potential cost to the town of implementing the retrofits.

The first step, beginning in September 2009, was to inspect the basins in the field to observe the conditions in person. Due to the location of the inlet channel and the outlet control structure, flows were short-circuiting within the basin. The short-circuiting combined with the large outlet rendered this basin completely non-functional. Runoff quickly enters and leaves the basin, which provides neither reduction of the peak rate or any water quality treatment.

The forebay was designed above the existing basin with the inlet swale being redirected to direct runoff into the forebay before reaching the basin.

A survey with topographic information was obtained to provide the necessary base information for design purposes. After the survey was done, it was time to analyze the contributing watershed areas for each basin in order to design the retrofits.

Small Basin

The small basin has a 24.5-acre watershed area consisting of residential roads, half-acre single-family lots and an athletic field. The basin itself has a small, elliptical footprint with the outlet structure located at the northwest corner of the basin. Runoff is directed to the northeast corner of the basin by a riprap swale, which conveys the runoff from the road drainage system. Due to the proximity of the inlet and outlet, the flow of the runoff takes a direct path between the two points, rendering most of the basin useless.

The peak rate of runoff for a 2-year storm was modeled in HydroCAD. Approximately 30.09 cfs is directed to the basin during this storm event. In addition, the Water Quality Volume (WQV) as defined in the Connecticut Department of Environmental Protection (CT DEP) 2004 Stormwater Quality Manual was determined for the watershed. The WQV is calculated as follows:

$$WQV = (1") (A) (Rv)/12$$, where

$Rv = 0.05 + 0.009(I)$,

WQV = Water Quality Volume in acre-feet

A = Watershed area in acres

I = Percent impervious coverage in watershed area

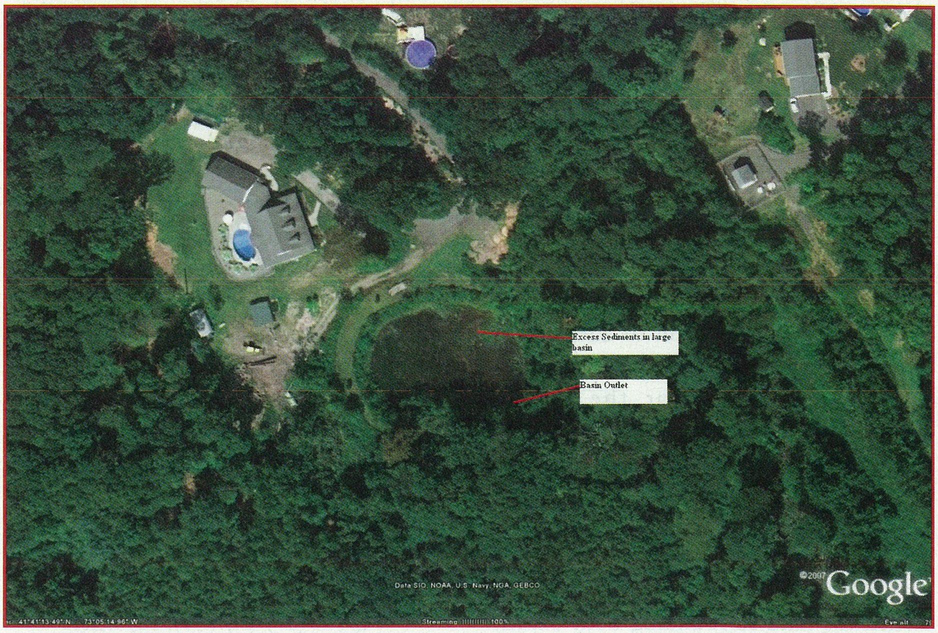
It is desirable to provide the required WQV as a fixed storage volume in order to provide adequate treatment of the runoff to reduce pollutant loads. In this case, a total of 35,278 cubic feet of storage volume would need to be provided to meet the required WQV.

Due to site and likely budget constraints, retrofit options were limited for this basin. A key part of the retrofit was the creation of a forebay to trap coarse sediments and encourage settling of fine sediments. The forebay was designed above the existing basin with the inlet swale being redirected to direct runoff into the forebay before reaching the basin. The forebay will provide 2,568 cubic feet of storage volume (7.3% of the WQV, although the goal was to have 10%). The forebay is slightly over four feet in depth, which will provide adequate storage volume for accumulated sediment as well as prevent resuspension of this material. The outlet from the forebay was directed to the southern end of the existing basin to provide the longest possible flow path within the basin. The forebay will be planted with wetland grasses to stabilize the earth slopes. As the forebay will always maintain a permanent pool, anaerobic conditions will exist where denitrification will occur.

As another retrofit option, consultants determined to excavate the basin to provide a single, deep pool feature six feet in depth. A vegetated, aquatic shelf is planned along the perimeter of the deep pool. The single outlet pipe will be replaced with a staged orifice outlet design to provide a slight reduction of the peak rate of runoff in the basin above the permanent pool. The peak rate of runoff for the 2-year event will be reduced slightly from 30.09 cfs to 28.87 cfs. While land area was available to enlarge the basin, this would have greatly increased the amount of excavation and therefore the cost.

The regraded basin and new forebay provide a total of 5,278 cubic feet of fixed additional volume for water quality purposes. This is approximately 15% of the calculated WQV, but is the maximum available based upon site limitations.

The Simple Method, developed by Tom Schueler, Executive Director of the Center for Watershed Protection was used to calculate the annual pollutant load for Total Suspended Solids (TSS), Total Phosphorous (TP), Total Nitrogen (TN), Zinc (Zn), and Total Petroleum Hydrocarbons (TPH). It was also used to evaluate the effectiveness of the retrofit design to reduce these pollutant loads. The result of this analysis is shown in Table 1.



Aerial view of large detention basin.

Small Basin					
	TSS	TP	TN	Zn	TPH
Current (lbs)	6872	29.2	215.9	17.3	163
With-Treatment (lbs)	302.6	17.2	57.6	0.2	18.6
% Removal	95.6	41.1	73.3	98.8	88.6

Table 1 - Results of Simple Method and Treatment System Evaluation.

Large Basin

The large basin has a 28.32-acre watershed area consisting of residential roads and half-acre single-family lots. The inlet swale enters this circular basin in the northeast corner while the outlet structure is located at the southeastern end. Similar to the small basin, short-circuiting of the basin occurs. The outlet control structure consists of a square 18" x 18" opening which does not provide any reduction in the peak rate of runoff. Approximately 8,500 cubic feet of storage is available below the invert of the outlet structure at the current time.

The peak rate of runoff for a 2-year storm was calculated. Approximately 30.66 cfs is directed to the basin during this storm event. In addition, the WQV was determined to be 41,810 cubic feet for this watershed.

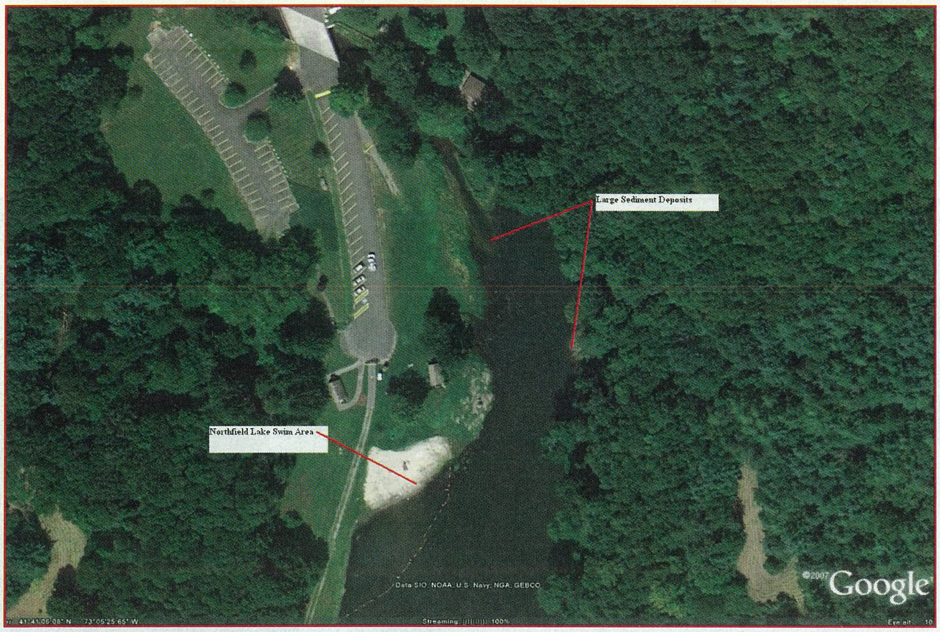
This basin is significantly larger so many more options were available as retrofits. After review of different stormwater basin configurations, creation of extended detention shallow wetlands to be used for detention was determined to be the best choice for the following reasons:

1. The bottom of the basin was large and flat which would facilitate the construction of deep and shallow marsh areas,
2. A shallow permanent pool already existed in the basin so the hydrology would be present for the marsh system,
3. The inlet could be reconfigured to create a long flow path between the inlet and outlet.

A large, separate forebay was designed above the existing basin on the north side. This forebay will be six feet in depth and provides a fixed storage volume of 5,285 cubic feet, which is 12.6% of the required WQV.

The flow from the existing inlet riprap swale will be directed into the forebay at the eastern end, with the outlet from the forebay being on the western end. A new riprap swale will direct runoff from the forebay to the northwest corner of the basin. A new 2.5' deep micro-pool will be placed at the end of the inlet swale. A second micro-pool 4.5' in depth will be created just before the existing outlet control structure. A low flow path will be created from the shallow micro-pool to the deeper one in a circuitous path.

The majority of the basin bottom will be planted with native wetland species, such as Coontail, Duckweed, Cattail, Soft-stem Bulrush and Sweet Flag to name a few to create a shallow marsh environment. Two areas will be raised by 6" to create high marsh areas, which will encourage a low, slow flow path for runoff within the basin as well as maximizing the contact



Aerial view of Northfield Lake.

Large Basin					
	TSS	TP	TN	Zn	TPH
Current (lbs)	8422	34.2	257.3	20.4	205.6
With-Treatment (lbs)	264.9	10.8	97	0.8	137.7
% Removal	96.9	68.4	62.3	96.1	33.0

Table 2 - Results of Simple Method and Treatment System Evaluation.

time between stormwater and the vegetation. A total of 17,996 cubic feet of fixed volume is provided between the forebay and permanent pool in the basin, which is approximately 43% of the required WQV.

The outlet structure was modified to create a staged orifice system. Due to the size of this basin, the 2-year peak rate of runoff will be reduced from 30.66 cfs to 5.00 cfs. This is a substantial reduction that will prevent the further erosion of the existing stream channel between the basin and Northfield Brook Lake.

Two areas will be raised by 6" to create high marsh areas, which will encourage a low, slow flow path for runoff within the basin as well as maximizing the contact time between stormwater and the vegetation.

A pollutant loading renovation analysis was also performed for this retrofit and the results are shown in Table 2.

By using a two-year rainfall event as the design basis for the retrofits, over 97% of the annual rainfall will be adequately treated by the retrofits, providing a large improvement in the water quality of the runoff, which will reach Northfield Lake.

After the retrofit designs were completed, approval was required from the Town of Thomaston Inland Wetlands Commission. An application was filed with the Commission to obtain approval of the retrofits. Sean Hayden prepared a presentation on the findings of the watershed study to provide the necessary background for designs. The Commission asked many questions concerning the water quality benefits that would be achieved by the retrofits and was pleased with the designs. The necessary approval by the Thomaston Inland Wetlands Commission was obtained in March of 2010.

Implementation

Due to municipal budget constraints brought on by the economic downturn, the Town of Thomaston does not have the necessary funds to implement these retrofits at the current time. On behalf of the town, NCD solicited bids from outside contractors to construct the basin retrofits. The costs to implement these retrofits were higher than expected, so the NCD has applied for additional 319 funding to facilitate the implementation of the retrofits.

Conclusion

The retrofits of these two stormwater basins will provide a measurable improvement to stormwater quality, which will ultimately reach Northfield Lake. In addition, the cost of implementing these retrofits by the Town of Thomaston was minimized by working with the natural conditions to the maximum extent possible.

The approaches and concepts used in these retrofits can easily apply to other stormwater basins to increase the benefits of old standard detention basins where expansion is feasible. **L&W**

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