City of Inver Grove Heights

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Northwest Quadrant Hydrologic & Hydraulic Analysis

February 27, 2004

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City of Inver Grove Heights
Northwest Quadrant Hydrologic & Hydraulic Analysis

EXECUTIVE SUMMARY

The geology of the City of Inver Grove Heights has resulted in closed basin drainage; that is, stormwater runoff flows to low areas that in most cases do not have outlets at normal water levels. Under existing conditions, water flows into these existing natural basins and leaves through a combination of seepage (infiltration) into the ground and evaporation. This is especially true of the Northwest Quadrant of the City. The issue facing the City is how to address stormwater management for the Northwest Quadrant under developed conditions. Approaches from previous studies have ranged between many areas remaining landlocked to expensive infrastructure, pumping systems and an outlet pipe to the Mississippi River.

Alternatively, to take advantage of the good soils and geologic conditions in the City, the City should adopt a stormwater management approach that minimizes connected impervious surfaces, increases flow path and time over pervious surfaces, and decentralizes treatment (smaller localized treatment as opposed to large-scale facility development) as a first measure of control. Once these measures have been implemented, excess water can be infiltrated in the numerous existing natural basins. A carefully planned and engineered approach that combines a number of alternative practices with infiltration would meet the City's goal. This infiltration approach would mimic and utilize the natural conditions of the Northwest Quadrant rather than simply collect and dispose of runoff to the Mississippi River.

To this end, an open-space corridor was defined to benefit both the natural resources of the area and protect the existing natural stormwater management capabilities of the Northwest Quadrant. This open-space corridor and the resulting preliminary land use concept developed in coordination with City staff and Hoisington Koegler Group, Inc. allow for an overall development density consistent with the City's 2020 Comprehensive Plan, while providing additional aesthetic and stormwater management value. An XP-SWMM model was developed to simulate both existing conditions and the preliminary land use concept for proposed conditions to determine if any of the subwatersheds in the Northwest Quadrant are subject to undesirable water levels for the critical 100-year event. This analysis looked at a number of rainfall events in evaluating the ability of an alternative stormwater management plan to mimic the natural hydrology of the system.

The finalized modeling results indicate that implementation of the proposed alternative stormwater management plan and preliminary land use concept would allow the Northwest Quadrant to be developed as a closed system. As long as proper sequencing of construction and system monitoring is conducted, the cost of implementation and maintenance should be similar to conventional systems at the local scale. At the regional scale, given that a conventional system would need a large outlet project, this proposed self-contained stormwater management system should be much more cost effective.

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INTRODUCTION

Background

The Northwest Quadrant of Inver Grove Heights, an over 2,000 acre area, is identified in the City's 2020 Comprehensive Plan for development into low density residential, high density residential, industrial office park, mixed use, and park and open space. The City previously retained a team of consultants to assist a Citizens' Task Force in the analysis of alternative development scenarios to reduce required storm sewer system infrastructure. The preliminary conclusion of this *Northwest Quadrant Study* (Hoisington Koegler Group, Inc., September 2001) was that a sustainable drainage system could be designed to minimize storm sewer infrastructure by using density transfers and stormwater management techniques designed to reduce runoff.

The next step outlined in the *Northwest Quadrant Study* was to perform an analysis of a Pilot Study Area with an event-based model approach to test the worst-case scenario. To complete this analysis, the City retained EOR to develop a hydrologic/hydraulic model for existing conditions and an alternative development scenario for a Pilot Study Area covering 340 acres within the Northwest Quadrant. The Pilot Study Area is bound by 70th Street on the north, Highway 55 on the south, Roberts Trail on the east, and Argenta Trail on the west. The main conclusion of the modeling effort for the Pilot Study Area was that it is possible to develop the area as a closed system. Results of this effort are summarized in the *Northwest Quadrant - Pilot Study Area Hydrologic & Hydraulic Analysis* (EOR, November 22, 2002).

This report, for the entire Northwest Quadrant (Figure 1), is an expansion of the original Pilot Study effort. Utilizing existing conditions and an alternative land development pattern, EOR conducted an event-based analysis of the entire Northwest Quadrant (except areas within the Gun Club Lake WMO) to determine the feasibility of developing this area in a manner similar to the land development pattern developed by the Hoisington Koegler Group, Inc. for the Pilot Study Area.

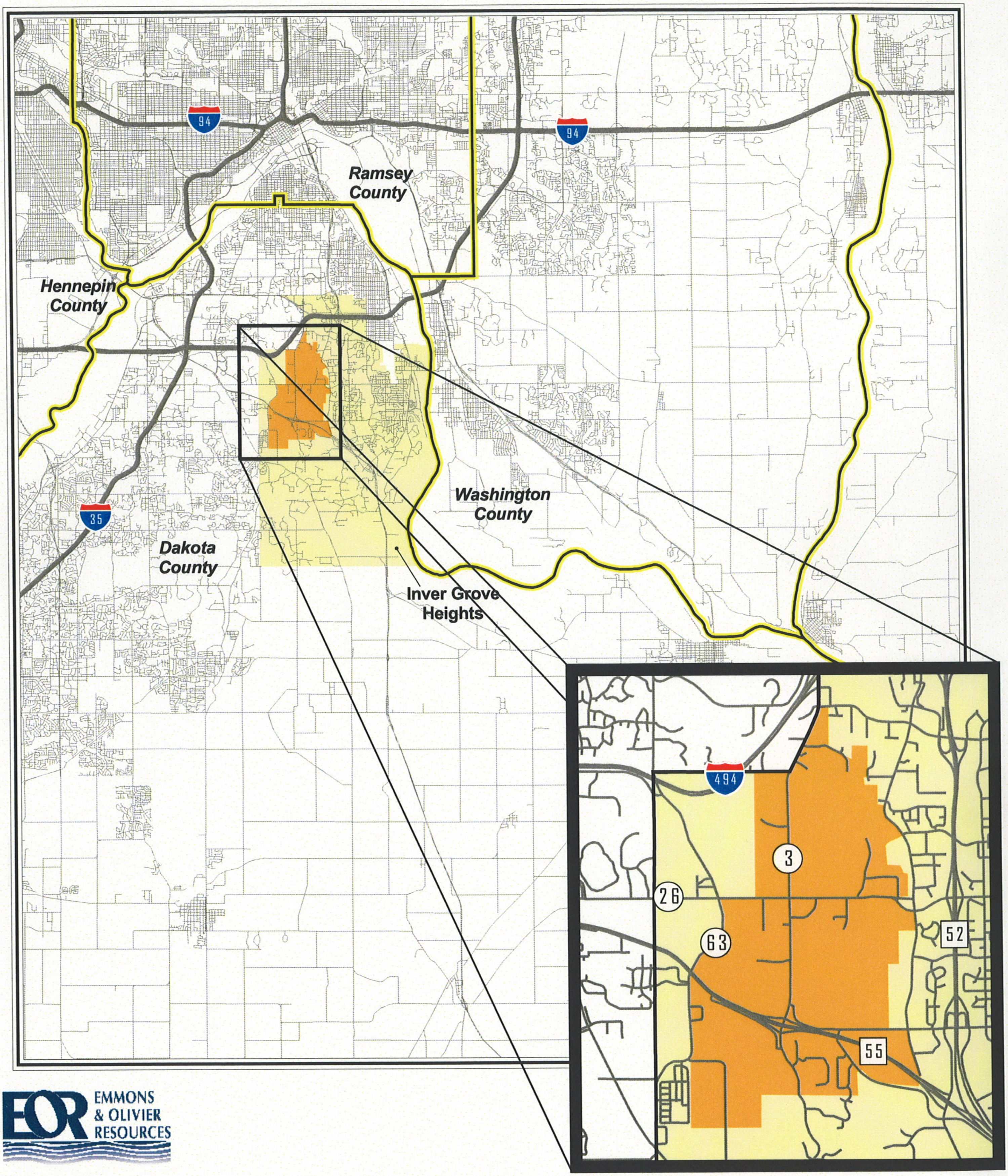
Project Goals

This study assesses the feasibility of developing the Northwest Quadrant utilizing an alternative stormwater management system that maintains the area as a closed system (no outlet), identifies any undesirable water levels realized for the critical 100-year event (under existing and proposed conditions), proposes solutions to address these water level issues, and defines operation and maintenance considerations for the alternative stormwater best management practices proposed.

To address these goals, an event-based model was developed for the Northwest Quadrant using XP-SWMM2000 to evaluate the system under existing and proposed conditions. As defined for this study, the critical 100-year event analysis did not consider shorter duration events (less than 24-hours) which represent greater intensities but less rainfall amounts which would not typically be critical in a volume-sensitive system such as this area.

Northwest Quadrant - Hydrologic & Hydraulic Analysis

Fig. 1 Location Map



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Alternative Stormwater Management

In the not too distant past, the goal of an urban drainage system was to rush water away as fast as possible into a receiving stream or nearby lake or wetland. When it became evident that this was not a sustainable water management practice, the approach changed to the routing of water into detention ponds. Although many of these ponds were designed according to EPA's Nationwide Urban Runoff Program (NURP) criteria based on 1980s studies, they too have some deficiencies in effective treatment and management of runoff.

Today, we have learned that there are better ways to treat runoff water which is to let it soak into the ground as close to its source as possible and mimic the natural hydrology of the system. In fact, soaking in every drop of precipitation where it falls is a good goal to strive for. This not only limits the volume and rate of runoff that occurs, it also eliminates the migration of polluting material that is picked up by runoff as it flows over urban surfaces. Infiltration also replenishes critical ground water supplies that are used as drinking water sources. So called "alternative" runoff management practices merely seek to mimic the way precipitation would behave without human intervention; that is, it attempts to soak water into the ground as if the land's surface did not have impervious surfaces. In this respect, the practices are an alternative to the collect and concentrate approaches from the past. The environmental benefits of this approach include reduced wetland and open space impact, potential regulatory credits (suitable for NPDES Phase II, TMDLs, and watershed/local stormwater planning), reduced runoff and erosion, closer to natural water infiltration/recharge, reduced negative upland habitat impact (ex. trees), enhanced public awareness, and the opportunity for retrofitting into existing developed areas.

The issue facing Inver Grove Heights is that the geology of the City has resulted in closed basin drainage; that is, flow moves to low areas that in most cases do not have outlets at normal water levels. Water flows into these basins and leaves through a combination of seepage (infiltration) into the ground and evaporation.

To take advantage of the good soils and geologic conditions in the City, the City should adopt a stormwater management approach that minimizes connected impervious surfaces, increases flow path and time over pervious surfaces, and decentralizes treatment (smaller localized treatment as opposed to large-scale facility development) as a first measure of control. Once these measures have been implemented as standard practice, an approach can be explored for collection and further treatment of excess water in the numerous existing natural basins. A carefully planned and engineered approach that combines a number of alternative practices with infiltration would meet the City's goal. This infiltration approach would mimic the natural condition rather than simply collect and dispose of runoff.

Alternative stormwater management practices provide measures for the City to reduce the overall volume of water draining to the closed basins, thus reducing the possibility that levels will rise and threaten surrounding property. The best potential for these practices is infiltration of water close to the location where the precipitation deposits it. Next, protecting the numerous natural basins that collect water in large events and allow it to infiltrate is important. Infiltrating this water mimics the natural system that existed prior to development.

The on-site controls approach tends to be more economical because there is less or no need to build expensive, artificial storage facilities designed for large events. Development can also be designed to minimize or eliminate curbs, gutters, wide roadways, and the inlets/outlets and pipes that must accompany all of these features. Rather, this approach is flexible in its application from use on a lot-by-lot basis to entire portions of a community. In places where water level fluctuation can cause problems, any mix of alternative and traditional uses is possible.

It is important to keep in mind that storm and melt events sometimes occur in excess of the ability of any management practice to treat. To avoid an expensive catastrophe, some consideration should be made for control of greatly excessive flows. Alternative management techniques typically do not use single-event designs (ex. 100-year frequency) like traditional systems that handle big events while disregarding routine/frequent events. This approach means that routine small events will not be "over-drained" as they would be in a traditional big conveyance system. Although alternative techniques try to match the natural hydrologic function as close to normal as possible, they would also be linked to the natural basins preserved and intended to continue to be utilized for infiltration of runoff. This will allow for routine treatment of small and moderate events, but also provides the added protection for large-scale flooding events.

This approach provides an ecologically friendly means to mitigate the impact that development brings to the water cycle. It integrates hydrologic function into site design and conserves natural resources and open space. Specific benefits of this approach are:

- Preservation of open space;
- Minimization of land disturbance;
- Protection of natural systems and processes, and incorporation of natural site elements into the hydrologic design;
- Customization of infrastructure to each site rather than uniform design;
- Decentralization of runoff collection;
- Management of surface water at its source; and
- Groundwater / aquifer recharge.

The list of practices included under the term "alternative" is extensive. Applications of special interest to Inver Grove Heights because of its need to reduce volume flowing to closed basins should focus on infiltration. Subsequent sections of this report identify and utilize infiltration raingardens as a primary practice to focus upon. However, other infiltration practices could include but are not limited to vegetated swales, parking lot bioretention, infiltration trenches/basins, and disconnection of impervious surfaces (ex. diverted roof leaders, rain barrels, permeable pavement).

SOILS & GROUNDWATER ANALYSIS

Determining that the site is suitable for the construction and management of stormwater management practices designed to reduce runoff (e.g. infiltration basins and raingardens) is critical in ensuring their success. Therefore, an analysis of the soils and surficial geology was performed to characterize the naturally occurring permeable material as well as the depth to the groundwater table. In addition, this information was used to assign infiltration rates to each basin in the study area.

Bedrock Geology

The bedrock in the Northwest Quadrant of Inver Grove Heights is typical of the bedrock found in most parts of the Twin Cities. From top to bottom, the bedrock formations are:

- Platteville-Glenwood Formations
- Saint Peter Sandstone
- Prairie du Chien Dolomite
- Jordan Sandstone
- St. Lawrence Shale/Sandstone
- Franconia Sandstone
- Ironton/Galesville Sandstone
- Eau Claire Sandstone
- Mount Simon/Hinckley Sandstone
- Precambrian Formations

Some of these bedrock layers are significant water supply aquifers, while others are considered to be confining layers. A detailed discussion of the properties of each layer can be found in several publications, including the groundwater model report developed for the City of Inver Grove Heights by Otto Strack (1993).

Within the majority of the Northwest Quadrant, the uppermost bedrock is the St. Peter Sandstone (Mossler, 1990). There is also a small area of the Platteville-Glenwood Formation in the far north portion of the study area. The St. Peter Sandstone is a massively bedded water-bearing sandstone. The St. Peter Sandstone is an important regional water supply, providing some of the drinking water supply to the City of Inver Grove Heights.

Surficial (Glacial) Geology

Existing geologic maps characterize the project area as having till, outwash, and ice contact stratified deposits associated with the Superior Lobe (Cromwell Formation) and Des Moines Lobe (New Ulm Formation) deposits.

The till is characterized by Wright, 1970, as: *"Chiefly sandy loam-textured, unsorted sediment (diamicton); pebbles, cobbles, and boulders; silty sand to cobbly gravel lenses are commonly present. Commonly overlain by 2 to 5 feet (0.6 to 1.5 m) of loess. Includes small areas of dark loamy to sandy colluvium in small depressions".*

The ice-contact deposits are not as wide-spread as the till, and are described by Wright, 1970, as: *"Sand, gravelly sand, and cobbly gravel; commonly includes interbeds of, and in places is capped by, sandy to loamy diamicton (mudflow sediment) and silt (lake sediment). Some deposits contain boulders. Many of the ice-contact deposits were laid down as deltas by meltwater entering ice-walled lakes. Other deposits were laid down along the courses (eskers) or at the mouths (kames) of subglacial streams".*

The outwash is only in the southwest portion of the study area and it is characterized by Mayer and Patterson, 1997, as: *"Sand, gravelly sand, and gravel. Deposited by meltwater issuing from the glacial ice margin at or near its maximum advance. Includes common to abundant clasts of Superior provenance eroded from older sediment; these clasts are generally more abundant to the north. Shale is absent to fairly common. Commonly capped by a mantle of loess less than 4 feet (1.3 m) thick".*

This background information indicates that the surficial geology can vary substantially over short distances. Generally, outwash and ice contact deposits exhibit high infiltration potential. Till deposits can have varying infiltration potential ranging from very low to very high, depending on the nature of the material and sand content. Soil borings or other site investigations are typically necessary to accurately characterize site conditions.

Site Geology

EOR staff conducted a field investigation of the soils, surficial geology and depth to water table for 9 basins within the study area. Existing data was compiled for the study area including soils and geologic data, wetland maps, subwatershed characteristics, topography and aerial photography. Surface water subwatersheds were investigated to determine the location, extent, and hydrologic characteristics of each basin.

Soils work was also completed as part of the *Northwest Quadrant - Pilot Study Area Hydrologic & Hydraulic Analysis* conducted in 2002. Three basins were investigated in an effort to determine the soil characteristics of wet and dry basins. Results of that study indicated that the soils at dry basins typically consisted of sand and gravel deposits while the soils at the wet basins typically had lower permeability soils in the bottom of the depression but yet surrounded by higher permeability soils.

The field investigation completed for the Northwest Quadrant Hydrologic & Hydraulic Analysis builds on the data collected as part of the Pilot Study. Each subwatershed was first classified into categories based on soils type - sand content and the presence of a wet or dry basin. Surficial geology and soils data were used to classify each subwatershed based on sand content. Two categories were developed, the first having a higher percentage of sand content than the second. The soils identified as having a higher percentage of sand included outwash and ice contact deposits. Less sandy soil types consist of till. Each subwatershed was then classified as containing a wet or dry basin, based on available aerial photography and wetland maps. Combining the soil and basin type resulted in four possible subwatershed classifications as summarized in Table 1.

Table 1. Subwatershed Classification

Subwatershed Classification	Soil type	Basin type
I	Less Sandy	Wet
II	Sandy	Wet
III	Less sandy	Dry
IV	Sandy	Dry

Figure 2 summarizes the results of the subwatershed analysis. From this analysis, six representative basins were chosen for additional field investigation including basins within the following subwatersheds:

- EP-066a (Type III);
- EP-059a (Type I);
- BP-036 (Type II);
- EP-025a (Type IV);
- BP-039a (Type III); and
- EP-027a (Type I).

In addition to the data collected at these six sites, data was available from the Pilot Study Area for basins located within the following subwatersheds:

- 7 (Type I);
- 17 (Type IV); and
- 6 (Type I).

Soil borings were advanced at each of the basins using a hand auger. These locations are identified on Figure 3. For those basins which contained ponded water, one boring was advanced as near to the water surface as possible and a second was advanced upslope of the water surface. One soil boring was advanced at the bottom of each dry basin. Soil boring logs are found in Appendix A.

Dry Basins. One soil boring was advanced at each of the 4 dry basins identified in Figure 2 within subwatersheds 17, BP-039a, EP-066a and EP-025a. Each of the basins was dry at the time of the field investigation. Soil borings were taken at the bottom of the basin in order to characterize the soils through which runoff is infiltrating.

The soils encountered were variable and included medium grained sand and gravel, silty sand, sand loam and silt loam. All of the encountered soils are consistent with the designated subwatershed soil type of sandy or less sandy, assigned above. Water was not encountered in any of the borings.

Wet Basins. Two soil borings were advanced at each of the 5 identified wet basins within subwatersheds including, 6, 7, BP-036, EP-027a and EP-059a. One boring was advanced adjacent to the existing water in the basin and a second was advanced approximately 10 feet away from the basin and 2-4 feet higher in elevation. These borings were used to identify and map the extent of any low permeability soils present in wet basins and the presence of a continuous water table. EP-027a was dry at the time of the field investigation given the below average late summer / fall rainfall received.

The soils encountered were variable and included silt, sand and clay loams, silty and sandy clays, and lenses of sand. All of the soils encountered were consistent with the designated subwatershed type of sandy or less sandy, as assigned above.

The water table was measured between 2 and 2.7 feet below the basins except at EP-066a where no water was encountered. None of the water levels measured at the time of the field investigation was an indication of the regional water table.

Review of Existing Groundwater Modeling Efforts

A review of existing groundwater modeling efforts was completed as part of the Pilot Study. None of the existing efforts were determined to be applicable to this study. Additional information is available within the *Northwest Quadrant - Pilot Study Area Hydrologic & Hydraulic Analysis* (EOR, November 22, 2002). No additional modeling efforts have been conducted for this area.

Infiltration Potential

There is high potential for stormwater infiltration in this area to play a key role in stormwater management based on the soils data collected as part of this study and interpretation of regional geologic and soils maps. Previous work conducted by EOR on infiltration processes in similar geologic and topographic settings in the Metro Area has identified a range of infiltration rates between 0.02 and 0.32 inches per hour for less sandy soils and 0.12 and 0.60 inches per hour for sandy soils. These infiltration rates have been measured as part of a seven year study on natural infiltration basins with ponded water at depths less than five feet in southern Washington County.

There is potential that infiltration enhancements such as infiltration trenches could increase the infiltration rate at all basins. Trenches have the ability to bypass impermeable layers beneath basins or low permeability soil layers, allowing for water to infiltrate into more permeable materials.

Proposed Basin Infiltration Rates. Conservative soil infiltration rates were assigned to each subwatershed type and applied across the entire study area. A single infiltration rate is assigned to basins identified as dry, while two infiltration rates are assigned to wet basins. Wet basins are less permeable in the bottom, where water has ponded historically. Soils data supports that higher permeable materials typically surrounds the low permeability materials, forming an outer ring. A higher infiltration rate is applied to the area within this ring, comparable to the infiltration rate applied over a dry basin with similar soil types.

Table 2 summarizes the assigned basin infiltration rates applied as a function of depth (for both existing and proposed condition models) for each subwatershed type.

Table 2. Infiltration Rates

Subwatershed Type	Depth in the Basin	Infiltration Rate
Type I: Wet basins in less sandy soils	0 to 4 feet	0.07 in/hr
	4+ feet	0.30 in/hr
Type II: Wet basins in sandy soils	0 to 4 feet	0.07 in/hr
	4+ feet	0.50 in/hr
Type III: Dry basins in less sandy soils	any	0.30 in/hr
Type IV: Dry basins in sandy soils	any	0.50 in/hr

References

Meyer, G.N. and C.J. Patterson. 1997. Surficial Geology of the Anoka 30x60 Minute Quadrangle, Minnesota: Minnesota Geological Survey Miscellaneous Map Series M-97, scale 1:100,000, W93°00'–92°00'/N45°30'–45°00' [electronic file].

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Strack, O.D.L., 1993. A Multi-Layer Analytic Element Groundwater Model for the City of Inver Grove Heights. Department of Civil and Mineral Engineering, University of Minnesota.

Wright, H.E., Jr., L.A. Mattson,, and J.A. Thomas. 1970. Geology of the Cloquet Quadrangle, Carlton County, Minnesota: Minnesota Geological Survey Geologic Map Series GM-3, 30 p., W92°30'-92°22'30"/N46°45'-46°37'30" [single printed sheet].

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Fig. 2 Geomorphic Subwatershed Classifications

Legend

- Subwatershed Boundaries
- Lakes
- Wetlands

Subwatershed Classifications

- I - Wet Basins, Less Sandy Soil
- II - Wet Basin, Sandy Soil
- III - Dry Basin, Less Sandy Soil
- IV - Dry Basin, Sandy Soil
- ★ Representative Subwatersheds

2000 0 2000 Feet

N E S W

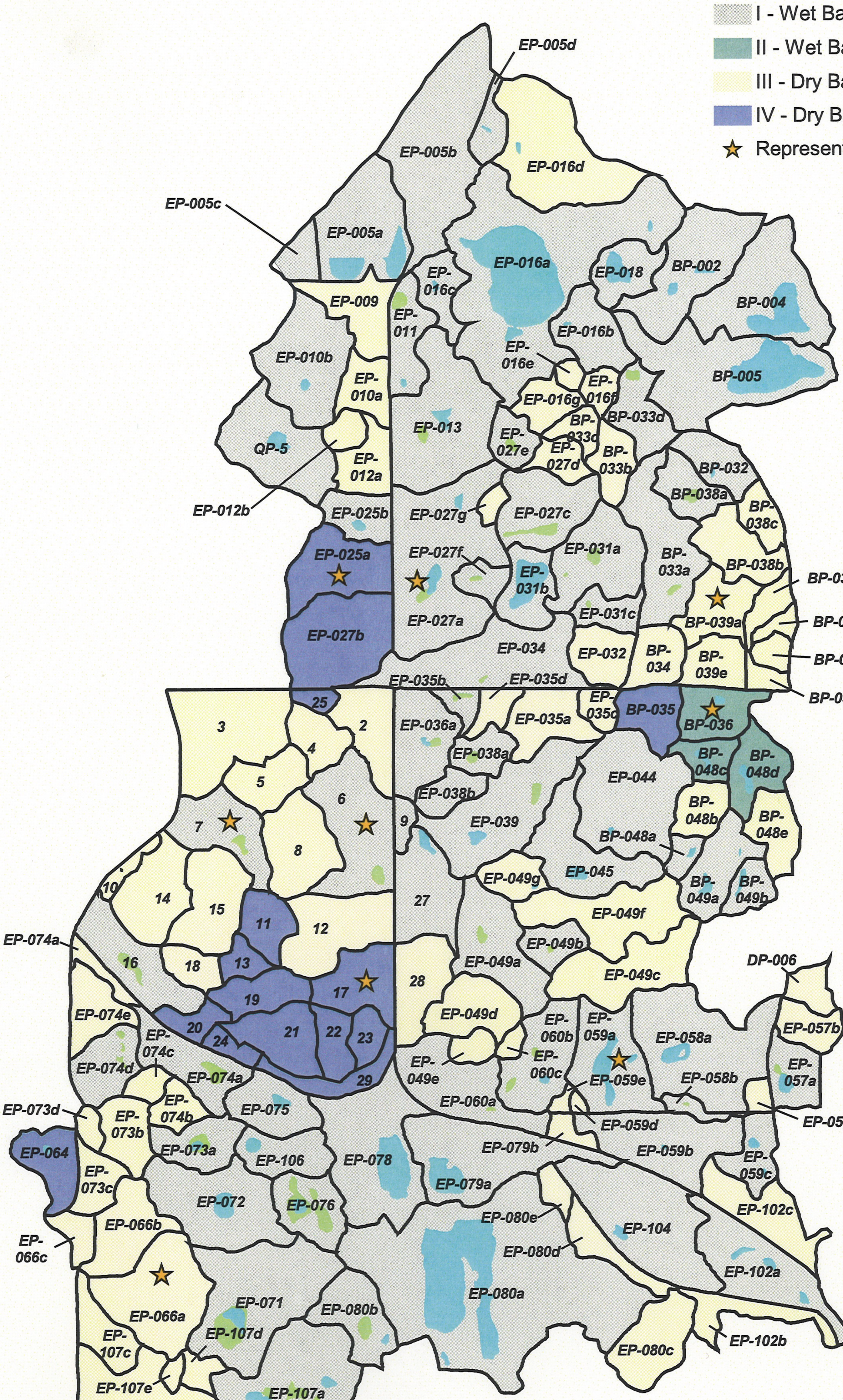

Figure 2

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Fig. 3 Soil Borings and Monitored Basins

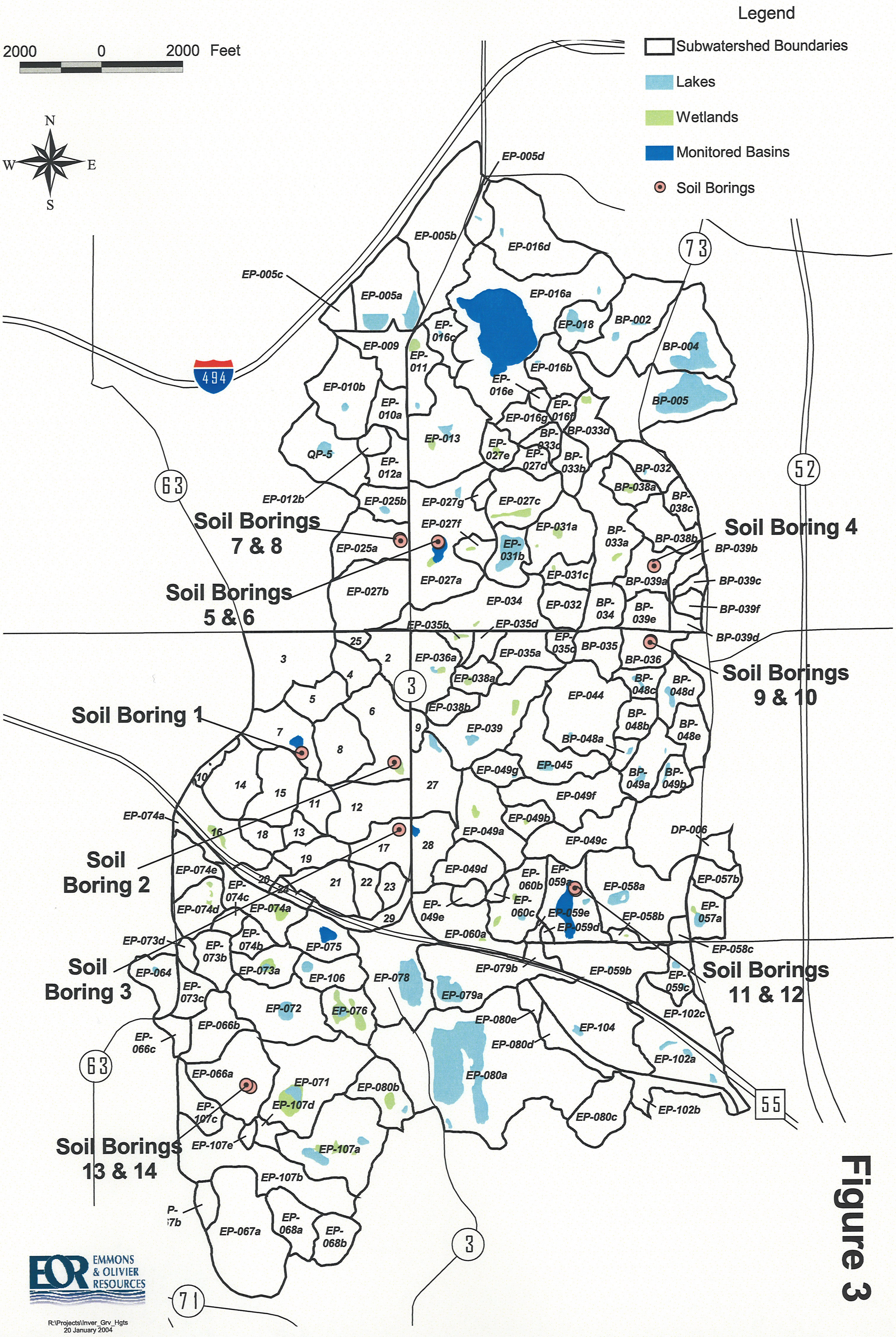

Figure 3

HYDROLOGIC & HYDRAULIC ANALYSIS

The surface water model of the Northwest Quadrant was developed using XP-SWMM2000, the latest user-friendly version of the USEPA SWMM model. The watershed tributary to the Northwest Quadrant is approximately 2,830 acres and includes the northern 3 basins of the Marcott Chain of Lakes. Topography varies greatly within the Northwest Quadrant with nearly all of the subwatersheds acting as self-contained (landlocked) basins under existing conditions.

Existing studies, topographic data, and modeling efforts were collected and reviewed and a field reconnaissance was conducted to locate primary culverts and fill in any other hydraulic routing gaps. The following sections summarize the information used to develop the model, modeling methodology and modeling results.

Model Input References

The following information was utilized in the development of subwatershed boundaries, hydrologic input (runoff generation) parameters and hydraulic network (runoff routing) for the Northwest Quadrant XP-SWMM2000 existing and proposed condition models:

- GIS layers of existing land cover, culvert inventory, steep slopes, waterbodies, and 2-ft contours (City of Inver Grove Heights)
- Minnesota Land Cover Classification System (MLCCS) GIS data and proposed greenway corridor (Dakota County SWCD)
- Inver Grove Heights Expanded Northwest Area Preliminary Land Use Concept (Hoisington Koegler Group, Inc.)
- USDA Dakota County Soil Survey
- City of Inver Grove Heights Water Resource Management Plan (Barr, October 1994)
- The Minnesota Geological Survey (MGS) surficial geology maps including: 1) Meyer, G. and Lusardi, B., 2000. "Surficial Geology of the St. Paul 30 x 60 Minute Quadrangle, Minnesota." Minnesota Geological Survey Map M-106, and 2) Hobbs, H., S. Aranow, and C.J. Patterson, 1990. "Dakota County Geologic Atlas, Surficial Geology." Minnesota Geological Survey, County Atlas Series, Atlas C-6
- MN/DOT Highway 55 Construction Plans for stormsewer, slope stabilization, and turf establishment (December 11, 1998)
- Inver Grove Heights Natural Wetland Resource Inventory Report (Bonestroo, October 2003)
- Daily rainfall and temperature data was obtained from the Climatology Working Group (State Climatology Office – DNR Waters, Extension Climatology Office – MES, and Academic Climatology – University of Minnesota) for the Minneapolis-St. Paul Airport. In addition, tipping bucket rainfall data from the City of Inver Grove Heights – City Hall rain gage was also obtained for the spring of 2002
- Wildwood Ranch Estates Grading Plans (James R. Hill, August 2003)
- Existing and proposed watershed boundaries for the Pilot Study Area was previously obtained from David Pitt of the Landscape Architecture Program, UMN

Field Reconnaissance

In addition to the resources listed above, field reconnaissance was conducted to verify subwatershed boundaries and outlets, collect soil boring at 9 basins, and collect water levels at 6 basins.

Subwatershed Boundaries. For areas within City limits, 2-foot topographic mapping was utilized to delineate subwatershed boundaries. Given that USGS 10-foot quadrangle maps was the best information available for areas tributary to but outside of City limits, these subwatershed boundaries were field checked to verify delineation accuracy.

Subwatershed Outlets. Culvert information from the City's GIS layer and Water Resources Management Plan was supplemented by a survey of subwatershed outlets. Based on review of topographic mapping and aerial photos, subwatersheds suspected of having culvert outlets were identified and field inspected for potentially undocumented culverts. Table 3 summarizes subwatersheds in the Northwest Quadrant with culvert outlets.

Table 3. Subwatershed – Culvert Outlets

Subwatershed	Culvert Size	Culvert Type	Invert Elevation*
BP-036	18-inch	RCP	926
EP-005a	13-inch x 16-inch	CMPA	925.5
EP-005b	15-inch	CMP	912
EP-010a	24-inch	RCP	None Observed
EP-011	24-inch	RCP	892
EP-016d	24-inch	CMP	907
EP-025a	24-inch	CMP	880
EP-027b	24-inch	RCP	894
EP-035a	24-inch	CMP	886
EP-035d	21-inch x 27-inch	Oval CMP	870
EP-058c	15-inch	CMP	936
EP-059b	24-inch	CMP	904
EP-059e	15-inch	CMP	912
EP-074f	21-inch	RCP	885
EP-078	24-inch	RCP	808
EP-079a	24-inch	RCP	810
EP-080a	15-inch	CMP	801
EP-080d	24-inch	RCP	902
EP-102c	36-inch	RCP	922
SB-20	18-inch	RCP	871
SB-24	18-inch	RCP	855
SB-29	24-inch	RCP	849
SP-28	36-inch	RCP	834
SP-3	12-inch	CMP	917.5

* Elevation sources include 2-foot contours if culvert is at basin bottom or lake NWL, City Water Resources Management Plan and Mn/DOT Hwy 55 Plans.

Note that the culverts serving as outlets for Basin EP-025a and Basin EP-079a are partially obstructed by trees and vegetation, therefore the culvert diameter in the model has been reduced to account for this flow obstruction. Basin EP-025a's outlet has been modeled as a 22-inch CMP, and Basin EP-079a's outlet has been modeled as a 21-inch RCP. Also note that the 24-inch RCP from Basin EP-010a to Basin EP-013 was not observed. The landowner recollected that there was once a culvert at this location, but that it has since been buried and non-functional for a number of years. This suspect culvert was not included in the model, therefore, simulated high water levels would be artificially high if maintenance on the suspect culvert is completed.

Soil Borings. A number of soil borings were collected within the Northwest Quadrant in order to better characterize soil types and infiltration rates to be expected. This information is discussed in detail in the previous Soil & Groundwater Analysis section of the report.

Basin Monitoring. A number of site visits were previously made to the Pilot Study Area to collect information which could be used to calibrate the model. The field data was collected for three basins (6, 7 and 17) as identified on Figure 3 in order to determine:

1. Existing and estimated high water levels on June 26, 2002 following a 3.35-inch rainfall event that fell over 5.3 hours (which occurred on June 21, 2002). These elevations and observed water surface elevation draw-down were later used to provide a preliminary calibration of the existing conditions model runoff and to estimate basin infiltration rates to be used for both existing and proposed conditions.

2. Ordinary High Water levels (OHW's) and ages and elevations of older trees. The OHW's were estimated using the methodology established by the Minnesota Department of Natural Resources. This process involved surveying trees and hydrologic features on the perimeter of the wetland (approximately 9 to 10 points were surveyed per wetland). The measured elevations were used to determine an approximate relative elevation of the ordinary high water level and historic high water levels of each basin. The estimated OHW's and older trees ranged from 4 to 6 feet above the basin bottoms, yet remained well below the overflow elevation of the basins.

These basins were selected because they represent the range of basin types located in the Pilot Study Area. This range of basin types includes shallow open water wetlands (Existing Basin 6), seasonally flooded wetlands (Existing Basin 7), and dry basins not exhibiting wetland indicators (Existing Basin 17).

Additional water level monitoring was conducted at several representative basins in the Northwest Quadrant and continuously-recording monitoring equipment was installed at two basins to supplement manual readings at all monitored basins. Due to the unusually dry summer and fall, the monitoring data collected was determined not to be representative of a typical year and will not be used for advanced calibration purposes. The soils, geology, vegetation and borings found in the basins during field investigations were however sufficiently similar to the Pilot Study Area that it was reasonable to extrapolate the monitoring results to the entire Northwest Quadrant. Therefore, calibration of the model for the entire Northwest Quadrant is based on the calibration of the Pilot Study area.

Methodology

As previously mentioned, the surface water model of the Northwest Quadrant was developed using XP-SWMM2000. The hydraulic calculations of XP-SWMM2000 include the full dynamic flow equations and the capacity to generate runoff and route flows for continuous flow simulations. The Northwest Quadrant is subdivided into 184 subwatersheds based on depressions with six or more vertical feet of storage. This was a significant effort including more subwatersheds than initially anticipated but was it felt that the additional detail was needed to accurately simulate the system.

Land-Use & Percent Impervious. Existing land use consists mainly of low to medium density residential, forest, tall grass and agriculture. Percent imperviousness for existing conditions is based on the Minnesota Land Cover Classification System (MLCCS) GIS data provided by the Dakota County SWCD.

The existing Comprehensive Plan was reviewed with City staff and Hoisington Koegler Group to develop a simplified alternative development plan based on principals used in Pilot Study Area. As a result of this effort, a concept open-space corridor was drafted based on existing natural depressions and the Draft Natural Wetland Resources Inventory (Bonestroo, 2003). With the concept open-space corridor in mind, Hoisington Koegler Group developed an alternative preliminary land use concept (Figure 4) consistent with the City's overall density for the Northwest Quadrant. This alternative preliminary land use concept is the basis for the proposed conditions land-use and percent imperviousness.

Runoff Methodology. The Green-Ampt Infiltration methodology within the runoff mode of XP-SWMM was used to simulate the infiltration of rainfall since this method is set up to function with continuous simulations and because this method has physically based parameters that can be predicted using existing data and previous studies. Application of the Green-Ampt equation within XP-SWMM requires definition of three parameters:

1. Initial soil moisture deficit - This parameter is an estimate of the antecedent soil moisture conditions, which affect the initial soil infiltration rate. This parameter becomes important for accurate estimation of infiltration during simulation of a single event or for initial storms of a continuous simulation.

2. Soil capillary suction - This parameter influences the movement of a wetting front through the soil profile. Estimation of this value influences the initial soil infiltration rate (during the early stage of a storm event), but loses impact over time.

3. Saturated hydraulic conductivity - This parameter estimates the rate of water movement through a saturated soil profile and represents the most variable component of the Green-Ampt equation. For this reason, it is also the best parameter to use for infiltration calibration. This is the most significant of the three parameters needed and ultimately drives the saturated infiltration rate. Estimation of this parameter is also (indirectly) responsible for the rate at which the soil moisture content is recovered after a storm event.

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Fig. 4 Preliminary Land Use Concept

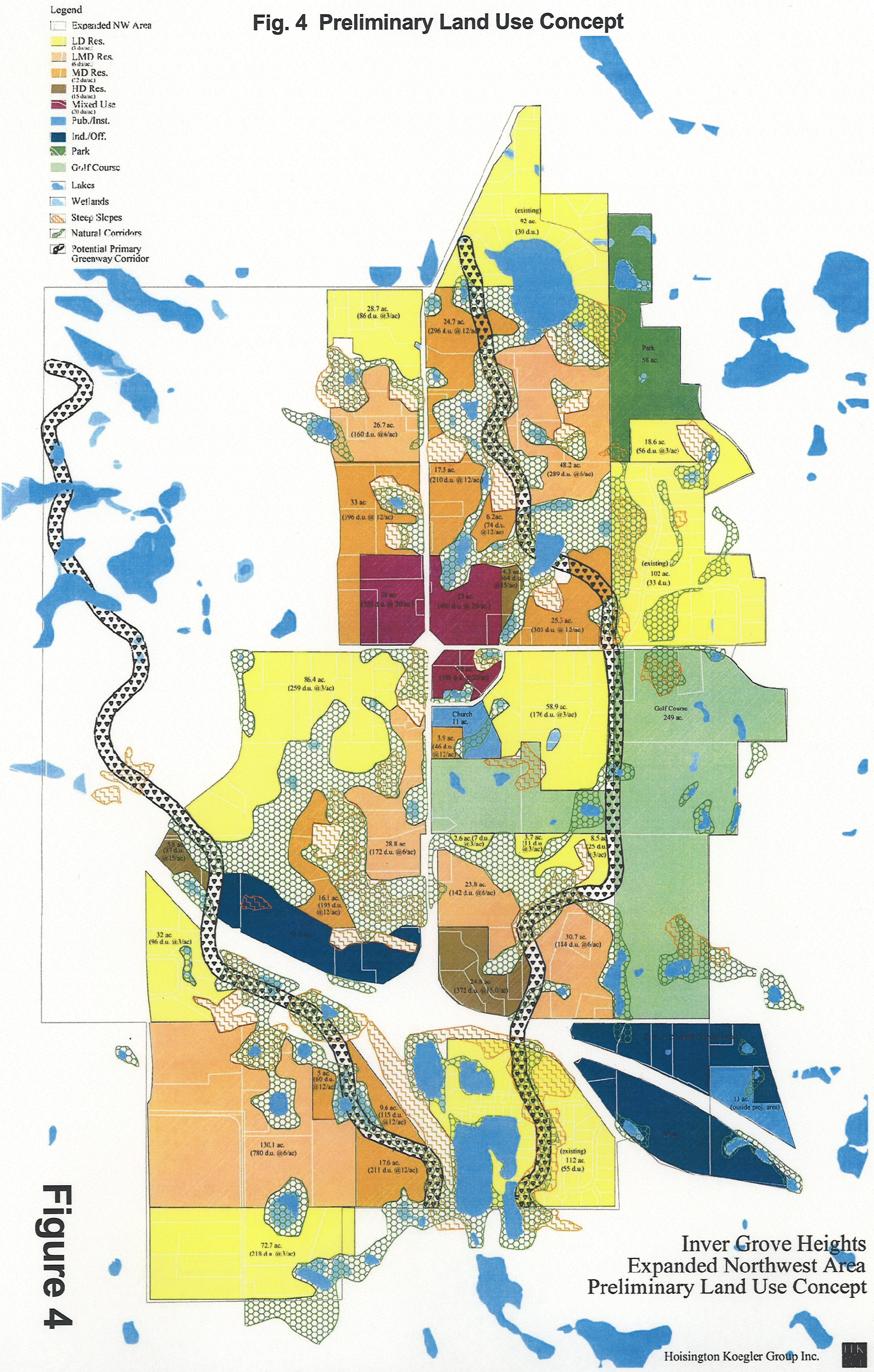

Figure 4

Initial values for these three parameters were assigned to each of the three USDA soil texture groups (Loamy Sand, Sandy Loam, and Silty Loam) within the Northwest Quadrant Area based on values recommended by XP-SWMM. Unique composite values for these parameters were developed for each subwatershed based on a soil-type weighted average.

Basin Storage. For existing conditions, basin stage-storage curves were developed from 2-foot topographic mapping. Storage under proposed conditions was modified from existing conditions to take into account grading activities. For subwatersheds proposed for development (areas other than the concept open-space corridor, existing residential areas, golf course and park) it was assumed that the existing basins have been eliminated and no longer available for stormwater management. It is unlikely that all of these basins will be eliminated during the development process. However, to error on the conservative side, it is assumed that these areas will develop to the maximum extent possible with reliance only on local onsite raingardens and then the existing regional basins (encompassed by the open-space corridor).

Basin Infiltration Rates. Rating curves were developed to simulate the infiltration capacity of the basins at different depths via the field observations (drawdown) in the Pilot Study Area for Basin 7 following a 3.35 inch rainfall event and via the defined subwatershed type. Further discussion of subwatershed type classification and applied infiltration rates is found under the previous Soil & Groundwater Analysis section of the report. For convenience, the applied infiltration rates applied as a function of depth are also listed below:

Subwatershed Type	Depth in the Basin	Infiltration Rate
Type I: Wet basins in less sandy soils	0 to 4 feet	0.07 in/hr
	4+ feet	0.30 in/hr
Type II: Wet basins in sandy soils	0 to 4 feet	0.07 in/hr
	4+ feet	0.50 in/hr
Type III: Dry basins in less sandy soils	any	0.30 in/hr
Type IV: Dry basins in sandy soils	any	0.50 in/hr

Evaporation. To account for water budget losses due to evaporation, mean monthly evaporation (inches) was used from the USDA SCS Hydrology Guide for Minnesota.

Preliminary Model Calibration. To provide accurate modeling results, calibration must be performed. The existing conditions model for the Pilot Study Area was calibrated using water levels staked and surveyed in the field following a 3.35-inch rainfall event (which occurred on June 21, 2002). These elevations and observed drawdown rates were used to calibrate the model by modifying input parameters to match existing conditions.

The calibrated hydraulic conductivities used in the model are well below published values because the Green-Ampt method does not account for slope of the topography and vegetative cover when calculating runoff volumes. Using the high water levels staked in the field, the hydraulic conductivities were lowered to more accurately model the system under existing conditions. As previously mentioned, this is the basis for preliminary calibration of the entire Northwest Quadrant as well.

Rainfall Events. Modeled rainfall events fall under two major categories 1) synthetic rainfall curves (SCS Type II) and 2) recorded rainfall.

Synthetic rainfall events modeled for the Northwest Quadrant include the 1-year 24-hour rainfall event, the 5-year 24-hour rainfall event, the 100-year 24-hour rainfall event, the 100-year 10-day rainfall event and the back-to-back 100-year 24-hour event. The back-to-back 100-year 24-hour event simulates two consecutive days with 100-year rainfall events. The SCS Type II distribution is the standard synthetic rainfall distribution used in this region.

Actual rainfall data was previously obtained from the Minneapolis-St. Paul Airport and used to run a continuous rainfall simulation for the Pilot Study Area from 1982 to 1987. The time period of 1982 to 1987 was selected for continuous simulation from the last 30 years of rainfall record since this represents the longest period of above average annual rainfall and contains the largest single event of record (9.15 inches on July 23, 1987), which significantly exceeds the 100-year 24-hour event of 7.2 inches of rain. Review of the result for the Pilot Study Area under proposed conditions for this continuous event demonstrated that all the major depressions recover from the precipitation events and do not continue to have rising water levels through this period. This is significant since back-to-back storms and extended wet periods could be a concern in this type of drainage system. Given the observed recovery of the basins in the Pilot Study Area, this continuous event was not run for the entire Northwest Quadrant. However, per the request of City Staff the back-to-back 100-year 24-hour rainfall event was modeled.

Snowmelt Runoff Event. The 100-year snowmelt runoff event is simulated by a 7.2 inch, 10-day spring runoff event. During snowmelt simulations, it is often assumed that the ground is frozen solid and that no infiltration occurs. In reality, there is usually some infiltration that occurs (even on frozen ground). The soils ability to infiltrate under frozen conditions is largely dependent upon the antecedent soil moisture conditions at the time of the initial freeze and the soils texture. If soil moisture is low when freeze occurs, soil pore spaces can be preserved. The most restrictive conditions occur if the soils freeze saturated, thereby forming a hardpan that does not allow infiltration. In either case, ground conditions are typically thawing over the 10-day simulation period with increasing infiltration rates over the period of the runoff simulation.

Given this reality, two snowmelt event scenarios were modeled. The first assumes that the ground is completely frozen (no infiltration) and is referred to as the worst-case scenario. The other scenario is that infiltration to a limited extent occurs during snowmelt. To simulate a semi-frozen ground, the infiltration rates were reduced to 20 percent of their unfrozen rates.

Modeling Results

An XP-SWMM model was developed for both existing and proposed conditions to determine if any of the subwatersheds in the Northwest Quadrant are subject to undesirable water levels for the critical 100-year event. During this analysis it became evident that the development of a system that mimics existing conditions (by incorporating volume control practices) requires an evaluation of multiple events. While the system should be designed for the worst case scenario, it should also be designed and managed so that the Best Management Practices will operate effectively for the smaller rainfall events (e.g. the 5-year 24-hour rainfall event) as well as the 100-year 24-hour rainfall event.

As a result this analysis looks at a number of rainfall events in evaluating the ability of Best Management Practices to mimic the natural hydrology of the system. These rainfall events include the 1-year 24-hour rainfall event (2.4"), the 5-year 24-hour rainfall event (3.6"), the 100-year 24-hour rainfall event (6.0"), the back-to-back 100-year 24-hour rainfall event (12.0"), the 100-year 10-day rainfall event (10.9") and the 100-year 10-day snowmelt/runoff event (7.2"). Shorter duration events represent greater intensities but less rainfall amounts which would not typically be critical in a volume-sensitive system such as this area.

Figures 5 and 6 illustrate the Northwest Quadrant under existing and proposed conditions. For consistency with the Pilot Study the same subwatershed identification numbers were used for this core area while the remainder of the Northwest Quadrant utilizes subwatershed identification numbers consistent with the City's Water Resources Management Plan.

Identification of Worst Case Scenario. A number of single larger events were modeled to determine the critical event for each subwatershed in the system. These events include the 100-year 24-hour rainfall event (6.0"), the 100-year 10-day rainfall event (10.9") and the 100-year 10-day runoff/snowmelt event (7.2"). In addition, the back-to-back 100-year 24-hour rainfall event (12.0") was also modeled. The results for each scenario under existing and proposed conditions are presented in Tables 5 and 6.

In evaluating the worst case scenario for both existing and proposed conditions, the 100-year 10-day runoff/snowmelt event is modeled with no infiltration and no depressional storage (raingardens). This is a very conservative estimate of the volume of runoff being generated for the event and assumes that of the 7.2 inches of runoff is completely delivered to the system. That is, all of the runoff is routed through the system without infiltration losses.

As Tables 5 and 6 indicate the critical event for the majority of the subwatersheds under existing and proposed conditions is the 100-year snowmelt runoff event (7.2 inches in 10 days). In those cases where the 100-year 24-hour high water level is equal to or slightly above the high water level for the 10-day runoff event, the difference is not considered to be significant enough to clearly demonstrate that the critical event is not the 10-day snowmelt event. Larger differences between these events are due to the inability of existing small culverts to handle the quick delivery of runoff produced by the 24-hour event. Conversely, the culverts are capable of handling the slow delivery of water in the 10-day event. The results in Tables 5 and 6 indicate that overall the system is "volume driven" and the critical flooding event is in almost all cases the 100-year 10-day snowmelt/runoff event.

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Fig. 5 Subwatershed Boundaries - Existing Conditions

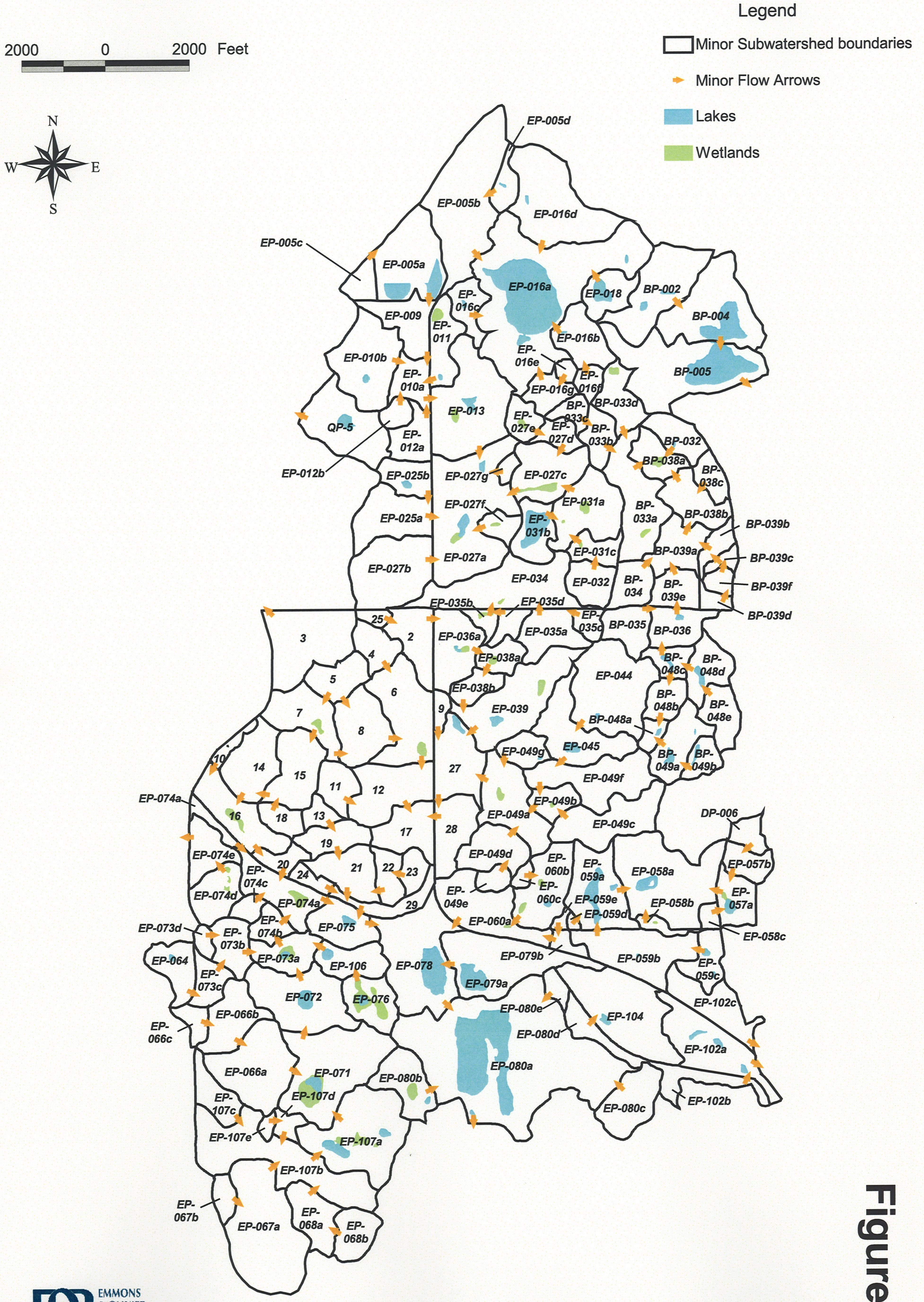

Figure 5

EMMONS & OLIVIER RESOURCES

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20 January 2004

Northwest Quadrant Study- Hydrologic & Hydraulic Analysis

Fig. 6 Subwatershed Boundaries - Proposed Conditions

Legend

- Minor Subwatershed boundaries
- Minor Flow Arrows
- Lakes
- Wetlands

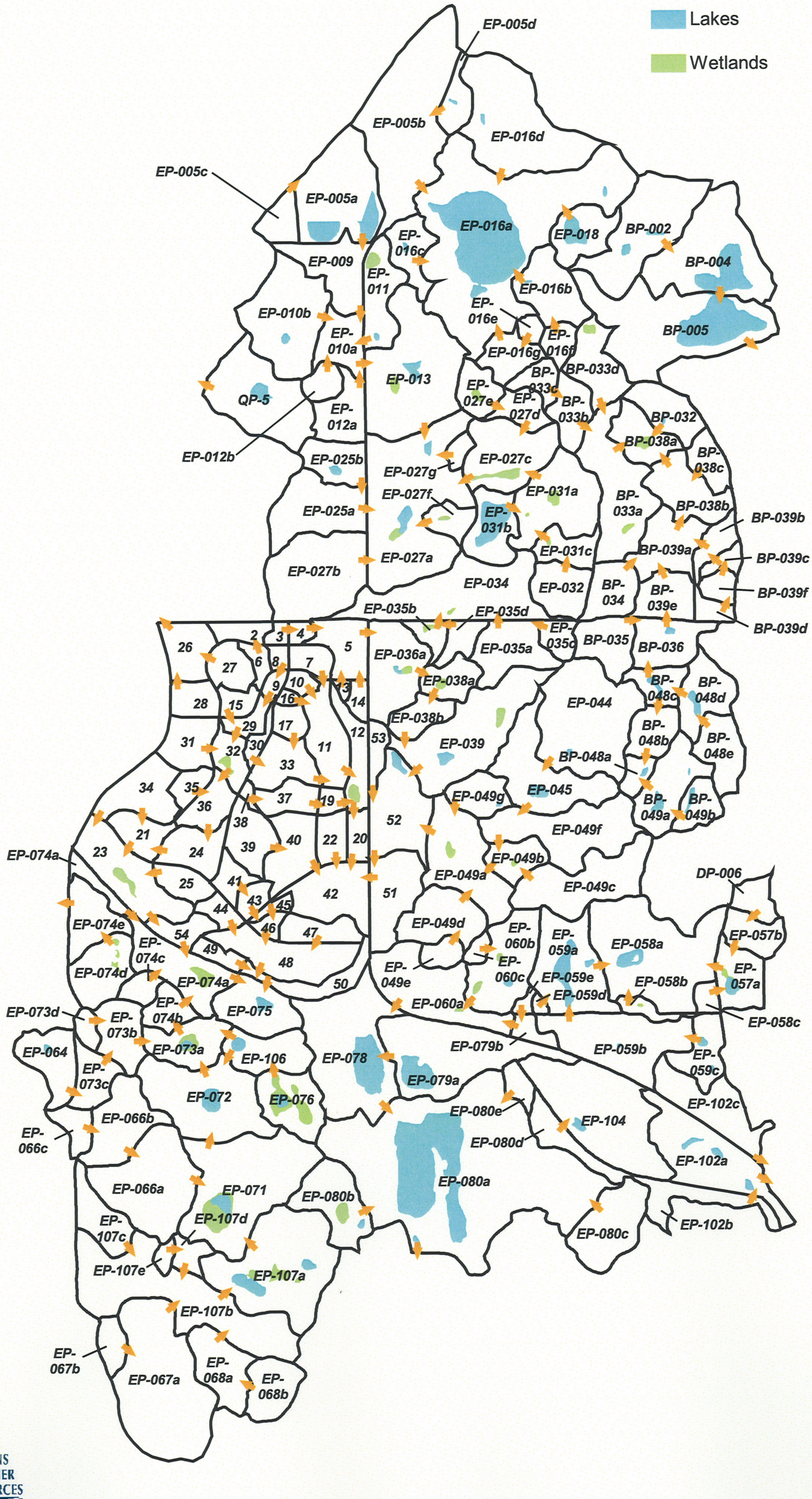

Figure 6

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Table 5. XP-SWMM Results for Large Storm Events under Existing Conditions

Basin ID EXISTING Conditions	Starting Water Elevation [feet]	Existing HWL 100-year 24-hr Rainfall event (6.0") [feet]	Existing HWL 100-year 10-Day Rainfall event (10.9") [feet]	Existing HWL 100-year 10-Day Runoff event (7.2") [feet]	Existing HWL 100-year 10-Day Runoff event without raingarden storage or infiltration (7.2") [feet]	Existing HWL back-to-back 100-year 24-hr Rainfall event (12.0") [feet]
BP-002	933	938.6	937.8	940.4	941.0	940.3
BP-004	911	912.3	912.2	912.3	912.4	912.9
BP-005	911	912.1	912.0	912.1	912.1	912.5
BP-032	891	895.5	892.6	900.0	900.6	897.8
BP-033a	913	921.1	918.7	923.6	924.2	922.6
BP-033b	929	933.9	929.7	938.7	939.2	935.8
BP-033c	943	947.3	944.5	949.6	950.2	948.3
BP-033d	943	949.9	945.9	953.2	953.7	951.7
BP-034	913	916.1	914.6	917.6	918.2	917.1
BP-035	917	921.6	917.8	926.2	927.4	923.4
BP-036	923	931.1	926.6	926.7	926.7	931.1
BP-038a	887	892.5	890.7	895.7	896.7	895.1
BP-038b	901	910.1	908.1	912.5	913.0	911.8
BP-038c	919	922.5	921.3	924.1	924.7	923.8
BP-039a	909	912.1	910.7	914.8	915.8	913.8
BP-039b	927	931.6	929.6	933.0	933.1	933.2
BP-039c	933	937.2	936.4	937.1	937.1	937.3
BP-039d	945	949.5	947.8	951.6	952.2	950.9
BP-039e	909	917.9	915.3	922.3	923.0	921.1
BP-039f	933	938.6	936.7	939.2	939.2	939.5
BP-048a	927	928.7	927.0	930.7	931.4	929.6
BP-048b	925	927.9	925.0	930.6	931.2	929.0
BP-048c	943	944.6	943.5	946.7	946.9	945.8
BP-048d	943	944.9	943.2	947.6	948.2	946.3
BP-048e	939	943.1	941.8	944.9	945.6	944.9
BP-049a	925	927.6	925.7	929.9	930.4	929.0
BP-049b	943	945.4	943.8	947.6	948.0	946.8
DP-006	937	941.6	939.3	944.2	944.8	943.0
EP-005a	924.9	925.5	925.2	925.7	925.7	925.9
EP-005b	912	915.6	915.1	915.1	915.1	915.6
EP-005c	924	929.3	927.6	931.3	931.9	930.9
EP-005d	953	955.8	954.9	957.4	957.8	957.0
EP-009	889	899.0	894.7	899.3	899.3	900.0
EP-010a	877	886.2	881.2	896.4	899.0	892.5
EP-010b	898	904.7	900.7	907.1	907.1	907.1
EP-011	883	889.8	886.6	896.4	899.1	892.5
EP-012a	909	912.6	910.4	914.9	915.1	913.8
EP-012b	923	928.6	926.3	930.6	931.2	930.0
EP-013	851	858.2	854.5	863.4	865.0	861.0
EP-016a	903	904.7	904.1	906.8	907.1	906.3
EP-016b	901	906.2	902.1	909.0	909.1	908.1
EP-016c	907	910.7	909.4	913.0	913.5	912.2
EP-016d	907	915.3	909.4	910.9	910.9	915.3
EP-016e	943	944.4	943.0	945.5	946.2	944.7
EP-016f	945	947.6	945.6	949.8	950.5	948.5
EP-016g	925	930.2	927.0	933.4	934.0	931.7
EP-018	935	935.5	935.1	935.2	935.2	935.5
EP-025a	879	886.5	880.7	881.7	881.7	886.5
EP-025b	897	900.0	898.1	903.4	903.9	901.9
EP-027a	847	853.6	849.2	859.3	860.2	856.9
EP-027b	891	895.7	893.9	895.0	895.0	896.4
EP-027c	888	890.7	889.2	893.0	893.0	892.2
EP-027d	923	926.8	923.3	929.7	930.4	928.0
EP-027e	941	944.9	944.4	946.8	947.2	946.9
EP-027f	849	851.2	849.0	853.9	854.6	852.0
EP-027g	903	905.1	903.0	906.2	907.0	905.4
EP-031a	875	881.0	876.4	886.4	886.9	883.7
EP-031b	901	901.7	901.4	902.4	902.5	902.3
EP-031c	897	903.5	900.5	906.8	907.4	905.6
EP-032	891	895.7	892.6	899.4	900.0	897.6
EP-034	849	859.2	855.2	864.9	865.7	862.2
EP-035a	885	889.2	886.3	886.9	887.0	889.2
EP-035b	853	857.7	855.8	864.0	864.9	861.5
EP-035c	931	934.2	932.2	935.1	935.1	935.1
EP-035d	869	871.2	870.2	870.3	870.3	871.2
EP-036a	861	866.1	865.1	868.6	869.4	867.9
EP-038a	867	872.0	870.5	872.1	872.1	872.4
EP-038b	867	872.6	870.3	874.8	875.4	874.0
EP-039	847	852.4	848.1	857.4	858.0	854.7
EP-044	885	890.5	886.0	895.0	895.1	892.6
EP-045	879	881.9	879.5	885.4	886.6	883.8
EP-049a	840	844.3	841.9	848.6	849.5	846.1
EP-049b	859	864.3	860.8	869.2	870.8	866.4
EP-049c	899	907.5	902.0	912.3	912.9	910.2
EP-049d	871	877.0	874.2	879.0	879.1	878.8
EP-049e	903	905.3	904.1	906.5	907.2	906.1
EP-049f	873	879.0	875.3	883.0	883.0	881.3
EP-049g	877	882.0	878.8	883.1	883.1	883.2
EP-057a	919	920.9	919.7	922.6	923.3	922.0
EP-057b	939	943.7	942.3	945.7	946.3	945.2
EP-058a	877	881.8	878.7	887.4	887.9	885.0
EP-058b	921	924.5	923.8	925.9	926.4	925.9
EP-058c	929	933.7	932.1	935.4	936.0	934.9
EP-059a	899	902.2	900.6	905.1	905.6	904.4
EP-059b	903	908.5	905.2	905.3	905.6	908.5
EP-059c	933	936.5	934.1	938.6	939.0	937.9
EP-059d	911	913.5	912.6	914.3	914.9	914.2
EP-059e	911	913.3	912.3	912.3	912.3	913.3
EP-060a	855	863.2	863.1	863.1	863.1	863.6
EP-060b	897	902.4	899.4	905.8	906.0	904.1
EP-060c	929	931.6	930.4	932.6	933.2	932.3
EP-064	893	898.5	895.2	900.7	901.5	900.2
EP-066a	851	858.7	853.0	861.4	862.4	860.0
EP-066b	871	875.3	872.5	878.1	878.1	876.9
EP-066c	883	886.0	885.2	886.8	887.5	886.7
EP-067a	859	860.5	859.4	861.7	862.4	860.9
EP-067b	879	882.2	879.2	883.8	884.4	882.8
EP-068a	857	860.0	858.2	862.2	862.9	861.1
EP-068b	861	868.2	866.7	870.0	870.5	869.7
EP-071	841	844.9	843.2	848.5	849.1	847.4
EP-072	841	844.1	842.6	846.9	847.4	846.0
EP-073a	840	842.3	840.9	845.1	846.5	843.8
EP-073b	889	893.0	890.5	894.9	895.0	893.8
EP-073c	891	894.2	891.5	896.7	897.2	895.3
EP-073d	907	909.0	907.2	910.3	910.9	909.5
EP-074a	825	828.5	827.0	832.2	832.8	830.9
EP-074b	837	841.5	839.0	842.1	842.1	842.2
EP-074c	883	886.3	885.1	887.5	888.1	887.1
EP-074d	891	894.9	893.9	895.8	896.3	895.6
EP-074e	889	893.2	891.8	894.4	895.0	894.1
EP-074f	883	885.9	885.3	885.3	885.3	886.0
EP-075	805	811.4	809.5	821.6	822.3	815.5
EP-076	893	893.5	893.2	893.2	893.2	893.5
EP-078	807	809.2	808.4	809.0	809.0	809.9
EP-079a	807	809.3	808.7	810.2	810.3	810.7
EP-079b	905	907.5	906.5	908.6	909.3	908.5
EP-080a	801	802.4	801.7	802.9	802.9	803.7
EP-080b	901	903.0	901.7	903.1	903.1	903.3
EP-080c	905	908.5	906.4	910.1	910.7	909.3
EP-080d	901	904.2	902.5	902.5	902.5	904.2
EP-080e	893	896.7	895.4	898.3	899.0	897.7
EP-102a	901	908.0	906.6	910.3	910.8	909.8
EP-102b	901	906.5	904.5	909.2	909.8	908.3
EP-102c	913	916.8	915.6	918.8	919.3	918.3
EP-104	891	897.6	894.9	900.4	901.0	899.3
EP-106	859	864.9	862.8	869.0	869.6	868.1
EP-107a	855	858.4	857.1	860.9	861.5	860.1
EP-107b	847	861.5	857.1	864.9	865.7	863.4
EP-107c	879	883.2	881.2	885.0	885.0	884.2
EP-107d	863	866.0	864.1	867.5	868.1	866.6
EP-107e	871	872.7	871.8	873.9	874.5	873.4
QP-5	923	926.1	923.8	929.2	929.7	927.8
SP-12	823	826.1	824.3	827.1	828.1	826.4
SP-13	895	897.9	895.7	899.6	900.2	898.5
SP-14	873	877.7	874.0	883.1	883.6	880.0
SP-15	891	894.7	891.3	898.5	899.0	896.2
SP-16	863	866.6	864.9	870.0	870.5	868.4
SP-17	811	817.7	812.6	827.1	828.1	821.0
SP-18	879	882.3	879.0	885.3	885.7	883.6
SP-2	871	881.1	878.9	881.1	881.1	881.2
SP-21	839	845.5	841.4	849.5	850.4	847.1
SP-22	843	847.2	844.8	849.8	850.7	848.7
SP-23	847	849.3	848.1	849.8	850.7	849.7
SP-25	957	958.2	957.4	958.2	958.2	958.2
SP-27	831	835.7	832.9	839.0	839.0	837.2
SP-28	833	835.4	834.3	834.6	834.6	835.4
SP-3	915	919.2	918.4	919.1	919.1	919.2
SP-4	935	939.1	936.8	939.1	939.1	939.1
SP-5	957	959.1	958.9	959.0	959.0	959.1
SP-6	835	841.8	837.3	848.2	849.0	844.7
SP-7	923	928.1	924.7	932.3	933.0	930.5
SP-9	863	867.8	865.6	868.1	868.1	868.2
--	959	--	--	--	--	--
--	959	--	--	--	--	--
--	909	--	--	--	--	--
--	833	--	--	--	--	--
--	831	--	--	--	--	--
--	863	--	--	--	--	--
--	871	--	--	--	--	--

'= Critical 100-year Event

'= Back-to-Back 100-yr > Critical Event

Table 6. XP-SWMM Results for Large Storm Events under Proposed Conditions

Basin ID PROPOSED Conditions	Starting Water Elevation [feet]	Proposed HWL 100-year 24-hr Rainfall event (6.0") [feet]	Proposed HWL 100-year 10-Day Rainfall event (10.9") [feet]	Proposed HWL 100-year 10-Day Runoff event (7.2") [feet]	Proposed HWL 100-year 10-Day Runoff event without raingarden storage or infiltration (7.2") [feet]	Proposed HWL 100-year 10-Day Runoff event with BMPs and 20% basin infiltration (7.2") [feet]	Proposed HWL back-to-back 100-year 24-hr Rainfall event (12.0") [feet]
BP-002	933	938.6	937.8	940.4	941.0	940.4	940.3
BP-004	911	912.3	912.2	912.3	912.4	912.3	912.9
BP-005	911	912.1	912.0	912.1	912.1	912.1	912.5
BP-032	891	895.4	893.6	900.0	900.6	899.4	897.6
BP-033a	913	920.9	918.4	923.6	924.2	923.5	922.5
BP-033b	929	933.9	931.8	940.1	942.0	939.4	936.0
BP-033c	943	--	--	--	--	--	--
BP-033d	943	949.8	946.3	953.2	953.7	953.0	951.7
BP-034	913	916.1	914.6	917.6	918.2	917.6	917.1
BP-035	917	921.6	917.8	926.2	927.4	926.2	923.3
BP-036	923	931.1	926.6	926.7	926.7	926.7	931.1
BP-038a	887	892.0	890.3	895.7	896.7	895.1	894.2
BP-038b	901	910.0	907.7	912.5	913.0	912.4	911.7
BP-038c	919	922.4	921.1	924.1	924.7	924.0	923.6
BP-039a	909	912.1	910.7	912.4	915.8	912.4	913.8
BP-039b	927	931.5	929.6	932.7	933.1	932.6	933.2
BP-039c	933	937.2	936.4	937.1	937.1	937.1	937.3
BP-039d	945	949.5	947.8	951.6	952.2	951.6	950.9
BP-039e	909	917.8	915.3	922.4	923.0	922.3	921.0
BP-039f	933	938.5	936.7	939.2	939.2	939.2	939.5
BP-048a	927	928.7	927.0	930.7	931.4	930.7	929.6
BP-048b	925	927.9	925.0	930.6	931.2	930.6	929.0
BP-048c	943	944.6	943.5	946.7	946.9	946.7	945.8
BP-048d	943	944.8	943.2	947.6	948.2	947.6	946.2
BP-048e	939	943.0	941.5	944.9	945.6	944.9	944.7
BP-049a	925	927.5	925.7	929.9	930.4	929.9	929.0
BP-049b	943	945.4	943.8	947.6	948.0	947.6	946.7
DP-006	937	941.6	939.3	944.2	944.8	944.2	943.0
EP-005a	924.9	925.5	925.2	925.7	925.7	925.7	925.9
EP-005b	912	915.6	915.1	915.1	915.1	915.1	915.6
EP-005c	924	929.3	927.6	931.2	931.9	931.2	930.8
EP-005d	953	955.8	954.9	957.4	957.8	957.4	957.0
EP-009	889	898.6	896.6	899.3	899.3	899.2	900.0
EP-010a	877	890.4	886.4	899.1	899.0	896.7	895.6
EP-010b	898	904.5	901.7	907.1	907.1	907.1	907.0
EP-011	883	892.1	889.6	899.1	899.1	896.7	895.6
EP-012a	909	--	--	--	--	--	--
EP-012b	923	--	--	--	--	--	--
EP-013	851	858.6	856.1	864.3	866.9	863.0	861.4
EP-016a	903	904.6	903.9	906.9	907.1	906.8	906.1
EP-016b	901	906.1	902.1	909.0	909.1	909.0	908.1
EP-016c	907	910.7	909.8	913.0	913.5	912.7	912.1
EP-016d	907	915.3	909.4	910.9	910.9	910.9	915.3
EP-016e	943	--	--	--	--	--	--
EP-016f	945	947.7	946.4	949.8	950.5	949.5	948.8
EP-016g	925	930.8	928.9	933.7	935.0	933.4	932.6
EP-018	935	935.5	935.1	935.2	935.2	935.2	935.5
EP-025a	879	886.6	881.4	881.7	881.7	881.7	886.6
EP-025b	897	900.2	898.8	903.4	903.9	903.1	902.2
EP-027a	847	855.3	853.7	859.7	860.4	857.9	858.9
EP-027b	891	--	--	--	--	--	--
EP-027c	888	890.7	889.9	893.0	893.0	892.5	892.1
EP-027d	923	926.9	925.3	929.7	930.4	929.4	928.3
EP-027e	941	943.9	943.1	946.8	947.2	946.0	945.5
EP-027f	849	851.3	850.0	853.9	854.6	853.8	852.3
EP-027g	903	905.1	903.0	906.2	907.0	906.2	905.4
EP-031a	875	881.2	878.0	887.6	888.7	887.3	884.0
EP-031b	901	901.6	901.3	902.4	902.5	902.4	902.1
EP-031c	897	--	--	--	--	--	--
EP-032	891	895.8	893.7	899.4	900.0	899.1	897.9
EP-034	849	860.6	858.7	865.3	866.0	863.6	864.1
EP-035a	885	--	--	--	--	--	--
EP-035b	853	857.6	856.5	864.1	864.9	862.7	860.9
EP-035c	931	--	--	--	--	--	--
EP-035d	869	--	--	--	--	--	--
EP-036a	861	867.7	865.5	873.2	874.1	871.6	871.5
EP-038a	867	871.7	870.7	872.1	872.1	872.0	872.4
EP-038b	867	872.8	871.9	874.8	875.4	874.0	874.2
EP-039	847	852.1	849.8	857.4	858.0	856.8	854.4
EP-044	885	890.4	886.4	895.1	895.1	895.0	892.5
EP-045	879	881.8	879.8	885.4	886.6	884.9	883.7
EP-049a	840	845.6	843.3	849.8	850.9	849.3	847.9
EP-049b	859	864.2	861.7	869.2	870.8	868.3	866.3
EP-049c	899	907.4	901.6	912.3	912.9	912.2	910.2
EP-049d	871	--	--	--	--	--	--
EP-049e	903	905.2	904.2	906.5	907.2	906.3	905.9
EP-049f	873	878.8	874.9	883.0	883.0	883.0	881.2
EP-049g	877	882.0	878.8	883.1	883.1	883.1	883.2
EP-057a	919	920.9	919.7	922.6	923.3	922.6	921.9
EP-057b	939	943.7	942.3	945.7	946.3	945.7	945.2
EP-058a	877	881.8	878.7	887.4	887.9	887.4	885.0
EP-058b	921	924.4	923.2	925.9	926.4	925.8	925.6
EP-058c	929	933.7	932.1	935.6	936.0	935.6	934.9
EP-059a	899	902.4	901.4	907.8	908.8	905.6	904.6
EP-059b	903	--	--	--	--	--	--
EP-059c	933	936.9	936.1	939.0	939.1	938.8	939.0
EP-059d	911	--	--	--	--	--	--
EP-059e	911	--	--	--	--	--	--
EP-060a	855	863.4	863.1	863.1	863.1	863.1	863.4
EP-060b	897	902.6	901.1	905.4	906.0	904.4	904.3
EP-060c	929	931.5	930.4	932.6	933.2	932.4	932.2
EP-064	893	898.5	895.2	901.2	902.3	901.2	900.2
EP-066a	851	--	--	--	--	--	--
EP-066b	871	--	--	--	--	--	--
EP-066c	883	--	--	--	--	--	--
EP-067a	859	860.4	859.4	861.7	862.4	861.7	860.9
EP-067b	879	882.2	879.2	883.8	884.4	883.8	882.8
EP-068a	857	860.0	858.2	862.2	862.9	862.2	861.1
EP-068b	861	868.2	866.7	870.0	870.5	870.0	869.7
EP-071	841	845.1	844.5	849.6	852.6	847.3	848.9
EP-072	841	844.0	843.0	846.9	847.4	845.7	845.9
EP-073a	840	842.4	841.4	845.1	848.2	844.8	844.0
EP-073b	889	--	--	--	--	--	--
EP-073c	891	--	--	--	--	--	--
EP-073d	907	--	--	--	--	--	--
EP-074a	825	828.8	827.0	832.6	833.5	832.3	831.2
EP-074b	837	841.5	839.7	842.1	842.1	842.1	842.2
EP-074c	883	--	--	--	--	--	--
EP-074d	891	--	--	--	--	--	--
EP-074e	889	--	--	--	--	--	--
EP-074f	883	--	--	--	--	--	--
EP-075	805	811.4	809.2	830.6	835.2	819.7	815.4
EP-076	893	893.5	893.2	893.2	893.2	893.2	893.5
EP-078	807	809.0	808.2	809.1	809.1	809.0	809.8
EP-079a	807	809.0	808.0	810.2	810.3	810.2	810.3
EP-079b	905	--	--	--	--	--	--
EP-080a	801	802.2	801.4	803.0	803.0	802.8	803.4
EP-080b	901	903.0	902.8	903.1	903.1	903.1	903.3
EP-080c	905	908.5	906.4	910.1	910.7	910.1	909.3
EP-080d	901	904.2	902.5	902.5	902.5	902.5	904.2
EP-080e	893	896.7	895.4	897.0	899.0	897.0	897.7
EP-102a	901	907.9	906.6	910.3	910.8	909.7	909.6
EP-102b	901	905.9	904.5	909.2	909.8	909.2	907.4
EP-102c	913	916.6	915.2	918.8	919.3	918.7	918.0
EP-104	891	894.0	892.6	898.2	898.7	896.9	897.4
EP-106	859	865.0	863.3	869.0	869.6	868.3	868.3
EP-107a	855	858.4	857.3	860.9	861.5	860.7	860.0
EP-107b	847	862.2	859.7	865.8	866.8	865.1	864.2
EP-107c	879	--	--	--	--	--	--
EP-107d	863	--	--	--	--	--	--
EP-107e	871	--	--	--	--	--	--
QP-5	923	926.4	925.5	929.2	929.7	928.8	928.0
--	823	--	--	--	--	--	--
41	895	898.1	896.9	899.6	900.2	899.6	898.9
21	873	879.0	876.4	883.5	884.1	882.8	881.3
24	891	893.9	892.3	897.6	899.2	896.9	895.0
23	863	866.6	866.1	869.3	869.6	868.7	868.6
42	811	819.2	815.9	826.4	828.1	824.1	823.1
25	879	883.0	882.9	885.1	885.4	884.1	884.6
5	871	881.2	879.8	881.1	881.1	881.1	881.2
48	839	848.6	846.4	852.6	852.6	852.5	852.5
--	843	--	--	--	--	--	--
--	847	--	--	--	--	--	--
4	957	958.6	957.8	959.5	960.0	959.3	959.0
--	831	--	--	--	--	--	--
--	833	--	--	--	--	--	--
26	915	919.2	919.0	919.1	919.1	919.1	919.3
10	935	938.7	938.1	940.4	941.0	940.1	939.5
29	957	959.7	958.8	961.0	961.1	961.0	960.8
12	835	844.0	840.8	849.2	849.2	848.7	848.6
32	923	927.7	926.2	931.0	931.0	930.6	929.8
--	863	--	--	--	--	--	--
9	959	961.3	959.9	961.9	961.9	961.7	962.2
28	959	960.2	959.7	960.3	960.3	960.2	960.4
36	909	912.0	909.8	915.0	915.1	915.0	914.2
51	833	835.8	834.5	834.6	834.6	834.6	835.8
52	831	835.7	833.0	839.0	839.0	838.8	837.3
53	863	867.6	865.5	868.1	868.1	868.1	868.2
54	871	872.4	871.3	871.4	871.4	871.4	872.4

'= Critical 100-year Event

'= Back-to-Back 100-yr > Critical Event

For comparison sake, the back-to-back 100-year, 24-hour rainfall event was also modeled. In most cases, the 100-year 10-day snowmelt/runoff event results in a higher water level than the back-to-back 100-year, 24-hour rainfall event.

Figures 7 and 8 illustrate the HWL for the worst case scenario (the 100-year 10-day snowmelt/runoff event) under existing and proposed conditions. The area covered by this event under existing and proposed conditions totals 380± acres and 346±acres, respectively. Considering these areas include 78± acres of open water (lakes), the land covered by proposed conditions is 269± acres or roughly 9.5% of the Northwest Quadrant watershed.

Proposed Conditions with Best Management Practices – Raingardens. After identifying the worst case scenario, the proposed conditions model was modified to evaluate the effect of Best Management Practices on the critical high water level for the basins. This scenario evaluated the construction of raingardens for volume control. Figure 9 illustrates a potentially more realistic scenario for the spring runoff event with some reduced infiltration capacity in both the raingardens and the regional depressions.

By making some generalizations about the size and capacity of the raingardens a simplified method for simulating the impact these practices would have on runoff was developed. It was assumed that a raingarden with the following maximum dimensions could be constructed to handle the runoff generated by two single family residential lots:

Length = 50 feet
Width = 10 feet
Storage Depth (at the surface) = 1 to 1.5 feet
Storage Depth (subsurface) = 4 feet

Figure 10 illustrates the concept design configuration for the raingardens. The construction of the perforated pipe is important since it serves as an observation well for future monitoring efforts as well as a conduit for runoff during frozen ground conditions. This design is based upon preliminary research results being developed by Dr. Kenneth Potter at the University of Wisconsin – Madison who is generating optimal design configurations for raingardens. This design configuration is also based upon a size that will be non-intrusive yet effective given the development setting. The trench may be constructed to the specifications identified above or it may be split into multiple practices provided the overall storage volume and infiltration capacity is being maintained.

Of the four parameters identified above, storage depth at the surface and below the surface are the least flexible and should not be changed. Restricting the maximum ponding depth above ground to 1–1.5 feet reduces the time that there will be standing water in the raingarden, provides a suitable habitat for the vegetation, and allows for wet-dry cycling of the soils. Restricting the storage depth underground ensures that the storage volume will be available within a reasonable time period allowing for back-to-back rainfall events.

Given this design configuration, the amount of depressional storage to be incorporated in the model was determined (Table 7). This depressional storage (defined as a depth in inches) is effectively retained in the subwatershed simulating the storage capacity of the raingardens by reducing the total volume of runoff generated for the given event.

Note that the depressional storage identified in Table 7 for single events was applied based on land-use intensity for the following land-use categories: low density residential (less than 30% impervious) and medium to high density residential (>30% impervious). This is a low or conservative estimate of the volume control that could be achieved in the system while also providing more volume control for land-uses with more imperviousness. This amounts to an overall land dedication for raingardens of about 2 to 3%. The proposed design configuration would allow for a reasonable land dedication that would fit the overall objectives of the preliminary land use concept and the City's 2020 Comprehensive Plan.

Table 7. Depressional Storage Values for the Raingarden Simulation

Rainfall/Runoff Event	**Depressional Storage due to Best Management Practices (BMPs)** [inches]	
	Low Density Residential ≤ 30% Impervious	**Medium to High Density Residential/Light Industrial/Commercial** >30% Impervious
1-year, 5-year and 100-year 24-hour rainfall events	0.8	1.2
100-year 10-day rainfall event	2.6	3.9
100-year 10-day snowmelt/runoff event	1.6	2.4

The higher depressional storage associated with the 100-year, 10-day events is due to the fact that the infiltration rate in the raingardens occurs for the complete duration of the event (10-days) instead of only one day.

Results Discussion. A comparison of the HWLs for each rainfall event (Table 8) indicates that the proposed raingarden design in most cases significantly reduces the runoff volume below the existing conditions runoff for the 1-year 24-hour rainfall event. The proposed raingarden design is also in most cases capable of retaining most of the increased runoff generated for the 5-year 24-hour rainfall event.

A comparison of the HWLs for the 100-year 10-day rainfall events demonstrate that the proposed raingarden design will not be able to retain the increase in runoff for this event. While the raingardens will reduce the volume of runoff being delivered downstream, they are not designed to retain the volume generated from this rainfall event. However, the 100-year 10-day HWLs are significantly reduced due to the raingardens operation. This positive effect is even more pronounced in the case of the 100-year 24-hour rainfall event and in most cases the infiltration capacity of the downstream existing basin is capable of handling the increased runoff with little to no increase in HWL. In the case of the 100-year 10-day runoff event (7.2" of runoff) the raingardens are able to maintain or reduce HWLs under proposed conditions below existing conditions levels.

Table 8. Comparison of HWLs for Various Rainfall Events for Existing & Proposed Conditions

Basin ID EXISTING Conditions	Basin ID PROPOSED Conditions	Starting Water Elevation [feet]	Existing HWL 1-year 24-hr Rainfall event (2.4") [feet]	Proposed HWL 1-year 24-hr Rainfall event (2.4") [feet]	Existing HWL 5-year 24-hr Rainfall event (3.6") [feet]	Proposed HWL 5-year 24-hr Rainfall event (3.6") [feet]	Existing HWL 100-year 24-hr Rainfall event (6.0") [feet]	Proposed HWL 100-year 24-hr Rainfall event (6.0") [feet]	Existing HWL 100-year 10-Day Rainfall event (10.9") [feet]	Proposed HWL 100-year 10-Day Rainfall event (10.9") [feet]
BP-002	BP-002	933	936.4	936.4	937.3	937.3	938.6	938.6	937.8	937.8
BP-004	BP-004	911	911.5	911.5	911.8	911.8	912.3	912.3	912.2	912.2
BP-005	BP-005	911	911.3	911.3	911.6	911.5	912.1	912.1	912.0	912.0
BP-032	BP-032	891	892.1	892.1	893.4	893.1	895.5	895.4	892.6	893.6
BP-033a	BP-033a	913	917.2	916.6	919.1	918.7	921.1	920.9	918.7	918.4
BP-033b	BP-033b	929	929.7	930.4	931.7	931.7	933.9	933.9	929.7	931.8
BP-033c	BP-033c	943	944.6	--	945.9	--	947.3	--	944.5	--
BP-033d	BP-033d	943	945.8	945.3	947.7	947.4	949.9	949.8	945.9	946.3
BP-034	BP-034	913	914.3	914.3	915.1	915.0	916.1	916.1	914.6	914.6
BP-035	BP-035	917	918.1	918.1	919.8	919.7	921.6	921.6	917.8	917.8
BP-036	BP-036	923	927.0	927.0	928.7	928.7	931.1	931.1	926.6	926.6
BP-038a	BP-038a	887	889.6	888.7	890.7	890.0	892.5	892.0	890.7	890.3
BP-038b	BP-038b	901	906.3	905.8	908.3	907.9	910.1	910.0	908.1	907.7
BP-038c	BP-038c	919	920.7	920.4	921.5	921.3	922.5	922.4	921.3	921.1
BP-039a	BP-039a	909	910.4	910.4	911.1	911.1	912.1	912.1	910.7	910.7
BP-039b	BP-039b	927	928.8	928.8	929.7	929.7	931.6	931.5	929.6	929.6
BP-039c	BP-039c	933	935.5	935.5	936.6	936.6	937.2	937.2	936.4	936.4
BP-039d	BP-039d	945	947.0	947.0	948.1	948.1	949.5	949.5	947.8	947.8
BP-039e	BP-039e	909	913.7	913.7	915.4	915.4	917.9	917.8	915.3	915.3
BP-039f	BP-039f	933	935.8	935.8	937.0	937.0	938.6	938.5	936.7	936.7
BP-048a	BP-048a	927	927.1	927.1	927.8	927.8	928.7	928.7	927.0	927.0
BP-048b	BP-048b	925	925.4	925.4	926.5	926.5	927.9	927.9	925.0	925.0
BP-048c	BP-048c	943	943.2	943.2	943.7	943.7	944.6	944.6	943.5	943.5
BP-048d	BP-048d	943	943.1	943.1	943.7	943.7	944.9	944.8	943.2	943.2
BP-048e	BP-048e	939	940.8	940.7	941.7	941.6	943.1	943.0	941.8	941.5
BP-049a	BP-049a	925	925.5	925.5	926.3	926.3	927.6	927.5	925.7	925.7
BP-049b	BP-049b	943	943.7	943.7	944.3	944.3	945.4	945.4	943.8	943.8
DP-006	DP-006	937	938.8	938.8	940.1	940.0	941.6	941.6	939.3	939.3
EP-005a	EP-005a	924.9	925.1	925.1	925.2	925.2	925.5	925.5	925.2	925.2
EP-005b	EP-005b	912	915.3	915.3	915.4	915.4	915.6	915.6	915.1	915.1
EP-005c	EP-005c	924	926.8	926.8	927.8	927.8	929.3	929.3	927.6	927.6
EP-005d	EP-005d	953	954.1	954.1	954.7	954.7	955.8	955.8	954.9	954.9
EP-009	EP-009	889	892.9	893.0	895.5	894.5	899.0	898.6	894.7	896.6
EP-010a	EP-010a	877	880.4	882.3	883.3	885.7	886.2	890.4	881.2	886.4
EP-010b	EP-010b	898	899.4	899.4	901.7	901.1	904.7	904.5	900.7	901.7
EP-011	EP-011	883	884.9	888.0	887.0	889.7	889.8	892.1	886.6	889.6
EP-012a	EP-012a	909	910.3	--	911.2	--	912.6	--	910.4	--
EP-012b	EP-012b	923	925.5	--	926.9	--	928.6	--	926.3	--
EP-013	EP-013	851	852.9	851.0	855.3	851.0	858.2	858.6	854.5	856.1
EP-016a	EP-016a	903	903.4	903.3	903.8	903.7	904.7	904.6	904.1	903.9
EP-016b	EP-016b	901	901.9	901.9	903.7	903.7	906.2	906.1	902.1	902.1
EP-016c	EP-016c	907	908.3	908.1	909.3	909.1	910.7	910.7	909.4	909.8
EP-016d	EP-016d	907	910.4	910.4	914.8	914.8	915.3	915.3	909.4	909.4
EP-016e	EP-016e	943	943.3	--	943.8	--	944.4	--	943.0	--
EP-016f	EP-016f	945	945.6	945.7	946.4	946.4	947.6	947.7	945.6	946.4
EP-016g	EP-016g	925	927.0	927.5	928.6	928.7	930.2	930.8	927.0	928.9
EP-018	EP-018	935	935.1	935.1	935.3	935.3	935.5	935.5	935.1	935.1
EP-025a	EP-025a	879	881.0	881.2	883.8	883.6	886.5	886.6	880.7	881.4
EP-025b	EP-025b	897	897.6	897.5	898.4	898.5	900.0	900.2	898.1	898.8
EP-027a	EP-027a	847	848.2	849.7	850.2	851.7	853.6	855.3	849.2	853.7
EP-027b	EP-027b	891	892.7	--	894.2	--	895.7	--	893.9	--
EP-027c	EP-027c	888	888.8	888.8	889.5	889.3	890.7	890.7	889.2	889.9
EP-027d	EP-027d	923	923.7	924.2	925.2	925.2	926.8	926.9	923.3	925.3
EP-027e	EP-027e	941	942.6	941.8	943.4	942.3	944.9	943.9	944.4	943.1
EP-027f	EP-027f	849	849.2	849.5	850.0	850.1	851.2	851.3	849.0	850.0
EP-027g	EP-027g	903	903.4	903.4	904.3	904.3	905.1	905.1	903.0	903.0
EP-031a	EP-031a	875	876.1	876.3	878.1	878.3	881.0	881.2	876.4	878.0
EP-031b	EP-031b	901	901.2	901.1	901.3	901.2	901.7	901.6	901.4	901.3
EP-031c	EP-031c	897	899.7	--	901.3	--	903.5	--	900.5	--
EP-032	EP-032	891	892.4	892.3	893.7	893.7	895.7	895.8	892.6	893.7
EP-034	EP-034	849	853.9	855.0	856.4	857.1	859.2	860.6	855.2	858.7
EP-035a	EP-035a	885	886.3	--	887.6	--	889.2	--	886.3	--
EP-035b	EP-035b	853	854.9	854.8	856.0	855.7	857.7	857.6	855.8	856.5
EP-035c	EP-035c	931	932.1	--	932.8	--	934.2	--	932.2	--
EP-035d	EP-035d	869	870.5	--	870.8	--	871.2	--	870.2	--
EP-036a	EP-036a	861	864.0	863.3	864.8	864.6	866.1	867.7	865.1	865.5
EP-038a	EP-038a	867	869.3	869.0	870.6	869.9	872.0	871.7	870.5	870.7
EP-038b	EP-038b	867	869.1	869.6	870.6	870.8	872.6	872.8	870.3	871.9
EP-039	EP-039	847	847.5	847.7	849.5	848.9	852.4	852.1	848.1	849.8
EP-044	EP-044	885	885.9	885.0	887.9	885.0	890.5	890.4	886.0	886.4
EP-045	EP-045	879	879.4	879.2	880.3	880.1	881.9	881.8	879.5	879.8
EP-049a	EP-049a	840	841.4	840.0	842.7	840.0	844.3	845.6	841.9	843.3
EP-049b	EP-049b	859	860.9	860.5	862.2	862.0	864.3	864.2	860.8	861.7
EP-049c	EP-049c	899	901.9	901.7	904.5	904.3	907.5	907.4	902.0	901.6
EP-049d	EP-049d	871	873.6	--	875.2	--	877.0	--	874.2	--
EP-049e	EP-049e	903	903.9	903.6	904.4	904.1	905.3	905.2	904.1	904.2
EP-049f	EP-049f	873	875.0	874.4	876.7	876.4	879.0	878.8	875.3	874.9
EP-049g	EP-049g	877	878.8	878.8	880.3	880.2	882.0	882.0	878.8	878.8
EP-057a	EP-057a	919	919.5	919.5	920.0	920.0	920.9	920.9	919.7	919.7
EP-057b	EP-057b	939	941.3	941.3	942.3	942.3	943.7	943.7	942.3	942.3
EP-058a	EP-058a	877	877.9	877.9	879.3	879.3	881.8	881.8	878.7	878.7
EP-058b	EP-058b	921	922.6	922.1	923.4	923.1	924.5	924.4	923.8	923.2
EP-058c	EP-058c	929	931.5	931.5	932.4	932.4	933.7	933.7	932.1	932.1
EP-059a	EP-059a	899	899.7	899.5	900.6	900.4	902.2	902.4	900.6	901.4
EP-059b	EP-059b	903	905.1	--	906.5	--	908.5	--	905.2	--
EP-059c	EP-059c	933	933.9	934.0	934.9	934.8	936.5	936.9	934.1	936.1
EP-059d	EP-059d	911	912.2	--	912.7	--	913.5	--	912.6	--
EP-059e	EP-059e	911	912.4	--	912.7	--	913.3	--	912.3	--
EP-060a	EP-060a	855	863.3	863.2	863.2	863.2	863.2	863.2	863.1	863.1
EP-060b	EP-060b	897	899.0	899.1	900.5	900.2	902.4	902.6	899.4	901.1
EP-060c	EP-060c	929	930.1	929.7	930.7	930.5	931.6	931.5	930.4	930.4
EP-064	EP-064	893	894.5	894.5	896.1	896.1	898.5	898.5	895.2	895.2
EP-066a	EP-066a	851	852.7	--	856.0	--	858.7	--	853.0	--
EP-066b	EP-066b	871	872.2	--	873.6	--	875.3	--	872.5	--
EP-066c	EP-066c	883	884.8	--	885.3	--	886.0	--	885.2	--
EP-067a	EP-067a	859	859.4	859.0	859.8	859.0	860.5	860.4	859.4	859.4
EP-067b	EP-067b	879	880.3	880.3	881.3	881.3	882.2	882.2	879.2	879.2
EP-068a	EP-068a	857	857.9	857.9	858.9	858.9	860.0	860.0	858.2	858.2
EP-068b	EP-068b	861	865.1	865.1	866.5	866.4	868.2	868.2	866.7	866.7
EP-071	EP-071	841	842.2	842.0	843.2	842.9	844.9	845.1	843.2	844.5
EP-072	EP-072	841	841.9	841.7	842.7	842.3	844.1	844.0	842.6	843.0
EP-073a	EP-073a	840	840.7	840.7	841.2	841.2	842.3	842.4	840.9	841.4
EP-073b	EP-073b	889	890.6	--	891.8	--	893.0	--	890.5	--
EP-073c	EP-073c	891	891.6	--	892.9	--	894.2	--	891.5	--
EP-073d	EP-073d	907	907.3	--	908.1	--	909.0	--	907.2	--
EP-074a	EP-074a	825	826.0	825.9	826.8	826.8	828.5	828.8	827.0	827.0
EP-074b	EP-074b	837	838.9	838.9	840.2	840.0	841.5	841.5	839.0	839.7
EP-074c	EP-074c	883	884.9	--	885.5	--	886.3	--	885.1	--
EP-074d	EP-074d	891	893.1	--	893.9	--	894.9	--	893.9	--
EP-074e	EP-074e	889	891.0	--	892.1	--	893.2	--	891.8	--
EP-074f	EP-074f	883	884.7	--	885.3	--	885.9	--	885.3	--
EP-075	EP-075	805	807.8	807.6	809.1	809.1	811.4	811.4	809.5	809.2
EP-076	EP-076	893	893.2	893.1	893.3	893.2	893.5	893.5	893.2	893.2
EP-078	EP-078	807	807.7	807.4	808.3	808.1	809.2	809.0	808.4	808.2
EP-079a	EP-079a	807	807.7	807.3	808.2	807.9	809.3	809.0	808.7	808.0
EP-079b	EP-079b	905	906.0	--	906.6	--	907.5	--	906.5	--
EP-080a	EP-080a	801	801.3	801.1	801.6	801.4	802.4	802.2	801.7	801.4
EP-080b	EP-080b	901	901.5	901.8	902.1	902.2	903.0	903.0	901.7	902.8
EP-080c	EP-080c	905	906.3	906.3	907.4	907.4	908.5	908.5	906.4	906.4
EP-080d	EP-080d	901	902.7	902.7	903.2	903.2	904.2	904.2	902.5	902.5
EP-080e	EP-080e	893	895.0	895.0	895.7	895.7	896.7	896.7	895.4	895.4
EP-102a	EP-102a	901	904.1	903.3	905.9	905.1	908.0	907.9	906.6	906.6
EP-102b	EP-102b	901	903.6	903.0	904.8	903.8	906.5	905.9	904.5	904.5
EP-102c	EP-102c	913	914.6	914.0	915.5	915.1	916.8	916.6	915.6	915.2
EP-104	EP-104	891	893.7	892.1	895.6	892.8	897.6	894.0	894.9	892.6
EP-106	EP-106	859	861.1	859.0	862.5	859.0	864.9	865.0	862.8	863.3
EP-107a	EP-107a	855	856.2	855.0	857.1	855.0	858.4	858.4	857.1	857.3
EP-107b	EP-107b	847	853.0	855.1	858.7	858.8	861.5	862.2	857.1	859.7
EP-107c	EP-107c	879	880.9	--	882.0	--	883.2	--	881.2	--
EP-107d	EP-107d	863	864.0	--	865.0	--	866.0	--	864.1	--
EP-107e	EP-107e	871	871.6	--	872.0	--	872.7	--	871.8	--
QP-5	QP-5	923	923.4	923.8	924.5	924.6	926.1	926.4	923.8	925.5
SP-12	--	823	823.9	--	825.3	--	826.1	--	824.3	--
SP-13	41	895	895.6	896.3	896.9	897.1	897.9	898.1	895.7	896.9
SP-14	21	873	873.8	874.3	875.0	876.2	877.7	879.0	874.0	876.4
SP-15	24	891	891.3	891.7	892.8	892.7	894.7	893.9	891.3	892.3
SP-16	23	863	864.1	863.5	865.0	864.6	866.6	866.6	864.9	866.1
SP-17	42	811	812.3	813.6	813.7	815.6	817.7	819.2	812.6	815.9
SP-18	25	879	879.4	880.7	880.8	881.6	882.3	883.0	879.0	882.9
SP-2	5	871	876.3	876.1	878.9	879.3	881.1	881.2	878.9	879.8
SP-21	48	839	841.1	843.1	843.0	844.9	845.5	848.6	841.4	846.4
SP-22	--	843	844.6	--	845.5	--	847.2	--	844.8	--
SP-23	--	847	847.8	--	848.4	--	849.3	--	848.1	--
SP-25	4	957	957.3	957.5	957.8	957.8	958.2	958.6	957.4	957.8
SP-27	--	831	832.6	--	833.9	--	835.7	--	832.9	--
SP-28	--	833	834.3	--	834.7	--	835.4	--	834.3	--
SP-3	26	915	917.6	917.8	919.1	919.0	919.2	919.2	918.4	919.0
SP-4	10	935	936.1	937.6	937.6	937.9	939.1	938.7	936.8	938.1
SP-5	29	957	958.2	958.2	959.0	958.8	959.1	959.7	958.9	958.8
SP-6	12	835	836.4	837.2	838.1	839.3	841.8	844.0	837.3	840.8
SP-7	32	923	924.2	924.6	925.5	925.7	928.1	927.7	924.7	926.2
SP-9	--	863	864.9	--	866.1	--	867.8	--	865.6	--
--	9	959	--	959.5	--	960.0	--	961.3	--	959.9
--	28	959	--	959.4	--	959.7	--	960.2	--	959.7
--	36	909	--	909.5	--	910.2	--	912.0	--	909.8
--	51	833	--	834.3	--	834.9	--	835.8	--	834.5
--	52	831	--	832.5	--	833.8	--	835.7	--	833.0
--	53	863	--	864.2	--	865.8	--	867.6	--	865.5
--	54	871	--	871.5	--	871.8	--	872.4	--	871.3

Table 8. Continued

Basin ID EXISTING Conditions	Basin ID PROPOSED Conditions	Starting Water Elevation [feet]	Existing HWL back-to-back 100-year 24-hr Rainfall event (12.0") [feet]	Proposed HWL back-to-back 100-year 24-hr Rainfall event (12.0") [feet]	Existing HWL 100-year 10-Day Runoff event (7.2") [feet]	Proposed HWL 100-year 10-Day Runoff event (7.2") [feet]	Existing HWL 100-year 10-Day Runoff event without raingarden storage or infiltration (7.2") [feet]	Proposed HWL 100-year 10-Day Runoff event without raingarden storage or infiltration (7.2") [feet]	Proposed HWL 100-year 10-Day Runoff event with BMPs (7.2") [feet]
BP-002	BP-002	933	940.3	940.3	940.4	940.4	941.0	941.0	940.4
BP-004	BP-004	911	912.9	912.9	912.3	912.3	912.4	912.4	912.3
BP-005	BP-005	911	912.5	912.5	912.1	912.1	912.1	912.1	912.1
BP-032	BP-032	891	897.8	897.6	900.0	900.0	900.6	900.6	899.4
BP-033a	BP-033a	913	922.6	922.5	923.6	923.6	924.2	924.2	923.5
BP-033b	BP-033b	929	935.8	936.0	938.7	940.1	939.2	942.0	939.4
BP-033c	BP-033c	943	948.3	--	949.6	--	950.2	--	--
BP-033d	BP-033d	943	951.7	951.7	953.2	953.2	953.7	953.7	953.0
BP-034	BP-034	913	917.1	917.1	917.6	917.6	918.2	918.2	917.6
BP-035	BP-035	917	923.4	923.3	926.2	926.2	927.4	927.4	926.2
BP-036	BP-036	923	931.1	931.1	926.7	926.7	926.7	926.6	926.7
BP-038a	BP-038a	887	895.1	894.2	895.7	895.7	896.7	896.7	895.1
BP-038b	BP-038b	901	911.8	911.7	912.5	912.5	913.0	913.0	912.4
BP-038c	BP-038c	919	923.8	923.6	924.1	924.1	924.7	924.7	924.0
BP-039a	BP-039a	909	913.8	913.8	914.8	912.4	915.8	915.8	912.4
BP-039b	BP-039b	927	933.2	933.2	933.0	932.7	933.1	933.1	932.6
BP-039c	BP-039c	933	937.3	937.3	937.1	937.1	937.1	937.1	937.1
BP-039d	BP-039d	945	950.9	950.9	951.6	951.6	952.2	952.2	951.6
BP-039e	BP-039e	909	921.1	921.0	922.3	922.4	923.0	923.0	922.3
BP-039f	BP-039f	933	939.5	939.5	939.2	939.2	939.2	939.2	939.2
BP-048a	BP-048a	927	929.6	929.6	930.7	930.7	931.4	931.4	930.7
BP-048b	BP-048b	925	929.0	929.0	930.6	930.6	931.2	931.2	930.6
BP-048c	BP-048c	943	945.8	945.8	946.7	946.7	946.9	946.9	946.7
BP-048d	BP-048d	943	946.3	946.2	947.6	947.6	948.2	948.2	947.6
BP-048e	BP-048e	939	944.9	944.7	944.9	944.9	945.6	945.6	944.9
BP-049a	BP-049a	925	929.0	929.0	929.9	929.9	930.4	930.4	929.9
BP-049b	BP-049b	943	946.8	946.7	947.6	947.6	948.0	948.0	947.6
DP-006	DP-006	937	943.0	943.0	944.2	944.2	944.8	944.8	944.2
EP-005a	EP-005a	924.9	925.9	925.9	925.7	925.7	925.7	925.7	925.7
EP-005b	EP-005b	912	915.6	915.6	915.1	915.1	915.1	915.1	915.1
EP-005c	EP-005c	924	930.9	930.8	931.3	931.2	931.9	931.9	931.2
EP-005d	EP-005d	953	957.0	957.0	957.4	957.4	957.8	957.8	957.4
EP-009	EP-009	889	900.0	900.0	899.3	899.3	899.3	899.3	899.2
EP-010a	EP-010a	877	892.5	895.6	896.4	899.1	899.0	899.0	896.7
EP-010b	EP-010b	898	907.1	907.0	907.1	907.1	907.1	907.1	907.1
EP-011	EP-011	883	892.5	895.6	896.4	899.1	899.1	899.1	896.7
EP-012a	EP-012a	909	913.8	--	914.9	--	915.1	--	--
EP-012b	EP-012b	923	930.0	--	930.6	--	931.2	--	--
EP-013	EP-013	851	861.0	861.4	863.4	864.3	865.0	866.9	863.0
EP-016a	EP-016a	903	906.3	906.1	906.8	906.9	907.1	907.1	906.8
EP-016b	EP-016b	901	908.1	908.1	909.0	909.0	909.1	909.1	909.0
EP-016c	EP-016c	907	912.2	912.1	913.0	913.0	913.5	913.5	912.7
EP-016d	EP-016d	907	915.3	915.3	910.9	910.9	910.9	910.9	910.9
EP-016e	EP-016e	943	944.7	--	945.5	--	946.2	--	--
EP-016f	EP-016f	945	948.5	948.8	949.8	949.8	950.5	950.5	949.5
EP-016g	EP-016g	925	931.7	932.6	933.4	933.7	934.0	935.0	933.4
EP-018	EP-018	935	935.5	935.5	935.2	935.2	935.2	935.2	935.2
EP-025a	EP-025a	879	886.5	886.6	881.7	881.7	881.7	881.7	881.7
EP-025b	EP-025b	897	901.9	902.2	903.4	903.4	903.9	903.9	903.1
EP-027a	EP-027a	847	856.9	858.9	859.3	859.7	860.2	860.4	857.9
EP-027b	EP-027b	891	896.4	--	895.0	--	895.0	--	--
EP-027c	EP-027c	888	892.2	892.1	893.0	893.0	893.0	893.0	892.5
EP-027d	EP-027d	923	928.0	928.3	929.7	929.7	930.4	930.4	929.4
EP-027e	EP-027e	941	946.9	945.5	946.8	946.8	947.2	947.2	946.0
EP-027f	EP-027f	849	852.0	852.3	853.9	853.9	854.6	854.6	853.8
EP-027g	EP-027g	903	905.4	905.4	906.2	906.2	907.0	907.0	906.2
EP-031a	EP-031a	875	883.7	884.0	886.4	887.6	886.9	888.7	887.3
EP-031b	EP-031b	901	902.3	902.1	902.4	902.4	902.5	902.5	902.4
EP-031c	EP-031c	897	905.6	--	906.8	--	907.4	--	--
EP-032	EP-032	891	897.6	897.9	899.4	899.4	900.0	900.0	899.1
EP-034	EP-034	849	862.2	864.1	864.9	865.3	865.7	866.0	863.6
EP-035a	EP-035a	885	889.2	--	886.9	--	887.0	--	--
EP-035b	EP-035b	853	861.5	860.9	864.0	864.1	864.9	864.9	862.7
EP-035c	EP-035c	931	935.1	--	935.1	--	935.1	--	--
EP-035d	EP-035d	869	871.2	--	870.3	--	870.3	--	--
EP-036a	EP-036a	861	867.9	871.5	868.6	873.2	869.4	874.1	871.6
EP-038a	EP-038a	867	872.4	872.4	872.1	872.1	872.1	872.1	872.0
EP-038b	EP-038b	867	874.0	874.2	874.8	874.8	875.4	875.4	874.0
EP-039	EP-039	847	854.7	854.4	857.4	857.4	858.0	858.0	856.8
EP-044	EP-044	885	892.6	892.5	895.0	895.1	895.1	895.1	895.0
EP-045	EP-045	879	883.8	883.7	885.4	885.4	886.6	886.6	884.9
EP-049a	EP-049a	840	846.1	847.9	848.6	849.8	849.5	850.9	849.3
EP-049b	EP-049b	859	866.4	866.3	869.2	869.2	870.8	870.8	868.3
EP-049c	EP-049c	899	910.2	910.2	912.3	912.3	912.9	912.9	912.2
EP-049d	EP-049d	871	878.8	--	879.0	--	879.1	--	--
EP-049e	EP-049e	903	906.1	905.9	906.5	906.5	907.2	907.2	906.3
EP-049f	EP-049f	873	881.3	881.2	883.0	883.0	883.0	883.0	883.0
EP-049g	EP-049g	877	883.2	883.2	883.1	883.1	883.1	883.1	883.1
EP-057a	EP-057a	919	922.0	921.9	922.6	922.6	923.3	923.3	922.6
EP-057b	EP-057b	939	945.2	945.2	945.7	945.7	946.3	946.3	945.7
EP-058a	EP-058a	877	885.0	885.0	887.4	887.4	887.9	887.9	887.4
EP-058b	EP-058b	921	925.9	925.6	925.9	925.9	926.4	926.4	925.8
EP-058c	EP-058c	929	934.9	934.9	935.4	935.6	936.0	936.0	935.6
EP-059a	EP-059a	899	904.4	904.6	905.1	907.8	905.6	908.8	905.6
EP-059b	EP-059b	903	908.5	--	905.3	--	905.6	--	--
EP-059c	EP-059c	933	937.9	939.0	938.6	939.0	939.0	939.1	938.8
EP-059d	EP-059d	911	914.2	--	914.3	--	914.9	--	--
EP-059e	EP-059e	911	913.3	--	912.3	--	912.3	--	--
EP-060a	EP-060a	855	863.4	863.4	863.1	863.1	863.1	863.1	863.1
EP-060b	EP-060b	897	904.1	904.3	905.8	905.4	906.0	906.0	904.4
EP-060c	EP-060c	929	932.3	932.2	932.6	932.6	933.2	933.2	932.4
EP-064	EP-064	893	900.2	900.2	900.7	901.2	901.5	902.3	901.2
EP-066a	EP-066a	851	860.0	--	861.4	--	862.4	--	--
EP-066b	EP-066b	871	876.9	--	878.1	--	878.1	--	--
EP-066c	EP-066c	883	886.7	--	886.8	--	887.5	--	--
EP-067a	EP-067a	859	860.9	860.9	861.7	861.7	862.4	862.4	861.7
EP-067b	EP-067b	879	882.8	882.8	883.8	883.8	884.4	884.4	883.8
EP-068a	EP-068a	857	861.1	861.1	862.2	862.2	862.9	862.9	862.2
EP-068b	EP-068b	861	869.7	869.7	870.0	870.0	870.5	870.5	870.0
EP-071	EP-071	841	847.4	848.9	848.5	849.6	849.1	852.6	847.3
EP-072	EP-072	841	846.0	845.9	846.9	846.9	847.4	847.4	845.7
EP-073a	EP-073a	840	843.8	844.0	845.1	845.1	846.5	848.2	844.8
EP-073b	EP-073b	889	893.8	--	894.9	--	895.0	--	--
EP-073c	EP-073c	891	895.3	--	896.7	--	897.2	--	--
EP-073d	EP-073d	907	909.5	--	910.3	--	910.9	--	--
EP-074a	EP-074a	825	830.9	831.2	832.2	832.6	832.8	833.5	832.3
EP-074b	EP-074b	837	842.2	842.2	842.1	842.1	842.1	842.1	842.1
EP-074c	EP-074c	883	887.1	--	887.5	--	888.1	--	--
EP-074d	EP-074d	891	895.6	--	895.8	--	896.3	--	--
EP-074e	EP-074e	889	894.1	--	894.4	--	895.0	--	--
EP-074f	EP-074f	883	886.0	--	885.3	--	885.3	--	--
EP-075	EP-075	805	815.5	815.4	821.6	830.6	822.3	835.2	819.7
EP-076	EP-076	893	893.5	893.5	893.2	893.2	893.2	893.2	893.2
EP-078	EP-078	807	809.9	809.8	809.0	809.1	809.0	809.1	809.0
EP-079a	EP-079a	807	810.7	810.3	810.2	810.2	810.3	810.3	810.2
EP-079b	EP-079b	905	908.5	--	908.6	--	909.3	--	--
EP-080a	EP-080a	801	803.7	803.4	802.9	803.0	802.9	803.0	802.8
EP-080b	EP-080b	901	903.3	903.3	903.1	903.1	903.1	903.1	903.1
EP-080c	EP-080c	905	909.3	909.3	910.1	910.1	910.7	910.7	910.1
EP-080d	EP-080d	901	904.2	904.2	902.5	902.5	902.5	902.5	902.5
EP-080e	EP-080e	893	897.7	897.7	898.3	897.0	899.0	899.0	897.0
EP-102a	EP-102a	901	909.8	909.6	910.3	910.3	910.8	910.8	909.7
EP-102b	EP-102b	901	908.3	907.4	909.2	909.2	909.8	909.8	909.2
EP-102c	EP-102c	913	918.3	918.0	918.8	918.8	919.3	919.3	918.7
EP-104	EP-104	891	899.3	897.4	900.4	898.2	901.0	898.7	896.9
EP-106	EP-106	859	868.1	868.3	869.0	869.0	869.6	869.6	868.3
EP-107a	EP-107a	855	860.1	860.0	860.9	860.9	861.5	861.5	860.7
EP-107b	EP-107b	847	863.4	864.2	864.9	865.8	865.7	866.8	865.1
EP-107c	EP-107c	879	884.2	--	885.0	--	885.0	--	--
EP-107d	EP-107d	863	866.6	--	867.5	--	868.1	--	--
EP-107e	EP-107e	871	873.4	--	873.9	--	874.5	--	--
QP-5	QP-5	923	927.8	928.0	929.2	929.2	929.7	929.7	928.8
SP-12	--	823	826.4	--	827.1	--	828.1	--	--
SP-13	41	895	898.5	898.9	899.6	899.6	900.2	900.2	899.6
SP-14	21	873	880.0	881.3	883.1	883.5	883.6	884.1	882.8
SP-15	24	891	896.2	895.0	898.5	897.6	899.0	899.2	896.9
SP-16	23	863	868.4	868.6	870.0	869.3	870.5	869.6	868.7
SP-17	42	811	821.0	823.1	827.1	826.4	828.1	828.1	824.1
SP-18	25	879	883.6	884.6	885.3	885.1	885.7	885.4	884.1
SP-2	5	871	881.2	881.2	881.1	881.1	881.1	881.1	881.1
SP-21	48	839	847.1	852.5	849.5	852.6	850.4	852.6	852.5
SP-22	--	843	848.7	--	849.8	--	850.7	--	--
SP-23	--	847	849.7	--	849.8	--	850.7	--	--
SP-25	4	957	958.2	959.0	958.2	959.5	958.2	960.0	959.3
SP-27	--	831	837.2	--	839.0	--	839.0	--	--
SP-28	--	833	835.4	--	834.6	--	834.6	--	--
SP-3	26	915	919.2	919.3	919.1	919.1	919.1	919.1	919.1
SP-4	10	935	939.1	939.5	939.1	940.4	939.1	941.0	940.1
SP-5	29	957	959.1	960.8	959.0	961.0	959.0	961.1	961.0
SP-6	12	835	844.7	848.6	848.2	849.2	849.0	849.2	848.7
SP-7	32	923	930.5	929.8	932.3	931.0	933.0	931.0	930.6
SP-9	--	863	868.2	--	868.1	--	868.1	--	--
--	9	959	--	962.2	--	961.9	--	961.9	961.7
--	28	959	--	960.4	--	960.3	--	960.3	960.2
--	36	909	--	914.2	--	915.0	--	915.1	915.0
--	51	833	--	835.8	--	834.6	--	834.6	834.6
--	52	831	--	837.3	--	839.0	--	839.0	838.8
--	53	863	--	868.2	--	868.1	--	868.1	868.1
--	54	871	--	872.4	--	871.4	--	871.4	871.4

Northwest Quadrant Study- Hydrologic & Hydraulic Analysis

Fig. 7 Existing Conditions
Worst Case Scenario
(10-day Snowmelt/Runoff Event)
High Water Levels

Legend

Subwatershed boundaries

Critical High Water Level

2000 0 2000 Feet

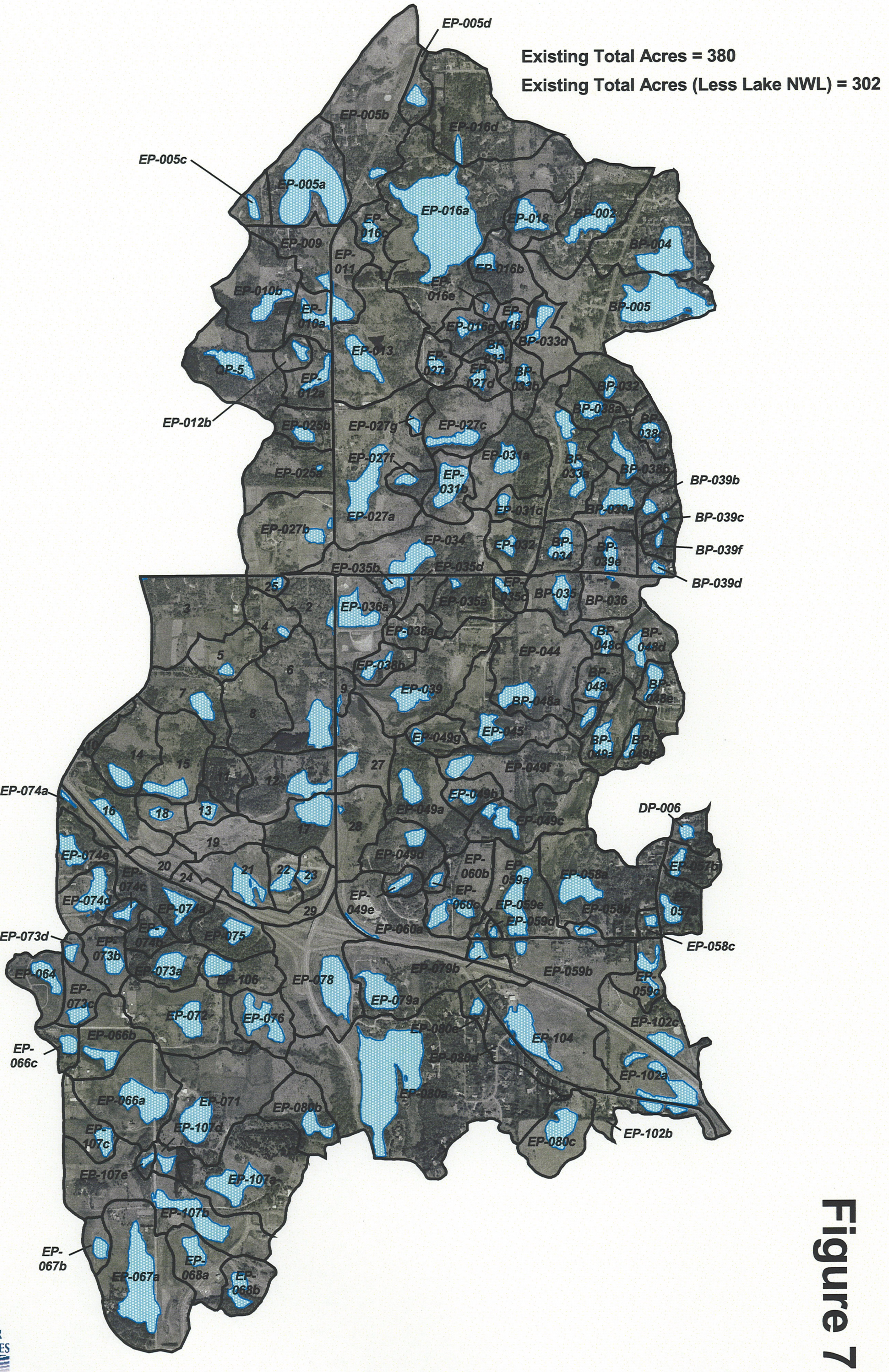

Figure 7

EMMONS & OLIVIER RESOURCES

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20 January 2004

Northwest Quadrant Study- Hydrologic & Hydraulic Analysis

Fig. 8 Proposed Conditions
Worst Case Scenario
(10-day Snowmelt/Runoff Event)
High Water Levels

Legend

Subwatershed boundaries

Critical High Water Level

2000 0 2000 Feet

N W E S

Proposed Total Acres = 347

Proposed Total Acres (Less Lake NWL) = 270

Figure 8

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Northwest Quadrant Study- Hydrologic & Hydraulic Analysis

Fig. 9 Proposed Conditions
With Rain Gardens & Limited Infiltration
(10-day Snowmelt/Runoff Event)
High Water Levels

2000 0 2000 Feet

Legend

Subwatershed boundaries

Critical High Water Level

Propsed Total Acres = 313

Proposed Total Acres (Less Lake NWL) = 236

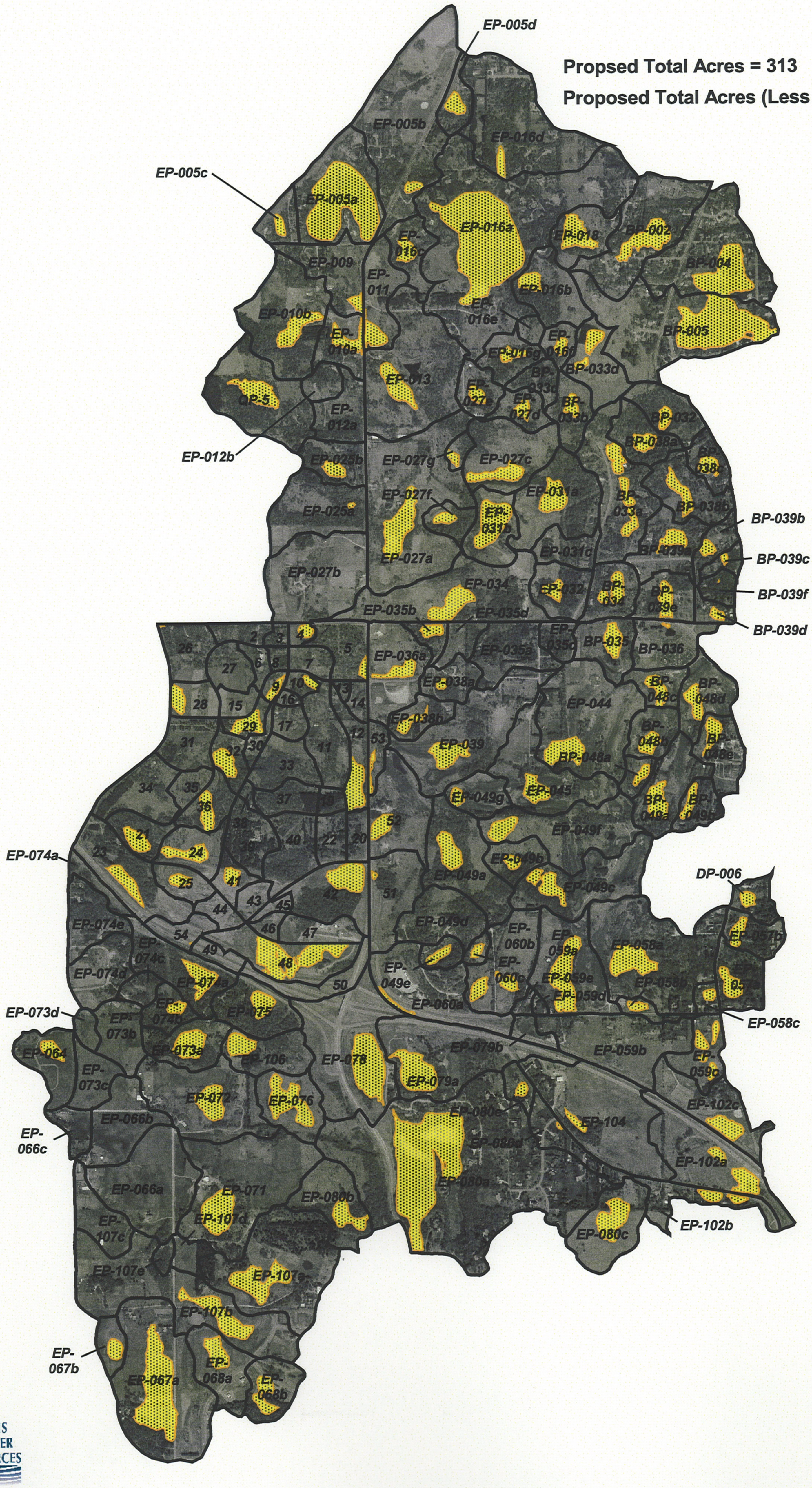

Figure 9

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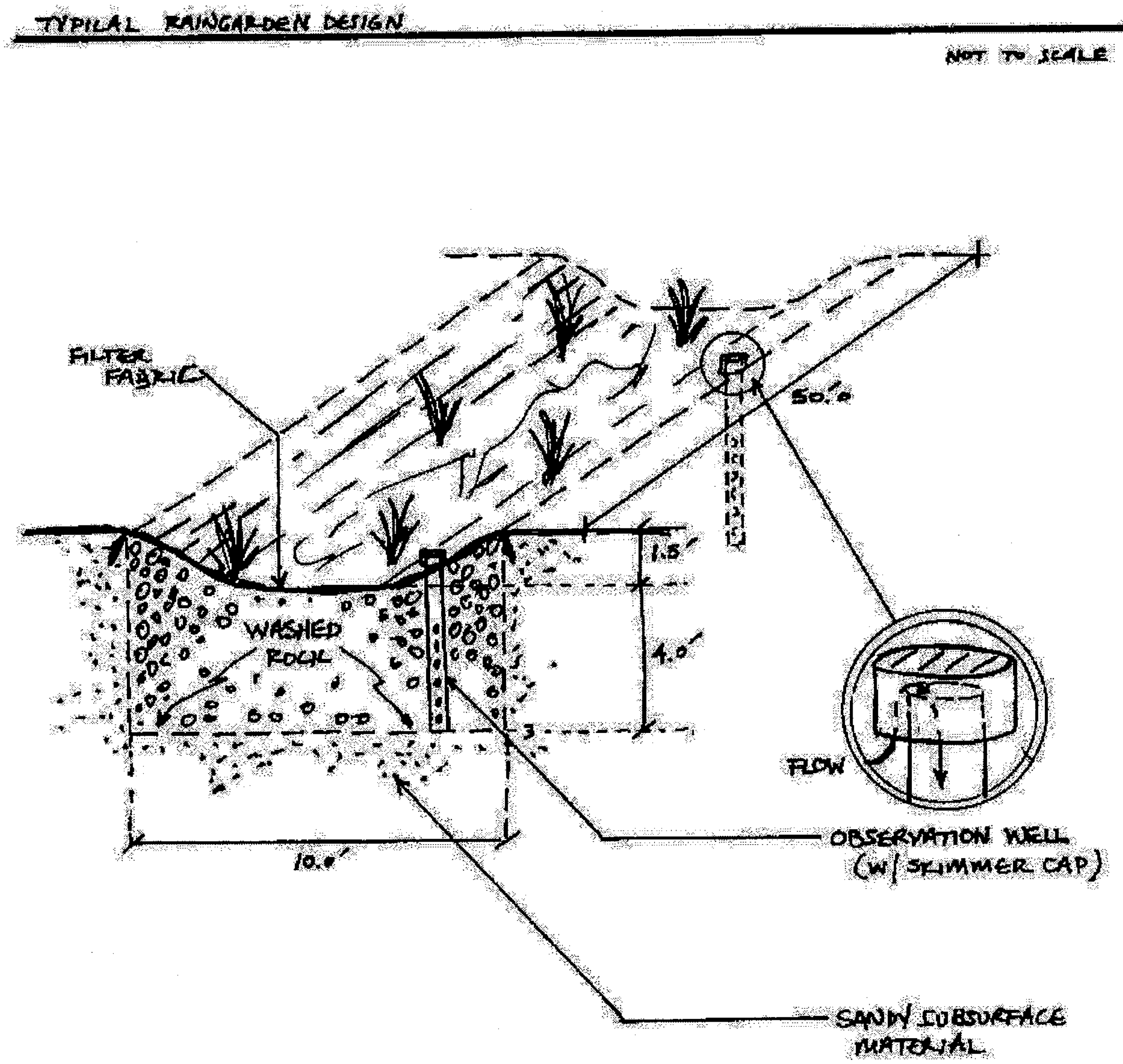
Northwest Quadrant - Hydrologic & Hydraulic Analysis

Fig. 10 Typical Rain Garden Design



EMMONS & OLIVIER RESOURCES

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20 January 2004

Modeling Conclusions

The open-space corridor has been defined to benefit both the natural resources of the area and protect the natural stormwater management capabilities of the Northwest Quadrant. In almost all subwatersheds, the concept open-space corridor allows the desired development density, while providing aesthetic and stormwater management value.

There were however, a few areas of minor concern with the existing open-space boundaries, land use boundaries, or proposed condition flood elevations. In assessing the proposed alternative stormwater management plan's ability to allow development of the Northwest Quadrant as a closed system under development via the preliminary land use concept and open-space corridor, three modeling result indicators were assessed:

1. The proposed condition storm bounce on the wetlands within the Northwest Quadrant as compared to the Recommended Wetland Management Standards proposed in the Natural Wetland Resource Inventory Report (Bonestroo, October 2003, Page 4-15).
2. Substantial increases (greater than 2 feet) from existing to proposed 100-year, 24-hour rainfall event high water elevations (HWLs) and potential for adverse impacts on adjacent high quality Upland Communities.
3. Encroachment of the worst-case scenario (100-year 10-day runoff/snowmelt event with no infiltration) outside of the proposed open-space corridor.

With respect to the first indicator, only 3 of the wetlands delineated in the Northwest Quadrant would realize a storm bounce that exceeded the recommended bounce criteria. These wetlands are within Subwatersheds EP-073a, EP-071 and 23. In order to prevent this undesired bounce, a slightly higher stormwater management standard (or additional stormwater management storage) is required within these subwatersheds upstream of the existing wetlands.

With respect to the second indicator, only 7 of the basin would have greater than a 2-foot increase from existing to proposed 100-year, 24-hour HWLs. These Subwatershed Basins include EP-075, EP-073a, EP-071, EP-011, 12, 42, and 48 (with a maximum increase in storm bounce of 3.5 feet). Basins EP-075 and EP-073a are surrounded by Manage 2 Upland. Additional stormwater management storage is required in these subwatersheds upstream of the existing basins. Basins EP-071, EP-011, 12, 42 and 48 are surrounded by Old Field, Manage 3 Upland or upland not proposed to be managed, and therefore the bounce on these basins for the 100-year, 24-hour event is of little concern.

With respect to the third indicator, there were 11 of the 184 basins in which the worst-case scenario (100-year 10-day runoff/snowmelt event with no infiltration) extended outside of the proposed open-space corridor. After assessing options and meeting with the City Engineer, one of the following three solutions was implemented for each subwatershed to address this issue:

1. The open-space boundary was adjusted within the subwatershed to encompass the HWL and allow development to occur where the open-space boundary is too inclusive.

2. A slightly higher stormwater storage (BMP) standard within the subwatershed was implemented.

3. Floodplain outside of the open-space boundary was assumed to be filled by development with a minor increase in the HWL realized or additional storage was excavated within the open-space boundary.

With these minor modifications, the finalized modeling results indicate that implementation of the proposed alternative stormwater management and preliminary land use concepts would allow the Northwest Quadrant to be developed as a closed system, at an overall development density consistent with the City's 2020 Comprehensive Plan.

OPERATION AND MAINTENANCE

Introduction

In the not too distant past, the goal of an urban drainage system was to rush water away as fast as possible into a receiving stream or nearby lake or wetland. When it became evident that this was not a sustainable water management practice, the approach changed to the routing of water into detention ponds. Although many of these ponds were designed according to EPA's Nationwide Urban Runoff Program (NURP) criteria based on 1980s studies, they too had some deficiencies in effective treatment.

This section of the report addresses the operation and maintenance (O&M) needs associated with alternative runoff control measures. It must always be kept in mind that these approaches are as well engineered as the more structural practices utilized in the water management system. Although concrete and conduit are not dominant features, the systems do have structure to them and have been sized to perform a specific function. Simply installing and ignoring them will result in their demise over a relatively short period of time. If, however, they are installed properly, monitored for effectiveness and properly maintained, these alternative systems will provide decades of low maintenance service.

Available Resources

Most of the information available today on alternative stormwater best management practices (BMPs) can be obtained in reference material compiled by the Center for Watershed Protection at its applications website (www.stormwatercenter.net), the Low Impact Development Center (www.lid-stormwater.net), the U.S. EPA (www.epa.gov/owow/nps), or various professional trade groups. Additional information can also be obtained from environmental organizations and occasionally from local governments that post information on their websites. Since this material is readily obtainable and summarizes state-of-the-art installations, these web sites and the links they provide to other informative sites along with EOR's experienced-based knowledge of the practices provide key sources of information for this section.

Specific sources of information for this study and among the best to look for additional information are:

- Low Impact Development Center, Beltsville, Maryland (www.lowimpactdevelopment.org)
- Center for Watershed Protection, Ellicott, Maryland (www.cwp.org and www.stormcenter.net)
- U.S. Environmental Protection Agency, Office of Water, Washington D.C. (www.epa.gov/owow)
- Stormwater Magazine, Santa Barbara, CA (www.stormh2o.com)
- The Natural Resources Defense Council (NRDC), New York, NY (www.nrdc.org)
- The Puget Sound Action Team, Olympia, WA (www.psat.wa.gov)
- Prince George's County, Maryland (www.goprincegeorgescounty.com)

Maintenance Issues

The approach necessary for Inver Grove Heights to succeed in stormwater management is to reduce the volume of water moving from the land that develops into closed drainage basins. To accomplish this, a system has to be designed that will function in the long-term without the possibility of losing its ability to infiltrate.

Table 9 contains recommendations for maintenance activities and schedules for a list of alternative management practices likely to be used by the City of Inver Grove Heights. The list was compiled from similar lists prepared by the Low Impact Development Center, the Center for Watershed Protection and the U.S. EPA, and was supplemented by EOR experience in dealing with these practices.

General Approach. Many alternative practices are installed because, once established, they require far less maintenance than traditional facilities. For example, a facility that relies on vegetation to filter and infiltrate runoff will ultimately need less personnel and expense to maintain than a structural pond with an inlet and outlet that often clog. This does not mean, however, that alternative approaches can be installed and subsequently ignored. Rather, the public works department, homeowners association, commercial park or individual charged with maintenance must learn how to undertake routine inspections and maintenance, spot potential problems, and keep the system healthy if vegetation is present. This could be different than normal maintenance activity, but does not have to be more difficult. In some cases, such as open space preservation, the maintenance activity could be as simple as annually inspecting the health of the trees within the area being preserved. In other cases, just leaving the parcel alone is all that is needed.

The primary maintenance function associated with most of the alternative management techniques is inspection and repair/replacement of system components (both biological and structural). It is important to train City personnel, property managers, homeowners or any others charged with maintenance about the function and operational design of the particular practice so that they know what to look for in performance.

When vegetation is used as part of the alternative practice, it is important to use native vegetation that is adapted to this region for water, nutrient and temperature needs. The appearance of this vegetation can vary from a fully manicured appearance to a large natural prairie, with maintenance varying accordingly. Generally, the longer the system is in place, the better it will operate as roots deepen, canopy increases and plants mature.

Pre-Treatment. Most of the suite of alternative practices likely to be used by the City incorporates some type of pre-treatment. This usually consists of a sump or small-scale detention area (forebay) that allows particulate material to drop out of suspension. Assuring the continuation of this function as designed involves occasional removal of accumulated debris (sediment, litter). Movement of soil into the pre-treatment area can be minimized by repairing all erosion upgrade of the facility. If vegetation is a part of this pre-treatment, it should also be routinely checked for overall health and replaced as needed.

Sequencing of Construction. It is important to learn from past mistakes and infiltration practices have now had enough applications that we are learning how to implement them much better than before. Many of the past problems with infiltration practices built around the country as well as some local examples has been caused in the construction phase and in that first year or two of site development. The problem arises in the sequencing of construction of the practice relative to construction of the area to be treated by the practice.

Standard practice of sequencing of storm water treatment in the past has been to build the required standard NURP ponds first and the rest of the site later. This is logical in terms of capturing the large amount of sediment created during site construction. Applying that approach to infiltration practices causes a problem since the infiltration practices rely on keeping the fine sediments from accumulating in the bottom and sides where the infiltration rate is controlled.

A simple yet important method to address this problem is to change the sequence and build the infiltration practice after the area to be treated is built out and/or stabilized with vegetation. This ensures the practice is not immediately filled with fine sediment that would impact its performance. Once the overall site is stable, there is actually very little sediment that is moving through the system.

Road sanding is one additional source of sediment beyond the build out period. This typically is not a problem for two reasons. First, pretreatment that is designed into the alternative practices captures most of the sediment. Second, since sand is what is being applied, sand is often no less conductive to water than the underlying sandy soils which are part of the infiltration design.

Sediment build up during the first years can also be removed from the infiltration practices at that time as an alternative. However, by building the raingarden or other practice last, it minimizes the amount of material that needs to be removed and prevents fine sediments migrating down into the system.

Erosion during construction is still an important issue for water quality that must be addressed. In order to still address construction erosion issues while still using alternative practices and under this sequencing approach, a combination of the following methods can be used:

- Utilize good erosion control on the site – straw mulch, filter fabric (steep areas), phasing grading, temporary cover crops, contour grading, no-grade zones, silt fence, etc.
- Construct pretreatment portion of treatment system first (with follow up sediment removal after site is stabilized)
- Rough grading of infiltration practice and berming, leaving at least two feet of native material over the final design grade
- Construct temporary sediment basins that can later be filled

Remembering the basic principal that the best sediment treatment method is to prevent erosion in the first place and not allow the soil to become sediment is a common-sense lesson that should be re-emphasized.

Maintenance Personnel and Staffing. Pursuing the use of alternative stormwater management means that the City will have less pipes, less ponds, and less overall structures to maintain. The public works maintenance functions formerly dedicated to these facilities can be diverted to such activities as maintaining pre-treatment systems, keeping streets clean, monitoring (visually) drainage functions, and maintaining open space areas. If the City intends to rely heavily on biological system components (ex. bioretention or raingardens), it should eventually acquire some staff with some botanical/ecological background to manage those features.

Installation of alternative practices into a commercial, industrial or institutional setting should include a plan for who will maintain the system. Typically, a landscape firm or division of the company is charged with grounds maintenance. The responsibilities for maintenance should be clearly set out in the development-related permits issued by the City. Failure to comply with the agreement will mean that the City has to undertake the effort and charged back costs to the property owner, so careful structuring of the agreement is warranted.

The inclusion of alternative management techniques can often be an appealing aspect of a home site. Asking a homeowner to maintain a simple practice, such as a raingarden, can result in a commitment by that homeowner to the alternative management philosophy. This should be treated as an amenity because it usually involves aesthetically pleasing additions to a neighborhood. Experience in Maplewood, Minnesota has shown that most residents view upkeep of these facilities as part of maintaining their property value. However, changing ownership, poor owner health, lack of interest or many other conditions could mean that maintenance fails over time. The City again must be prepared to take over or re-negotiate for the maintenance of properties where maintenance does not otherwise occur.

Finally, maintenance should be an essential component of any alternative design. This must then be followed-up with adequate training of whoever is charged with the operation and maintenance of the facility. This is much easier to accomplish with City staff than with homeowners or commercial land managers. In any case, it should be fully defined before the system is implemented.

Enforcement and Funding. If the City does not chose to be the maintenance provider for all alternative systems installed within the City, it will need to develop some enforcement provisions defining how it will deal with owners/operators who are unwilling or unable to correct problems. Good examples of ordinance or regulations can be reviewed at www.stormcenter.net). Appendix C contains an example of a Stormwater Management/BMP Facilities Agreement from Albemarle Co., VA. The City will also need to define how it will financially implement the desired maintenance practices, keeping in mind that any non-City failure to maintain could mean a responsibility shift to the City to correct the problem.

Appropriate funding sources include a municipal stormwater utility fund, permit and inspection fees, general tax revenue, association fees, individual homeowner landscaping expenses, or even dedicated contributions. Again, all of these factors should be part of the design and implementation agreement that the City makes with the developer or the homeowner prior to approval of any alternative management practice.

Maintenance Checklist. The easiest way to assure that desired maintenance is performed is to develop a formal checklist of the various activities that need to be performed. The checklist could include the information contained in Table 9, but in a format that walks the maintenance staff or homeowner who might be unfamiliar with the system through a prescribed series of routine steps designed to assure continued effective operation of the system. A checklist not only assures that certain tasks are completed on a routine basis, it also assures consistency among inspectors and provides a historic record of maintenance and system performance. It also identifies consistently those elements causing problems and those elements that need little attention.

Specific Recommendations for IGH Practices. Previous tasks within this section of the report recommended several runoff management practices for the City to focus upon in its efforts to promote infiltration. This part of the report selects two practices with the most potential for wide-scale use, and adds some specific recommendations for maintenance.

<u>Infiltration Raingardens (Bioretention)</u>
The Environmental Protection Agency (EPA) has identified typical components found in bioretention cells. The following list is an adaptation of that list adjusted for a bioretention system that promotes infiltration as a primary function:

1. Forebay/pre-settling area to dissipate runoff energy and facilitate the settling of particulates and evaporation of excess water;
2. Vegetated buffer strips to reduce runoff velocity and filter particulate matter prior to discharge to the infiltration component;
3. Planting soil to provide the area for stormwater storage and nutrient uptake by plants (planting soils contain small amounts of clays which adsorb pollutants such as hydrocarbons, heavy metals and nutrients);
4. Vegetation (plants) to assist in the removal of water through evapotranspiration and pollutant removal through nutrient cycling;
5. Organic layer to perform the function of decomposition of organic material by providing a medium for biological growth (such as microorganisms) to degrade petroleum-based pollutants, filter pollutants and prevent soil erosion;
6. Sand bed to provide aeration and drainage of the planting soil and assist in the treatment of pollutants migrating downward from soil materials; and
7. Overflow routes for excess flow from events too large to be stored and infiltrated.

In bioretention, raingardens, vegetated swales or any similar practice that relies on soil filtration, it is important to make sure that the soils continue to function at design assumptions. Clogging of infiltration systems is the primary reason for their failure. Standing water during dry weather is a key warning sign that the system is not allowing downward movement of water.

In addition to clogging, it is possible for the adsorptive capacity of the soil to remove pollutants to be lost over time. Testing the soil characteristics should be done on occasion (see Table 1 recommendation). Replacing soil or mulch used in concert with the existing soil can be anticipated in areas receiving typical urban runoff over long time periods.

The major maintenance activities associated with these systems involve:

- vegetation management to assure plant coverage and health;
- removal of the sediment and debris accumulated in the forebay/pre-treatment parts of the system;
- erosion control in the area draining to the bioretention system; and
- routine inspection of the infiltration performance of the system, with follow-up remediation if performance is unsuitable.

Schedules for each of these components are contained in Table 9.

Disconnected Impervious Areas
A simple means that can be used to reduce runoff volume is to remove impervious area contributions to the runoff collection system. These methods can be incorporated into development design at the time of construction, or retro-fit into runoff improvement programs associated with re-development.

Examples of typical methods that can be used to disconnect impervious areas include:

- routing roof leaders to a vegetated area or a rain barrel;
- minimizing paved surfaces through such methods as using narrow streets in residential areas, limiting commercial parking space, and locating businesses and residences close to the street to minimize driveway length;
- using permeable pavement or paving blocks for low traffic and overflow parking areas;
- amending soil and/or loosening it after compaction to encourage infiltration; and
- using vegetated swales or raingardens to accept runoff rather than pipes.

Of all of those items listed above, the use of permeable pavement/pavers requires the most maintenance, especially in cold climate where sand and salt are spread routinely.

The term "permeable pavement" is used for a wide variety of surfaces that are becoming far more accepted for use even in winter climates. The list of these devices includes lattice or paving blocks, porous concrete and asphalt, reinforced/amended soil, or simply vegetated areas intended for occasional uses such as overflow or seasonal parking. Common maintenance includes watering if the surface is vegetated, keeping the infiltration surface clean by washing/vacuuming, replacing aggregate if any is used to fill voids, implementing a minimal sanding and salting plan during winter. As with any other alternative management system, routine inspection to identify problems and taking corrective action when warranted is prudent.

Regional Scale Natural Depressions. The numerous depressions in the Northwest Quadrant are important in larger events and serve to store and infiltrate runoff. Their existence today and the wooded fringes surrounding many of them is testament to their storage and infiltration capabilities. Their presence also demonstrates their robust performance under many different climatic conditions over time and through changing land uses and disturbances as this are has been altered by agricultural and pasturing uses. If these basins had not functioned well at infiltrating runoff, then many of the old growth trees, such as oaks, down in the basins would likely not exist. There would also be a defined drainage network (channels or stream bed) connecting the basins to a downstream outlet.

In order to maintain this very effective landscape of numerous depressions, measures will be needed to protect their continued effectiveness. Many of the practices discussed under the local scale practices above apply to the natural regional depressions in the system. In particular, there are two especially important aspects that the city will need to implement:

- Continued monitoring of water levels and thus infiltration capacity
- Implement temporary sediment basins in developments to retain sediment

The monitoring is important since this will serve as the trigger of when (or if) maintenance might be needed in each basin. Since each basin will likely have its unique infiltration rate, each basin should have a base-line infiltration rate at different elevations established before major development occurs. A preliminary infiltration rate vs. elevation curve should be attainable in a one to three year period, unless it is an unusually dry period. Then to evaluate when or if a basin is in need of maintenance, the on-going, monitored infiltration rate can be a comparison to the base-line rate for that basin.

Establishing the infiltration behavior of the basin is not as complicated as it may seem. In essence, a reliable infiltration rate can be estimated simply by visually (or with electronic monitoring equipment) measuring the drop in water levels over time in the basins following a major runoff event. Therefore, developing a water level elevation vs. time curve will provide the needed information to evaluate overall performance of the basin.

The landscape of the Northwest Quadrant of Inver Grove Heights also lends itself well to the water level measurement approach since there are not large extended drainage networks feeding into these basins. This is important, since the city should collect the data after the basins has filled to its highest extent and the water level is beginning to decline. This is a simple version of a water balance since infiltration is the major variable effecting water levels and by allowing the runoff event to fill the basin and then monitor falling water levels, one is effectively monitoring infiltration indirectly. Evaporation is the only other variable that may have some effect, but it is likely negligible unless the time period being measured is more than two weeks, which is not typically the case in this landscape.

Maintenance needs could vary slightly for each basin, but likely would consist of sediment removal and re-vegetation of the site (with low impact methods to prevent compaction). Other alternatives such as adding infiltration trenches or infiltration chambers along the fringes of the basin can also be used to enhance the performance, but would likely only be needed as a backup strategy.

Temporary sediment basins in the upstream watershed will prevent sediment from development grading from reaching and clogging the basin. The past agricultural history in this area suggests that the basins have been able to continue to operate effectively even with significant soil erosion in the area. Nevertheless, it would provide additional redundancy in the system to utilize temporary sediment basins to maximize the efficiency of the regional basins. Once the upstream areas are built out and raingardens or other local practices are in place, the temporary sediment basins can be filled and used for whatever purpose is desired in the development, such as additional lots, parks, or open space set-asides. By sequencing local infiltration practices to be the last phase of construction, the excavation for those practices could be used to fill in the temporary sediment basins, if desired.

Establishing an O&M Program

Formally establishing a City controlled O&M program is essential to effectively implementing alternative stormwater management. The following steps are adapted from EPA's recommended steps to establish such a program:

1. Establish a regulatory framework (ordinance or regulations) within which to formalize a cooperative agreement with a homeowner, developer or any other entity, including the City, that will be maintaining an alternative system;
2. Incorporate maintenance into design and construction specifications, including pre-treatment;
3. Identify the mechanism for stable, long-term funding (even if it is the homeowner);
4. Formalize a regular inspection schedule, criteria for departing from the schedule (ex. after a large event or when a problem is evident) and keep a log of inspections;
5. Define triggers for action (ex. 5" of sediment accumulation will trigger action to clean a forebay);
6. Prevent sediment, debris and litter from moving into and accumulating into the system;
7. Make provisions for monitoring (visual or actual sampling) of treatment criteria;
8. Develop a training and education program, possibly with a certification element;
9. If water is not draining down after 4 to 6 days, remove accumulated fine sediments until coarse soils are exposed and replant with raingarden vegetation; and
10. Develop an informational booklet for homeowners on need and role of infiltration raingardens in neighborhoods.

General O&M Recommendations

The use of "alternative" stormwater management techniques usually requires that a community's work force become familiar with a new way of maintaining water facilities. The community will find that these systems are easier to maintain than more structural systems, but it should always keep in mind that a well designed "alternative" system has also been engineered to perform a function. Although something like an infiltration raingarden might appear simplistic, it is part of a whole system that has been designed to minimize the adverse impacts of runoff.

The following are summary statements on recommendations for the City of Inver Grove Heights on operating and maintaining these systems:

- Integrate alternative stormwater management practices into site planning activities as early in the planning process as possible, while emphasizing their simple, nonstructural, low-tech, and low cost nature.
- Emphasize the value-added amenity that a homeowner, association or landowner will realize from these environmentally compatible, aesthetically pleasing, and cost-effective practices.
- Ensure the design and construction phasing incorporates pre-treat in any discharge to an alternative runoff management system to maintain its proper operation and minimize future maintenance. This is especially true for any system designed to infiltrate water.
- To focus local attention on the operation of an alternative facility, the creation of a special "district" within which the facility operates is desirable. This designation could become a selling point to emphasize the environmental stewardship within a particular development.
- The City should also establish a long-term visual monitoring plan to watch the performance of these facilities and respond accordingly if the facility does not function as designed. Monitoring can become a charge of the department carrying out the O&M function for the City or a landowner/association charge.
- Alternative designs should have as a goal the reduction of runoff and the material it carries at the source so that far more expensive downstream solutions are not needed.
- The City should consider adoption of formal "maintenance agreements" with landowners to identify the person or organization responsible for maintenance, define a control plan, specify responsibilities for financing and emergency repair and assure property access for City staff for inspection and maintenance if ever needed. Caution, however, should be taken not to make this agreement too cumbersome or complicated so that it does not drive a potential cooperator away.
- Any design involving vegetation should choose vegetation that the public wants to see - let them choose, for example, the type of plants their raingarden will contain.
- The degree of maintenance will be dependent upon the scope of project, and should be planned accordingly. For example, large-scale applications should be maintained by the City, or cooperating company or association with the technical and financial resources to do an adequate job. Small-scale projects can be handled by a homeowner.

Table 9. Maintenance Activities and Schedules for Alternative Management Practices

ALTERNATIVE MANAGEMENT PRACTICE	MAINTENANCE ACTIVITY	FREQUENCY
Bioretention (raingarden) - Soil and Mulch	• Visually inspect and repair erosion • Check the pH and apply an alkaline product, such as limestone, if needed • Re-mulch any void areas by hand as needed • Add a fresh mulch layer • Remove old mulch layer before applying new one in the spring • Remove and replace soil that has lost its ability to reduce pollutants	• Monthly • Annually • As needed • Spring and fall • Every 2-3 years • As needed (about every 10-20 years)
Bioretention (raingarden) - Plants	• Immediately after the completion of cell construction, water plant material for 14 consecutive days unless there is sufficient natural rainfall • When trees have taken root, or at least by 6 months, remove stakes and wires • Visually inspect vegetation for disease or pest problems. If treatment is warranted, use the least toxic approach • Remove and replace all dead and diseased vegetation considered beyond treatment • During times of extended drought, look for physical features of stress (un-revived wilting, yellow, spotted or brown leaves, loss of leaves, etc.). Water in the early morning as needed • Weed regularly • Prune excess growth (trimmed materials may be recycled back in with replenished mulch or land filled if there is a concern of heavy metals accumulation) • Replace vegetation in void areas	• As needed • As needed • Monthly • Twice a year, from March 15th to April 30th and October 1st to November 30th • As needed • As needed • Annually • As needed
Bioretention (raingarden) - Drainage	• Inspect the cell and make sure that the drainage paths into and within the system are clear and that ponding water dissipates over 4-6 hours (Water may pond for longer times during the winter and early spring)	• After rainfall events
Permeable Pavement/Pavers - Cleaning	• Inspection of the site after construction • Routine inspection after stabilization to assure rapid water removal and surface integrity • Conventional street sweepers equipped with vacuums, water, and brushes to restore permeability , followed by proper disposal of material collected • Follow the sweeping with high-pressure hosing of the surface pores (if necessary, add additional aggregate fill material made up of clean gravel) • Potholes and cracks can be filled with patching mixes, and spot clogging of porous concrete may be fixed by drilling approximately 0.5-inch holes every few feet • Replace damaged interlocking paving blocks • Develop plan to minimize winter sanding and de-icing	• Weekly or more often if clogging apparent • Annual detail inspection and routinely after rain events • Four times per year • After sweeping • As needed • As needed • Incorporate into maintenance plan
Dry Detention Pond	• Inspect for operation as designed • Clean and remove of debris after major storm events (>2" rainfall) • Harvest vegetation when a 50% reduction in the original open water surface area occurs • Repair embankment, side slopes and control structure if inspection reveals problem • Remove accumulated sediment from forebays or sediment storage areas when 60% of the original volume has been lost • Removal of accumulated sediment from main cells of pond once 50% of the original volume has been lost	• Annually • As needed • As needed • As needed • As needed (about every 5 years) • As needed (about every 10-20 years)
Constructed Wetland	• Inspect for operation as designed and health of vegetation • Repair erosion and replace unhealthy vegetation • Remove accumulated debris/sediment from pre-settling area (forebay)	• Annually • As needed • As needed (about every 5 years)

Table 9. Continued

ALTERNATIVE MANAGEMENT PRACTICE	MAINTENANCE ACTIVITY	FREQUENCY
Infiltration basin/trench	• Clean and remove debris after major storm events • Mow and maintain upland vegetated areas • Pre-settlement area sediment inspection • Inspect infiltration media/aggregate during dry weather to make sure well drained and functioning • Clean and/or replace infiltration media/aggregate • Remove accumulated sediment from forebays or sediment storage areas when 50% of the original volume has been reduced • Conduct inspection to assure that system de-waters within 24-48 hours; if not, replace clogged media	• As needed • Monthly • Annually • Annually • As needed after inspection • As needed (about every 5 years) • Semi-annual
Sand Filter	• Inspect for filtration design capacity retention • Remove trash and debris from control openings • Repair leaks from the sedimentation chamber or deterioration of structural components • Remove the top few inches of sand, and cultivation of the surface, when filter bed is clogged • Clean out accumulated sediment from sedimentation chamber once depth exceeds 12 inches • Clean out accumulated sediment from filter bed chamber once depth exceeds approximately ½ inch, or when the filter layer will no longer draw down within 24 hours	• Annually • As needed • Immediately when discovered • As needed (about 5-10 years) • As needed (about every 5 years) • As needed (about 5-10 years)
Vegetated Filter Strips	• Mow or trim vegetation to height appropriate for vegetation (ex. native grasses let grow to full height, turf grass cut to 3-4") • Remove litter/debris • Apply nutrients/pesticide after testing and/or inspection determines need • Aerate soil on the filter strip • Repair eroded or sparsely vegetated areas	• Weekly during growing season; dictated by type of vegetation • Weekly • As needed; do not over apply • Every 1-2 years • As needed
Dry Swales, Grassed Channels, Biofilters	• Inspect for proper operation and for erosion in or close to facility • Mow or trim vegetation; replace damaged or missing vegetation • Remove litter/debris • Stabilize eroded side slopes and bottom • Apply nutrients/pesticide after testing and/or inspection determines need • De-thatch swale bottom and removal of thatching • Disk, roto-till and/or aerate swale bottom • Scrape swale bottom and remove sediment to restore original cross section and infiltration rate • Seed or sod to restore ground cover (use proper erosion and sediment control)	• Annually (more frequently when new) • Weekly during growing season; dictated by type of vegetation • Weekly • Immediately upon discovery • As needed; do not over apply • Annually • Annually • Every 5 years • As needed
Disconnected Impervious Areas	• Inspect after rainfall events to assure proper drainage as designed, including movement of water away from building foundations • Repair vegetation damage or loss from extended wetness	• As needed • As needed
Preservation of Open Space	• Inspect to assure land being maintained according to habitat plan and that vegetation and other desirable resources remaining in good condition	• Annually

Compiled from following references: LID Center's "Bioretention Maintenance"; LID Center's "Permeable Pavers Maintenance"; EPA's National Mgmt. Measures to Control NPS Pollution from Urban Areas - Management Measure 11: O&M; and CWP "Fact Sheet" series

CONCLUSION & RECOMMENDATIONS

The objective of this study was to develop and simulate both existing conditions and a preliminary land use concept for proposed conditions to determine if any of the subwatersheds in the Northwest Quadrant are subject to undesirable water levels for the critical 100-year event. Figure 11 compares the existing and proposed conditions under the worst case scenario high water levels. The modeling completed for this study demonstrates that the preliminary land use concept and alternative stormwater management plan will mimic the existing hydrology. Furthermore, the results indicate that it is feasible to design a system that would detain, store and infiltrate the increase in stormwater runoff due to development without the need for an outlet.

Sustainability Using Raingardens

Modeling and analyzing a variety of storm event sizes including smaller events ensured that the BMPs would be designed to mimic existing conditions. As the results indicate, the raingardens designed provide a significant reduction in runoff volume to off-set development runoff. The results also demonstrate that the preliminary land use concept and stormwater management system is effective at maintaining the natural depressions and hydrology of the area. This is important in order to maintain the long-term sustainability of the natural infiltration basins.

Management & Monitoring Needs

Certain management techniques and operation and maintenance activities will be needed to ensure that the proposed storage and infiltration capacity are provided and preserved once the BMPs are constructed. The management techniques also apply to the regional infiltration basins to ensure their long-term sustainability. These management techniques include:

- Proper sizing and design – such as site selection of raingardens or basin depth, aggregate type, soil mixture, and vegetation selection.
- Proper construction techniques – such as the use of low compaction equipment, sequencing BMPs after grading and site revegetation is complete, and preventing mining or over excavation of good materials at BMP locations.
- Vegetation management – including periodic replanting if native plants die back.
- Monitoring and Sediment removal – sediment removal based on visual monitoring of water levels and infiltration rates.
- Groundwater monitoring – adding groundwater monitoring wells to the system, possibly 6-10 wells, will track water table trends and future water quality.

Continued monitoring of the identified monitoring sites this coming year is perhaps not absolutely necessary, but a good idea to provide additional calibration data for the area. The monitoring can then be used to refine the modeling as well as establish the base-line for comparison to future data and performance evaluation.

The frequency and magnitude of the maintenance for these facilities, with proper design, will be similar to current standard BMPs such as NURP ponds. Also with education, raingarden maintenance can also be completed by land owners.

Appendix A – Soil Boring Logs

EMMONS & OLIVIER RESOURCES
651 Hale Ave N.
Oakdale, MN 55128
(651) 770-8448
Fax: (651) 770-2552

Project: Inver Grove Heights
Location: Inver Grove Heights
Date: 8/16/2002
Basin ID 7
Boring Number: SB-1

Depth (ft)	Soil Boring Log	Instrument .. Units:	Sample no., type, interval	Blow counts	Sample recovery
	0-1.5', black clay LOAM, dry, organic rich				
-1-					
	1.5-2', black clay LOAM, dry, few mottles present				
-2-	2-3', brown and gray silty CLAY, moist, predominately mottled				
-3-	3-4', brown and gray clay LOAM moist, increasing sand and pebble content				
-4-	4-5', brown and gray clay LOAM, wet				
-5-	End of boring				
-6-	Water found 3' 8" below surface, after 20 minutes, water level 2' 7" below ground				
-7-					
-8-					

No. SB-1	Sheet 1 of 1	Start 8/16/2002	Finish 8/16/2002
Driller	Logged by JLO/MD	Landowner	File
Drill type hand auger	Contractor	Elev.: Surf	T.O.C.

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(651) 770-8448
Fax: (651) 770-2552

Project: Inver Grove Heights
Location: Inver Grove Heights
Date: 8/16/2002
Basin ID 6
Boring Number: SB-2

Depth (ft)	Soil Boring Log	Instrument .. Units:	Sample no., type, interval	Blow counts	Sample recovery
	0-1', black silt LOAM, few mottles present at bottom of sample				
-1-	1-2', black sandy LOAM, moist				
-2-	2-4', black SAND and GRAVEL in matrix of clay and silt, wet		#2		
-3-					
-4-	End of boring Water found at 2' below surface				
-5-					
-6-					
-7-					
-8-					

No. SB-2	Sheet 1 of 1	Start	8/16/2002	Finish	8/16/2002
Driller	Logged by JOL/MD	Landowner		File	
Drill type hand auger	Contractor	Elev.: Surf		T.O.C.	

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Fax: (651) 770-2552

Project: Inver Grove Heights
Location: Inver Grove Heights
Date: 8/16/2002
Basin ID 17
Boring Number: SB-3

Depth (ft)	Soil Boring Log	Instrument .. Units:	Sample no., type, interval	Blow counts	Sample recovery
	0-3', light brown medium grained SAND and GRAVEL, dry				
-1-					
-2-					
-3-	End of boring Completed three holes to a depth of 3', auger refusal at each hole due to large rocks				
-4-					
-5-	Site is very close to existing gravel pit, additional information may be avaible from pit operators on depth to water table				
-6-					
-7-					
-8-					

No. SB-3	Sheet 1 of 1	Start 8/16/2002	Finish 8/16/2002
Driller	Logged by JLO/MD	Landowner	File
Drill type hand auger	Contractor	Elev.: Surf	T.O.C.

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Project: Inver Grove Heights
Location: Inver Grove Heights
Date: 11/17/2003
Basin ID BP-039A
Boring Number: SB-4

Depth (ft)	Soil Boring Log	Instrument .. Units:	Sample no., type, interval	Blow counts	Sample recovery
	0-3.5', brown silt LOAM		#1		
-1-					
-2-					
-3-					
	3.5-5.0', dark brown silt LOAM		#2		
-4-					
-5-	End of boring No water present in basin				
-6-					
-7-					
-8-					

No. SB-4	Sheet 1 of 1	Start 11/17/2003	Finish 11/17/2003
Driller	Logged by MM	Landowner	File
Drill type hand auger	Contractor	Elev.: Surf	T.O.C.

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Fax: (651) 770-2552

Project: Inver Grove Heights
Location: Inver Grove Heights
Date: 11/17/2003
Basin ID EP-027A
Boring Number: SB-5

Depth (ft)	Soil Boring Log	Instrument .. Units:	Sample no., type, interval	Blow counts	Sample recovery
	0-2.5', light brown silt LOAM, few mottles present		#1		
-1-					
-2-					
	2.5-3.7', dark brown silty clay		#2		
-3-					
-4-	3.7-6.0', moist, brown SAND				
-5-					
-6-	6.0-7.0'+, moist, light brown silt LOAM		#3		
-7-	Soils becoming finer SAND with more silt at 7.0'				
	End of boring				
-8-	No water present in basin				

No. SB-5	Sheet 1 of 1	Start 11/17/2003	Finish 11/17/2003
Driller	Logged by MM	Landowner	File
Drill type hand auger	Contractor	Elev.: Surf	T.O.C.

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Fax: (651) 770-2552

Project: Inver Grove Heights
Location: Inver Grove Heights
Date: 11/17/2003
Basin ID EP-027A
Boring Number: SB-6

Depth (ft)	Soil Boring Log	Instrument .. Units:	Sample no., type, interval	Blow counts	Sample recovery
	0-1.0', light brown SAND, few mottles present				
-1-	1.0-5.0', medium grained, light brown SAND				
-2-					
-3-					
-4-					
-5-	5.0-6.0', dark brown sandy LOAM		#1		
-6-	6.0-7.0'+, moist, brown sandy clay		#2		
-7-	End of boring, upland boring				
-8-					

No. SB-6	Sheet 1 of 1	Start 11/17/2003	Finish 11/17/2003
Driller	Logged by MM	Landowner	File
Drill type hand auger	Contractor	Elev.: Surf	T.O.C.

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Fax: (651) 770-2552

Project: Inver Grove Heights
Location: Inver Grove Heights
Date: 11/17/2003
Basin ID EP-025A
Boring Number: SB-7

Depth (ft)	Soil Boring Log	Instrument .. Units:	Sample no., type, interval	Blow counts	Sample recovery
	0-3.0', light brown sandy LOAM		#1		
-1-					
-2-					
-3-	3.0-3.5', SAND				
	3.5-5.5', light brown silty SAND				
-4-					
-5-					
	5.5-6.0', dark brown silt LOAM		#2		
-6-	End of boring				
-7-	No water present in basin				
-8-					

No.	SB-7	Sheet	1 of 1	Start	11/17/2003	Finish	11/17/2003
Driller		Logged by	MM	Landowner		File	
Drill type	hand auger	Contractor		Elev.: Surf		T.O.C.	

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Fax: (651) 770-2552

Project: Inver Grove Heights
Location: Inver Grove Heights
Date: 11/17/2003
Basin ID EP-025A
Boring Number: SB-8

Depth (ft)	Soil Boring Log	Instrument .. Units:	Sample no., type, interval	Blow counts	Sample recovery
	0-3.5', sandy LOAM				
-1-					
-2-					
-3-					
	3.5-4.5' +, brown sandy clay		#1		
-4-					
	End of boring, upland boring				
-5-					
-6-					
-7-					
-8-					

No. SB-8	Sheet 1 of 1	Start 11/17/2003	Finish 11/17/2003
Driller	Logged by MM	Landowner	File
Drill type hand auger	Contractor	Elev.: Surf	T.O.C.

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Fax: (651) 770-2552

Project: Inver Grove Heights
Location: Inver Grove Heights
Date: 11/17/2003
Basin ID BP-036
Boring Number: SB-9

Depth (ft)	Soil Boring Log	Instrument .. Units:	Sample no., type, interval	Blow counts	Sample recovery
	0-0.5', dark brown silt LOAM, few mottles present				
	0.5-5.5', moist brown silty SAND		#1		
-1-					
-2-					
-3-					
-4-					
-5-					
	5.5-6.0', moist light brown coarse SAND and GRAVEL		#2		
-6-	End of boring Water present in basin				
-7-					
-8-					

No. SB-9	Sheet 1 of 1	Start 11/17/2003	Finish 11/17/2003
Driller	Logged by MM	Landowner	File
Drill type hand auger	Contractor	Elev.: Surf	T.O.C.

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651 Hale Ave N.
Oakdale, MN 55128
(651) 770-8448
Fax: (651) 770-2552

Project: Inver Grove Heights
Location: Inver Grove Heights
Date: 11/17/2003
Basin ID BP-036
Boring Number: SB-10

Depth (ft)	Soil Boring Log	Instrument .. Units:	Sample no., type, interval	Blow counts	Sample recovery
	0-3.0' +, brown sandy LOAM w/gravel		#1		
-1-					
-2-					
-3-	End of boring, upland boring below 3.0 ft. because of gravel content				
-4-	Three borings attempted, unable to bore below 3.0 ft. because of gravel content				
-5-					
-6-					
-7-					
-8-					

No. SB-10	Sheet 1 of 1	Start 11/17/2003	Finish 11/17/2003
Driller	Logged by MM	Landowner	File
Drill type hand auger	Contractor	Elev.: Surf	T.O.C.

EMMONS & OLIVIER RESOURCES
651 Hale Ave N.
Oakdale, MN 55128
(651) 770-8448
Fax: (651) 770-2552

Project: Inver Grove Heights
Location: Inver Grove Heights
Date: 11/17/2003
Basin ID EP-059A
Boring Number: SB-11

Depth (ft)	Soil Boring Log	Instrument .. Units:	Sample no., type, interval	Blow counts	Sample recovery
	0-0.8', light brown sandy LOAM				
-1-	0.8-1.0', wet brown SAND		#1		
	1.0-2.0', moist sandy CLAY		#2		
-2-	2.0-2.5' +, moist, dark brown, silty CLAY		#3		
	End of boring				
-3-					
	Perched water table at 0.8'				
-4-	Depth to water- 2.0' After 15 min.- 1.9'				
	Water present in basin				
-5-					
-6-					
-7-					
-8-					

No. SB-11	Sheet 1 of 1	Start 11/17/2003	Finish 11/17/2003
Driller	Logged by MM	Landowner	File
Drill type hand auger	Contractor	Elev.: Surf	T.O.C.

EMMONS & OLIVIER RESOURCES
651 Hale Ave N.
Oakdale, MN 55128
(651) 770-8448
Fax: (651) 770-2552

Project: Inver Grove Heights
Location: Inver Grove Heights
Date: 11/17/2003
Basin ID EP-059A
Boring Number: SB-12

Depth (ft)	Soil Boring Log	Instrument .. Units:	Sample no., type, interval	Blow counts	Sample recovery
	0-1.0', silty LOAM		#1		
-1-	1.0-2.0', dark brown sandy LOAM		#2		
-2-	2.0-3.5', moist reddish brown sandy CLAY		#3		
-3-					
	End of boring, upland boring Depth to water- 3.3' After 15 min.- 3.2'				
-4-					
-5-					
-6-					
-7-					
-8-					

No. SB-12	Sheet 1 of 1	Start 11/17/2003	Finish 11/17/2003
Driller	Logged by MM	Landowner	File
Drill type hand auger	Contractor	Elev.: Surf	T.O.C.

EMMONS & OLIVIER RESOURCES
651 Hale Ave N.
Oakdale, MN 55128
(651) 770-8448
Fax: (651) 770-2552

Project: Inver Grove Heights
Location: Inver Grove Heights
Date: 11/17/2003
Basin ID EP-066A
Boring Number: SB-13

Depth (ft)	Soil Boring Log	Instrument .. Units:	Sample no., type, interval	Blow counts	Sample recovery
	0-0.8', SAND and GRAVEL				
-1- -2-	0.8-3.0', dark brown silt LOAM		#1		
-3- -4-	3.0-4.7', dark brown clay LOAM		#2		
-5-	4.7-5.0', light brown silt LOAM				
-6- -7- -8-	End of boring No water present in basin, pastured				

No.	SB-13	Sheet	1 of 1	Start	11/17/2003	Finish	11/17/2003
Driller		Logged by	MM	Landowner		File	
Drill type	hand auger	Contractor		Elev.: Surf		T.O.C.	

EMMONS & OLIVIER RESOURCES
651 Hale Ave N.
Oakdale, MN 55128
(651) 770-8448
Fax: (651) 770-2552

Project: Inver Grove Heights
Location: Inver Grove Heights
Date: 11/17/2003
Basin ID EP-066A
Boring Number: SB-14

Depth (ft)	Soil Boring Log	Instrument .. Units:	Sample no., type, interval	Blow counts	Sample recovery
	0-2.0', brown silty LOAM				
-1-					
-2-	2.0-4.5', brown sandy LOAM		#1		
-3-					
-4-					
	4.5-5.5', brown sandy LOAM w/mottles				
-5-					
	End of boring, upland boring				
-6-					
-7-					
-8-					

No. SB-14	Sheet 1 of 1	Start 11/17/2003	Finish 11/17/2003
Driller	Logged by MM	Landowner	File
Drill type hand auger	Contractor	Elev.: Surf	T.O.C.

Appendix B – Existing/Proposed Hydrologic Input Parameters

Appendix B. Existing and Proposed Condition Hydrologic Input Parameters

Existing Condition Input Parameters

Node Name	Area (acres)	Width (feet)	Impervious (%)	Slope (%)	Pervious Manning's "n"	Average Capillary Suction	Saturated Hydraulic Conductivity	Initial Moisture Deficit
BP-002	31.4	518	35	3.9	0.03	5	0.20	0.20
BP-004	37.3	813	48	6.8	0.03	5	0.15	0.16
BP-005	49.1	532	42	3.7	0.03	5	0.15	0.15
BP-032	11.6	358	5	12.8	0.06	5	0.23	0.21
BP-033a	28.3	314	16	1.5	0.05	5	0.25	0.22
BP-033b	9.6	150	1	3.6	0.05	4	0.29	0.24
BP-033c	5.6	201	0	8.5	0.05	4	0.27	0.23
BP-033d	13.7	236	0	1.7	0.03	5	0.20	0.20
BP-034	11.0	306	13	7.4	0.04	5	0.19	0.19
BP-035	12.2	393	1	10.1	0.03	4	0.29	0.24
BP-036	13.5	352	28	4.6	0.03	4	0.28	0.23
BP-038a	11.0	361	25	14.2	0.08	5	0.20	0.19
BP-038b	15.5	242	14	5.4	0.06	6	0.16	0.18
BP-038c	7.4	299	19	7.4	0.03	6	0.16	0.18
BP-039a	15.1	412	16	4.3	0.04	6	0.19	0.19
BP-039b	6.1	139	18	3.8	0.03	6	0.15	0.17
BP-039c	3.3	142	13	7.2	0.06	6	0.15	0.17
BP-039d	3.9	120	18	2.3	0.03	5	0.23	0.21
BP-039e	10.8	621	12	6.9	0.05	5	0.19	0.19
BP-039f	4.2	213	8	6.0	0.07	6	0.15	0.17
BP-048a	4.2	262	0	6.9	0.05	4	0.29	0.24
BP-048b	9.3	270	0	4.3	0.03	3	0.34	0.26
BP-048c	7.5	325	10	3.6	0.03	4	0.28	0.24
BP-048d	13.5	327	3	2.9	0.03	4	0.30	0.24
BP-048e	11.9	253	32	4.7	0.05	6	0.18	0.19
BP-049a	16.6	329	3	4.5	0.05	6	0.18	0.19
BP-049b	7.3	264	2	8.3	0.06	6	0.18	0.19
DP-006	6.2	254	10	7.5	0.04	5	0.25	0.22
EP-005a	31.9	1143	57	2.8	0.04	4	0.30	0.24
EP-005b	53.0	515	31	4.1	0.05	5	0.21	0.20
EP-005c	6.8	427	25	3.1	0.03	5	0.23	0.21
EP-005d	6.8	164	22	0.6	0.03	5	0.25	0.22
EP-009	16.1	297	14	9.2	0.04	4	0.28	0.24
EP-010a	10.5	200	4	14.4	0.06	5	0.25	0.22
EP-010b	30.6	606	8	6.5	0.05	5	0.24	0.21
EP-011	13.9	190	12	4.4	0.03	4	0.28	0.24
EP-012a	11.4	341	6	6.3	0.04	6	0.19	0.19
EP-012b	5.0	210	2	11.5	0.04	6	0.15	0.17
EP-013	42.9	480	9	5.3	0.04	5	0.26	0.22
EP-016a	96.9	809	33	4.1	0.04	5	0.37	0.32
EP-016b	15.7	335	0	7.5	0.06	5	0.23	0.21
EP-016c	10.0	151	18	1.9	0.07	4	0.27	0.23
EP-016d	41.8	1160	13	9.2	0.05	5	0.23	0.21
EP-016e	2.5	277	0	19.0	0.04	4	0.30	0.25
EP-016f	5.0	317	0	10.0	0.04	5	0.24	0.22
EP-016g	9.0	408	4	11.7	0.05	4	0.28	0.23
EP-018	12.4	364	19	5.7	0.04	5	0.22	0.21
EP-025a	22.0	295	2	7.4	0.05	4	0.27	0.23
EP-025b	10.6	444	9	13.8	0.05	5	0.22	0.21
EP-027a	55.4	656	10	7.3	0.04	5	0.23	0.21
EP-027b	32.0	432	9	5.9	0.03	5	0.23	0.21
EP-027c	22.4	428	13	8.1	0.04	5	0.26	0.23
EP-027d	7.1	282	1	10.5	0.03	4	0.30	0.24
EP-027e	7.9	345	41	6.8	0.05	4	0.27	0.23
EP-027f	6.0	219	0	11.7	0.08	2	0.44	0.31
EP-027g	2.8	120	0	11.0	0.05	4	0.30	0.25
EP-031a	25.0	523	2	6.9	0.06	5	0.24	0.21
EP-031b	13.5	736	30	7.0	0.04	5	0.25	0.22
EP-031c	8.2	179	6	6.4	0.03	6	0.17	0.18
EP-032	11.7	402	7	8.2	0.06	5	0.22	0.20
EP-034	38.1	422	9	5.4	0.04	5	0.22	0.20
EP-035a	15.6	309	6	8.5	0.05	4	0.28	0.24
EP-035b	4.3	133	17	4.0	0.07	5	0.23	0.21
EP-035c	5.2	227	7	10.8	0.03	5	0.22	0.21
EP-035d	5.5	219	11	9.1	0.03	4	0.30	0.24
EP-036a	20.2	474	25	3.9	0.03	6	0.16	0.18
EP-038a	8.4	364	15	9.6	0.05	5	0.26	0.23
EP-038b	7.9	215	11	6.5	0.05	5	0.26	0.23
EP-039	36.5	375	4	6.2	0.04	4	0.28	0.23
EP-044	40.0	611	2	7.0	0.03	4	0.27	0.23
EP-045	25.8	384	2	5.2	0.03	5	0.20	0.20
EP-049a	25.6	474	6	10.4	0.07	5	0.21	0.20
EP-049b	8.3	372	0	14.4	0.05	5	0.22	0.21
EP-049c	25.5	313	0	3.7	0.05	5	0.20	0.20
EP-049d	16.2	372	9	6.1	0.06	5	0.25	0.22
EP-049e	4.6	387	20	12.3	0.06	5	0.24	0.22
EP-049f	28.0	305	1	4.7	0.04	6	0.17	0.18
EP-049g	8.8	256	1	5.9	0.04	5	0.20	0.20
EP-057a	11.9	429	12	12.9	0.06	6	0.18	0.19
EP-057b	8.8	174	13	4.7	0.05	6	0.16	0.18
EP-058a	45.9	595	8	4.8	0.05	5	0.21	0.20
EP-058b	3.7	1249	23	2.8	0.03	6	0.15	0.17
EP-058c	3.1	322	7	6.4	0.03	6	0.15	0.17
EP-059a	26.2	588	18	6.2	0.04	6	0.18	0.19
EP-059b	29.2	420	10	3.3	0.03	6	0.16	0.18
EP-059c	10.9	290	4	2.9	0.03	5	0.21	0.20
EP-059d	1.1	109	18	4.4	0.03	6	0.15	0.17
EP-059e	1.6	89	17	3.6	0.03	6	0.15	0.17
EP-060a	26.6	1504	33	3.8	0.03	5	0.26	0.22
EP-060b	22.2	384	4	5.1	0.03	5	0.19	0.19
EP-060c	2.5	178	7	9.3	0.03	6	0.16	0.18
EP-064	13.3	237	19	5.7	0.03	4	0.31	0.25
EP-066a	32.5	536	7	4.5	0.03	4	0.27	0.23
EP-066b	18.5	357	8	2.7	0.03	4	0.30	0.24
EP-066c	5.8	209	33	3.3	0.03	4	0.30	0.24
EP-067a	49.9	618	7	2.7	0.04	4	0.28	0.23
EP-067b	5.7	254	0	3.7	0.04	4	0.30	0.25
EP-068a	15.2	354	10	4.1	0.03	4	0.32	0.25
EP-068b	11.9	336	30	5.2	0.04	4	0.28	0.23
EP-071	45.8	540	16	4.3	0.03	5	0.19	0.19
EP-072	33.4	606	16	5.1	0.03	5	0.19	0.19
EP-073a	13.6	435	10	7.1	0.05	5	0.24	0.21
EP-073b	12.0	366	3	4.8	0.03	4	0.31	0.25
EP-073c	9.4	203	2	2.2	0.03	4	0.31	0.25
EP-073d	3.3	198	1	3.8	0.03	3	0.34	0.27
EP-074a	19.1	315	15	0.7	0.05	5	0.21	0.20
EP-074b	7.1	179	4	12.0	0.05	5	0.26	0.23
EP-074c	4.4	1048	14	12.7	0.04	5	0.20	0.20
EP-074d	14.4	412	14	5.0	0.05	6	0.18	0.18
EP-074e	12.8	84	9	2.8	0.06	6	0.15	0.17
EP-074f	4.3	333	33	0.5	0.05	5	0.24	0.21
EP-075	15.5	449	8	12.0	0.05	5	0.26	0.23
EP-076	15.3	392	34	3.8	0.03	6	0.19	0.19
EP-078	42.5	661	34	4.7	0.03	4	0.20	0.18
EP-079a	36.7	366	32	5.2	0.04	4	0.22	0.20
EP-079b	3.8	152	21	2.9	0.03	6	0.15	0.17
EP-080a	129.6	795	30	3.8	0.04	4	0.23	0.20
EP-080b	17.5	457	6	1.9	0.04	5	0.24	0.22
EP-080c	19.0	447	2	5.8	0.04	5	0.23	0.21
EP-080d	9.7	169	17	1.9	0.03	5	0.21	0.20
EP-080e	4.3	180	18	2.9	0.03	5	0.24	0.22
EP-102a	29.1	312	27	1.2	0.03	4	0.27	0.23
EP-102b	11.3	166	20	3.8	0.03	4	0.28	0.23
EP-102c	19.0	255	26	56.2	0.03	5	0.25	0.22
EP-104	41.6	594	9	3.3	0.04	5	0.19	0.19
EP-106	13.6	296	8	6.4	0.04	6	0.18	0.19
EP-107a	42.9	613	17	3.5	0.04	5	0.24	0.22
EP-107b	47.2	441	8	1.5	0.04	4	0.27	0.23
EP-107c	11.4	200	9	2.8	0.03	4	0.28	0.24
EP-107d	4.4	222	4	1.6	0.05	4	0.30	0.25
EP-107e	2.1	146	22	7.6	0.07	4	0.30	0.25
QP-5	29.2	618	6	3.5	0.05	4	0.30	0.24
SB-11	10.5	250	5	0.1	0.08	4	0.28	0.24
SB-19	11.7	271	0	0.1	0.02	4	0.26	0.23
SB-20	5.0	200	14	0.1	0.04	2	0.45	0.31
SB-24	3.3	83	27	0.1	0.06	2	0.45	0.31
SB-29	7.9	197	45	0.0	0.06	4	0.30	0.24
SB-8	21.3	356	4	0.1	0.08	5	0.24	0.22
SP-10	3.6	465	17	0.4	0.08	6	0.15	0.17
SP-12	25.1	473	6	0.1	0.08	4	0.26	0.23
SP-13	5.3	293	0	0.1	0.06	4	0.26	0.22
SP-14	20.7	273	2	0.1	0.08	5	0.22	0.21
SP-15	21.7	368	0	0.1	0.08	5	0.25	0.22
SP-16	18.8	399	10	0.0	0.07	4	0.29	0.24
SP-17	16.5	367	6	0.1	0.08	5	0.21	0.20
SP-18	7.3	316	0	0.1	0.03	3	0.34	0.26
SP-2	17.6	289	15	0.1	0.08	5	0.21	0.20
SP-21	16.4	272	6	0.1	0.06	4	0.34	0.26
SP-22	8.7	219	5	0.1	0.05	3	0.38	0.28
SP-23	6.2	258	19	0.1	0.07	4	0.29	0.24
SP-25	3.1	150	11	0.1	0.07	5	0.26	0.23
SP-27	15.2	370	8	0.1	0.07	4	0.26	0.22
SP-28	17.0	398	6	0.1	0.07	5	0.22	0.20
SP-3	34.1	370	5	0.0	0.07	6	0.18	0.18
SP-4	10.3	245	6	0.1	0.07	5	0.23	0.21
SP-5	12.9	336	3	0.0	0.06	6	0.15	0.17
SP-6	31.4	354	7	0.1	0.07	5	0.22	0.20
SP-7	19.9	387	4	0.1	0.07	5	0.20	0.20
SP-9	2.6	62	9	0.1	0.07	4	0.31	0.24

Proposed Condition Input Parameters

Node Name	Area (acres)	Width (feet)	Impervious (%)	Slope (%)	Pervious Manning's "n"	Average Capillary Suction	Saturated Hydraulic Conductivity	Initial Moisture Deficit
2	4.8	110	27	4.2	0.08	5	0.21	0.20
3	2.0	100	28	20.1	0.07	6	0.19	0.19
4	2.3	113	25	3.2	0.06	4	0.30	0.24
5	12.9	211	26	6.3	0.06	5	0.21	0.20
6	3.3	111	30	4.3	0.06	6	0.17	0.18
7	5.2	139	30	6.8	0.06	5	0.19	0.19
8	2.0	75	30	1.7	0.06	6	0.19	0.19
9	2.3	118	18	1.9	0.08	6	0.15	0.17
10	2.8	148	26	6.2	0.07	4	0.29	0.24
11	14.3	189	21	7.2	0.07	5	0.24	0.21
12	9.6	137	43	0.7	0.06	6	0.18	0.19
13	1.1	87	38	3.6	0.06	5	0.24	0.21
14	3.1	113	32	3.7	0.06	5	0.25	0.22
15	4.3	150	25	4.6	0.06	6	0.15	0.17
16	1.4	75	28	4.6	0.06	6	0.16	0.18
17	4.6	151	30	4.4	0.06	6	0.15	0.17
19	2.8	132	51	6.4	0.06	5	0.26	0.23
20	4.7	128	35	3.3	0.06	4	0.30	0.24
21	8.1	253	3	10.7	0.08	4	0.29	0.24
22	6.4	173	51	5.4	0.06	5	0.23	0.21
24	10.8	291	8	6.8	0.07	4	0.29	0.24
25	6.8	278	60	6.5	0.06	4	0.34	0.26
26	11.0	243	26	5.3	0.06	5	0.19	0.19
27	7.8	214	30	5.0	0.06	6	0.16	0.18
28	7.1	177	23	3.2	0.06	6	0.15	0.17
29	4.3	193	12	3.1	0.08	6	0.15	0.17
30	3.0	93	18	3.0	0.08	6	0.18	0.19
31	10.8	198	29	3.0	0.06	6	0.16	0.18
32	6.9	234	4	7.2	0.08	5	0.23	0.21
33	11.3	203	22	8.6	0.08	5	0.24	0.22
34	14.8	373	26	4.6	0.06	6	0.17	0.18
35	4.8	205	23	7.5	0.06	5	0.22	0.21
36	8.3	202	5	7.0	0.08	5	0.26	0.22
37	7.4	152	26	9.2	0.08	4	0.28	0.24
38	1.2	56	68	3.7	0.08	4	0.30	0.25
39	11.1	223	42	8.3	0.08	4	0.28	0.24
40	13.5	302	20	13.4	0.08	4	0.27	0.23
41	5.3	283	20	6.4	0.07	5	0.24	0.21
42	17.8	333	12	7.5	0.08	5	0.21	0.20
43	4.0	164	71	6.9	0.06	6	0.19	0.19
44	4.3	129	60	6.5	0.06	3	0.40	0.29
45	2.2	72	58	4.7	0.06	5	0.20	0.20
46	2.6	128	37	13.4	0.06	4	0.27	0.23
47	8.3	218	30	9.6	0.07	4	0.30	0.25
48	20.0	333	52	6.6	0.06	3	0.37	0.27
49	3.0	82	35	7.0	0.06	4	0.30	0.25
50	7.9	197	38	1.3	0.06	4	0.30	0.25
51	17.0	398	52	8.1	0.07	5	0.22	0.20
52	15.2	370	12	5.4	0.07	4	0.26	0.22
53	2.6	62	9	5.4	0.07	4	0.31	0.24
54	5.0	117	42	10.7	0.06	2	0.45	0.31
BP-002	31.4	518	35	3.9	0.03	5	0.20	0.20
BP-004	37.3	813	48	6.8	0.03	5	0.15	0.16
BP-005	49.1	532	42	3.7	0.03	5	0.15	0.15
BP-032	11.6	358	18	12.8	0.06	5	0.23	0.21
BP-033a	28.3	314	18	1.5	0.05	5	0.25	0.22
BP-033b	9.6	150	13	3.6	0.05	4	0.29	0.24
BP-033c	5.6	201	52	8.5	0.05	4	0.27	0.23
BP-033d	13.7	236	8	1.7	0.03	5	0.20	0.20
BP-034	11.0	306	13	7.4	0.04	5	0.19	0.19
BP-035	12.2	393	1	10.1	0.03	4	0.29	0.24
BP-036	13.5	352	28	4.6	0.03	4	0.28	0.23
BP-038a	11.0	361	33	14.2	0.08	5	0.20	0.19
BP-038b	15.5	242	14	5.4	0.06	6	0.16	0.18
BP-038c	7.4	299	20	7.4	0.03	6	0.16	0.18
BP-039a	15.1	412	16	4.3	0.04	6	0.19	0.19
BP-039b	6.1	139	18	3.8	0.03	6	0.15	0.17
BP-039c	3.3	142	13	7.2	0.06	6	0.15	0.17
BP-039d	3.9	120	18	2.3	0.03	5	0.23	0.21
BP-039e	10.8	621	12	6.9	0.05	5	0.19	0.19
BP-039f	4.2	213	8	6.0	0.07	6	0.15	0.17
BP-048a	4.2	262	0	6.9	0.05	4	0.29	0.24
BP-048b	9.3	270	0	4.3	0.03	3	0.34	0.26
BP-048c	7.5	325	10	3.6	0.03	4	0.28	0.24
BP-048d	13.5	327	3	2.9	0.03	4	0.30	0.24
BP-048e	11.9	253	27	4.7	0.05	6	0.18	0.19
BP-049a	16.6	329	3	4.5	0.05	6	0.18	0.19
BP-049b	7.3	264	2	8.3	0.06	6	0.18	0.19
DP-006	6.2	254	10	7.5	0.04	5	0.25	0.22
EP-005a	31.9	1143	57	2.8	0.04	4	0.30	0.24
EP-005b	53.0	515	31	4.1	0.05	5	0.21	0.20
EP-005c	6.8	427	23	3.1	0.03	5	0.23	0.21
EP-005d	6.8	164	22	0.6	0.03	5	0.25	0.22
EP-009	16.1	297	28	9.2	0.04	4	0.28	0.24
EP-010a	10.5	200	21	14.4	0.06	5	0.25	0.22
EP-010b	30.6	606	21	6.5	0.05	5	0.24	0.21
EP-011	13.9	190	60	4.4	0.03	4	0.28	0.24
EP-012a	11.4	341	52	6.3	0.04	6	0.19	0.19
EP-012b	5.0	210	52	11.5	0.04	6	0.15	0.17
EP-013	42.9	480	26	5.3	0.04	5	0.26	0.22
EP-016a	96.9	809	39	4.1	0.04	5	0.37	0.32
EP-016b	15.7	335	1	7.5	0.06	5	0.23	0.21
EP-016c	10.0	151	35	1.9	0.07	4	0.27	0.23
EP-016d	41.8	1160	13	9.2	0.05	5	0.23	0.21
EP-016e	2.5	277	37	19.0	0.04	4	0.30	0.25
EP-016f	5.0	317	24	10.0	0.04	5	0.24	0.22
EP-016g	9.0	408	26	11.7	0.05	4	0.28	0.23
EP-018	12.4	364	19	5.7	0.04	5	0.22	0.21
EP-025a	22.0	295	55	7.4	0.05	4	0.27	0.23
EP-025b	10.6	444	28	13.8	0.05	5	0.22	0.21
EP-027a	55.4	656	54	7.3	0.04	5	0.23	0.21
EP-027b	32.0	432	70	5.9	0.03	5	0.23	0.21
EP-027c	22.4	428	37	8.1	0.04	5	0.26	0.23
EP-027d	7.1	282	22	10.5	0.03	4	0.30	0.24
EP-027e	7.9	345	35	6.8	0.05	4	0.27	0.23
EP-027f	6.0	219	15	11.7	0.08	2	0.44	0.31
EP-027g	2.8	120	0	11.0	0.05	4	0.30	0.25
EP-031a	25.0	523	12	6.9	0.06	5	0.24	0.21
EP-031b	13.5	736	35	7.0	0.04	5	0.25	0.22
EP-031c	8.2	179	37	6.4	0.03	6	0.17	0.18
EP-032	11.7	402	24	8.2	0.06	5	0.22	0.20
EP-034	38.1	422	63	5.4	0.04	5	0.22	0.20
EP-035a	15.6	309	29	8.5	0.05	4	0.28	0.24
EP-035b	4.3	133	28	4.0	0.07	5	0.23	0.21
EP-035c	5.2	227	14	10.8	0.03	5	0.22	0.21
EP-035d	5.5	219	27	9.1	0.03	4	0.30	0.24
EP-036a	20.2	474	52	3.9	0.03	6	0.16	0.18
EP-038a	8.4	364	25	9.6	0.05	5	0.26	0.23
EP-038b	7.9	215	52	6.5	0.05	5	0.26	0.23
EP-039	36.5	375	14	6.2	0.04	4	0.28	0.23
EP-044	40.0	611	5	7.0	0.03	4	0.27	0.23
EP-045	25.8	384	11	5.2	0.03	5	0.20	0.20
EP-049a	25.6	474	16	10.4	0.07	5	0.21	0.20
EP-049b	8.3	372	10	14.4	0.05	5	0.22	0.21
EP-049c	25.5	313	4	3.7	0.05	5	0.20	0.20
EP-049d	16.2	372	45	6.1	0.06	5	0.25	0.22
EP-049e	4.6	387	35	12.3	0.06	5	0.24	0.22
EP-049f	28.0	305	8	4.7	0.04	6	0.17	0.18
EP-049g	8.8	256	1	5.9	0.04	5	0.20	0.20
EP-057a	11.9	429	12	12.9	0.06	6	0.18	0.19
EP-057b	8.8	174	13	4.7	0.05	6	0.16	0.18
EP-058a	45.9	595	8	4.8	0.05	5	0.21	0.20
EP-058b	3.7	1249	33	2.8	0.03	6	0.15	0.17
EP-058c	3.1	322	7	6.4	0.03	6	0.15	0.17
EP-059a	26.2	588	31	6.2	0.04	6	0.18	0.19
EP-059b	29.2	420	57	3.3	0.03	6	0.16	0.18
EP-059c	10.9	290	41	2.9	0.03	5	0.21	0.20
EP-059d	1.1	109	44	4.4	0.03	6	0.15	0.17
EP-059e	1.6	89	45	3.6	0.03	6	0.15	0.17
EP-060a	26.6	1504	60	3.8	0.03	5	0.26	0.22
EP-060b	22.2	384	42	5.1	0.03	5	0.19	0.19
EP-060c	2.5	178	33	9.3	0.03	6	0.16	0.18
EP-064	13.3	237	19	5.7	0.03	4	0.31	0.25
EP-066a	32.5	536	48	4.5	0.03	4	0.27	0.23
EP-066b	18.5	357	52	2.7	0.03	4	0.30	0.24
EP-066c	5.8	209	56	3.3	0.03	4	0.30	0.24
EP-067a	49.9	618	8	2.7	0.04	4	0.28	0.23
EP-067b	5.7	254	0	3.7	0.04	4	0.30	0.25
EP-068a	15.2	354	10	4.1	0.03	4	0.32	0.25
EP-068b	11.9	336	30	5.2	0.04	4	0.28	0.23
EP-071	45.8	540	51	4.3	0.03	5	0.19	0.19
EP-072	33.4	606	45	5.1	0.03	5	0.19	0.19
EP-073a	13.6	435	28	7.1	0.05	5	0.24	0.21
EP-073b	12.0	366	47	4.8	0.03	4	0.31	0.25
EP-073c	9.4	203	48	2.2	0.03	4	0.31	0.25
EP-073d	3.3	198	47	3.8	0.03	3	0.34	0.27
EP-074a	19.1	315	15	0.7	0.05	5	0.21	0.20
EP-074b	7.1	179	15	12.0	0.05	5	0.26	0.23
EP-074c	4.4	1048	22	12.7	0.04	5	0.20	0.20
EP-074d	14.4	412	29	5.0	0.05	6	0.18	0.18
EP-074e	12.8	84	28	2.8	0.06	6	0.15	0.17
EP-074f	4.3	333	34	0.5	0.05	5	0.24	0.21
EP-075	15.5	449	8	12.0	0.05	5	0.26	0.23
EP-076	15.3	392	63	3.8	0.03	6	0.19	0.19
EP-078	42.5	661	38	4.7	0.03	4	0.20	0.18
EP-079a	36.7	366	32	5.2	0.04	4	0.22	0.20
EP-079b	3.8	152	48	2.9	0.03	6	0.15	0.17
EP-080a	129.6	795	33	3.8	0.04	4	0.23	0.20
EP-080b	17.5	457	45	1.9	0.04	5	0.24	0.22
EP-080c	19.0	447	2	5.8	0.04	5	0.23	0.21
EP-080d	9.7	169	17	1.9	0.03	5	0.21	0.20
EP-080e	4.3	180	18	2.9	0.03	5	0.24	0.22
EP-102a	29.1	312	49	1.2	0.03	4	0.27	0.23
EP-102b	11.3	166	20	3.8	0.03	4	0.28	0.23
EP-102c	19.0	255	34	56.2	0.03	5	0.25	0.22
EP-106	13.6	296	28	6.4	0.04	6	0.18	0.19
EP-107a	42.9	613	27	3.5	0.04	5	0.24	0.22
EP-107b	47.2	441	23	1.5	0.04	4	0.27	0.23
EP-107c	11.4	200	37	2.8	0.03	4	0.28	0.24
EP-107d	4.4	222	30	1.6	0.05	4	0.30	0.25
EP-107e	2.1	146	30	7.6	0.07	4	0.30	0.25
QP-5	29.2	618	28	3.5	0.05	4	0.30	0.24

Appendix C – Example Stormwater Management/BMP Facility Agreement

STORMWATER MANAGEMENT/BMP

FACILITIES AGREEMENT

Albemarle County, VA

Water Resources Management

(804) 296-5861

This document is downloadable in WordPerfect format.

THIS AGREEMENT, made and entered into this ___ day of ___________, 19___, by and between (Insert Full Name of Owner)_______________________________________ hereinafter called the "Landowner", and the Board of Supervisors of Albemarle County, Virginia, hereinafter called the "County". WITNESSETH, that WHEREAS, the Landowner is the owner of certain real property described as (Albemarle County tax Map/Parcel Identification Number) ____________________________________ as recorded by deed in the land records of Albemarle County, Virginia, Deed Book _________ Page _________, hereinafter called the "Property". WHEREAS, the Landowner is proceeding to build on and develop the property; and WHEREAS, the Site Plan/Subdivision Plan known as ______________________________, (Name of Plan/Development) hereinafter called the "Plan", which is expressly made a part hereof, as approved or to be approved by the County, provides for detention of stormwater within the confines of the property; and

WHEREAS, the County and the Landowner, its successors and assigns, including any homeowners association, agree that the health, safety, and welfare of the residents of Albemarle County, Virginia, require that on-site stormwater management/BMP facilities be constructed and maintained on the Property; and

WHEREAS, the County requires that on-site stormwater management/BMP facilities as shown on the Plan be constructed and adequately maintained by the Landowner, its successors and assigns, including any homeowners association.

NOW, THEREFORE, in consideration of the foregoing premises, the mutual covenants contained herein, and the following terms and conditions, the parties hereto agree as follows:

1. The on-site stormwater management/BMP facilities shall be constructed by the Landowner, its successors and assigns, in accordance with the plans and specifications identified in the Plan.

2. The Landowner, its successors and assigns, including any homeowners association, shall adequately maintain the stormwater management/BMP facilities. This includes all pipes and channels built to convey stormwater to the facility, as well as all structures, improvements, and vegetation provided to control the quantity and quality of the stormwater. Adequate maintenance is herein defined as good working condition so that these facilities are performing their design functions. The Annual Inspection Report form dated 6/2/92 (or latest date form available) is to be used to establish what good working condition is acceptable to the County.

3. The Landowner, its successors and assigns, shall inspect the stormwater management/BMP facility and submit an inspection report annually. The purpose of the inspection is to assure safe and proper functioning of the facilities. The inspection shall cover the entire facilities, berms, outlet structure, pond areas, access roads, etc. Deficiencies shall be noted in the inspection report.

4. The Landowner, its successors and assigns, hereby grant permission to the County, its authorized agents and employees, to enter upon the Property and to inspect the stormwater management/BMP facilities whenever the County deems necessary. The purpose of inspection is to follow-up on reported deficiencies and/or to respond to

citizen complaints. The County shall provide the Landowner, its successors and assigns, copies of the inspection findings and a directive to commence with the repairs if necessary.

5. In the event the Landowner, its successors and assigns, fails to maintain the stormwater-management/BMP facilities in good working condition acceptable to the County, the County may enter upon the Property and take whatever steps necessary to correct deficiencies identified in the inspection report and to charge the costs of such repairs to the Landowner, its successors and assigns. This provision shall not be construed to allow the County to erect any structure of permanent nature on the land of the Landowner outside of the easement for the stormwater management/BMP facilities. It is expressly understood and agreed that the County is under no obligation to routinely maintain or repair said facilities, and in no event shall this Agreement be construed to impose any such obligation on the County.

6. The Landowner, its successors and assigns, will perform the work necessary to keep these facilities in good working order as appropriate. In the event a maintenance schedule for the stormwater management/BMP facilities (including sediment removal) is outlined on the approved plans, the schedule will be followed.

7. In the event the County pursuant to this Agreement, performs work of any nature, or expends any funds in performance of said work for labor, use of equipment, supplies, materials, and the like, the Landowner, its successors and assigns, shall reimburse the County upon demand, within thirty (30) days of receipt thereof for all actual costs incurred by the County hereunder.

8. This Agreement imposes no liability of any kind whatsoever on the County and the Landowner agrees to hold the County harmless from any liability in the event the stormwater management/BMP facilities fail to operate properly.

9. This Agreement shall be recorded among the land records of Albemarle County, Virginia, and shall constitute a covenant running with the land, and shall be binding on the Landowner, its administrators, executors, assigns, heirs and any other successors in interests, including any homeowners association.

WITNESS the following signatures and seals:

____

Company/Corporation/Partnership Name (Seal)

By: ____

____

(Type Name)

____

(Type Title)

STATE OF __________________

COUNTY OF __________________

The foregoing Agreement was acknowledged before me this ____ day of ___________, 19___, by

____.

____

NOTARY PUBLIC

My Commission Expires: ___________

COUNTY OF ALBEMARLE, VIRGINIA

By: ___________________________________

____

(Type Name)

____

(Type Title)

STATE OF __________________

COUNTY OF __________________

The foregoing Agreement was acknowledged before me this ____ day of ___________, 19___, by

____.

____

NOTARY PUBLIC

My Commission Expires: ___________

Approved as to Form:

______________________________ ___________

County Attorney Date