MINNEHAHA CREEK WATERSHED DISTRICT
QUALITY OF WATER QUALITY OF LIFE

MEMORANDUM

To: MCWD Board of Managers

From: James Wisker

Date: November 6, 2014

Re: Response to October 23, 2014 Project and Program Concerns

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Purpose:
To provide a response to the project and program status concerns stated on October 23, 2014; and to facilitate Board determination on the need for further discussion, or appropriate next steps.

Background:
At the October 23, 2014 Board Meeting, Manager Olson identified the following 18 areas of concern regarding the status of District projects and programs.

1. Upland Farms negotiation
2. Land Management Plans,
    a. Cross River Consulting status
    b. Halverson Dimler restoration
3. Himle Rapp Outreach Plan
4. Creek Signage
5. Minneapolis Infiltration Projects
6. Lakeview Golf Course
7. Wayzata Lake Effect
8. Comprehensive Plan Process
    a. Role of the Board and CAC
9. Ecosystem Evaluation Program
10. Carp Study
11. Baseflow Study and Comprehensive Evaluation of Grays Bay Operation
12. Subwatershed Review for Comprehensive Plan
13. Flood Damage Response
14. Sanitary Sewer Infiltration and Inflow
15. Street Sweeping Study
16. Aquatic Invasive Species
    a. Zebra Mussel
    b. Flowering Rush
17. District Land Policies/Public Access
18. MCWD-MPRB Partnership

While staff provided a brief verbal status update on October 23, this memorandum and its attachments are intended to provide a more detailed response to the list of concerns. The information contained herein generally includes a brief background on each project, current status, and potential next steps. Any affiliated information deemed pertinent to these status updates has also been attached.

Several of the items listed above are interrelated, and therefore have been combined for simplicity. Below is a table of contents that indicates which items have been combined:

Included in each packet item is the relevant staff contact. Should you have questions in advance of the Board Meeting, please contact the appropriate staff person.

MINNEHAHA CREEK WATERSHED DISTRICT
QUALITY OF WATER QUALITY OF LIFE

MEMORANDUM

To: MCWD Board of Managers

From: James Wisker

Date: November 6, 2014

Re: Upland Farms Status

Purpose:
To provide a status report on discussions with the Upland Farm Homeowners Association, as requested at the October 23, 2014 Board Meeting.

Background:
At the June 28, 2012, MCWD Board Meeting, Bruce Magnuson, President of the Upland Farm Homeowners Association (HOA) presented the Board of Managers with a letter from the association outlining its interest in seeking a transaction for properties, including outlots totaling approximately 95 acres.

District staff formally responded to the letter, which requested consideration for wetlands the HOA valued at $17,000 per acre. The response noted the federal and state protections over the wetland, and information compiled by the Board of Water and Soil Resources under the 2013 Reinvest In Minnesota (RIM) program, valuing non-cropland in the seven county metro area in a range of $2,000 - $6,000 per acre.

As discussed with the Board of Managers, given the lack of buildable acreage on the outlots, the requested value as it compares to state wetland value data, and the market basis of the District's land conservation program, District staff recommended against entertaining a value of $17,000 per acre.

Since that time, District staff and its real estate consultants have maintained contact with the Upland Farm HOA, periodically revisiting the question of outlot value. Without any new information, no update to the Board of Managers has been deemed necessary.

If there are questions in advance of the meeting, please contact: James Wisker at 952-641-4509.

MINNEHAHA CREEK WATERSHED DISTRICT
QUALITY OF WATER QUALITY OF LIFE

MEMORANDUM

To: MCWD Board of Managers

From: Tiffany Schaufler

CC: James Wisker

Date: November 6, 2014

Re: District property management plans and policies, and Six Mile Marsh Prairie

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Purpose:

To provide a status report on land management plans and policies, and the Six Mile Marsh Prairie Restoration, as requested at the October 23, 2014 Board Meeting.

Background:

Management Plans

Staff is working to develop management plans for each property the District has interest either in fee title or easement. As previously reviewed and approved on August 22, 2013 in Resolution 13-083, and the April 3, 2014 Operations and Programs Committee, each management plan will generally include:

- Acquisition documentation
- Financial information
- Land description
- Existing conditions
- Restoration goals
- Public access goals
- Education goals
- Insurance details
- Risk management plans
- Monitoring and inspection protocol
- Ongoing maintenance requirements and cost estimates
- Restoration and implementation strategies and cost estimates

Resolution 13-083, approved on August 22, 2013, authorized the execution of a contract with Cross River Consulting, to perform natural resource inventories on 12 properties that had not previously been inventoried. All natural resource inventories have been completed at this time. Subsequent steps involve the synthesis of natural resource information into a cohesive management plan including the areas listed above. This requires coordination with project partners, legal counsel, insurance providers, neighbors, etc. These final steps were delayed in 2014 due to unprecedented flooding, as staff resources were reallocated to damage assessment, interagency coordination with FEMA, and repair planning. All management plans will be finalized following the conclusion of the FEMA process.

<u>Policy for Public Access to MCWD Land:</u>
Specific to public access, the Operations and Programs Committee agreed with staff recommendations on April 3, 2014, that public access policies should reflect and be responsive to individual project/land goals. Therefore, public access details and risk management will be planned on an individual project basis, and incorporated into Board approved management plans.

Project History:

- December 21, 2004: RBA 04-061: Policy Guidance for Land Conservation Program
- December 21, 2006: RBA 06-071: District Land Restoration Program—Authorization for Program Implementation
    - Required the preparation of management plans at the time of acquisition.

Recent Board Action/Discussion:

- January 24, 2013 Board Meeting: Board approved Resolution 13-009 to approve final design for the Six Mile Marsh Prairie Restoration and authorization to solicit bids for construction services
- August 22, 2013 Board Meeting: Board approved Resolution 13-083 to enter into a contract with Cross River Consulting for $42,700 to develop natural resource management plans for District properties.
- April 3, 2014 Operations and Programs Committee: Tony DeMars from Cross River Consulting and Tiffany Schaufler provided a presentation on the natural resource inventories of District lands.

<u>Six Mile Marsh Prairie Restoration Project (Halverson-Dimler) Oak Savanna Establishment</u>

- The Board reviewed the plans and natural resource management plan (NRMP) for this project at the January 3, 2013 Board Meeting.
- Final restoration plans and the NRMP were approved at the January 24, 2013 Board Meeting.
- The transition from prairie to oak savanna was discussed at the January 3, 2013 meeting and was also addressed on page 19 of the natural resource management plan. Staff is implementing the approved plan.

Status Summary:

- Natural resource inventories have been completed for all District properties.
- The finalization of management plans was temporarily delayed in 2014 due to the reallocation of staff resources to flood damage assessment, FEMA coordination, and repair planning. Following the conclusion of the District's work with FEMA, all management plans will be finalized.
- Prairie vegetation at the Six Mile Marsh Prairie Restoration Project (Halverson-Dimler) is in its second year of establishment. Buckthorn was removed from the oak savanna areas this past winter. Pursuant to the approved NRMP, while both plant communities respond to initial management inputs, staff is monitoring the and assessing the need for supplemental plantings, and evaluating the option for on-site versus off-site nurseries.

Attachments:

- April 3, 2014 Operation and Programs Committee Presentation (Cross River)
- Natural Resource Management Plan for the Six Mile Marsh Prairie Restoration

If there are questions in advance of the meeting, please contact: Tiffany Schaufler, 952-471-4513 or Tscaufler@minnehahacreek.org

MINNEHAHA CREEK WATERSHED DISTRICT

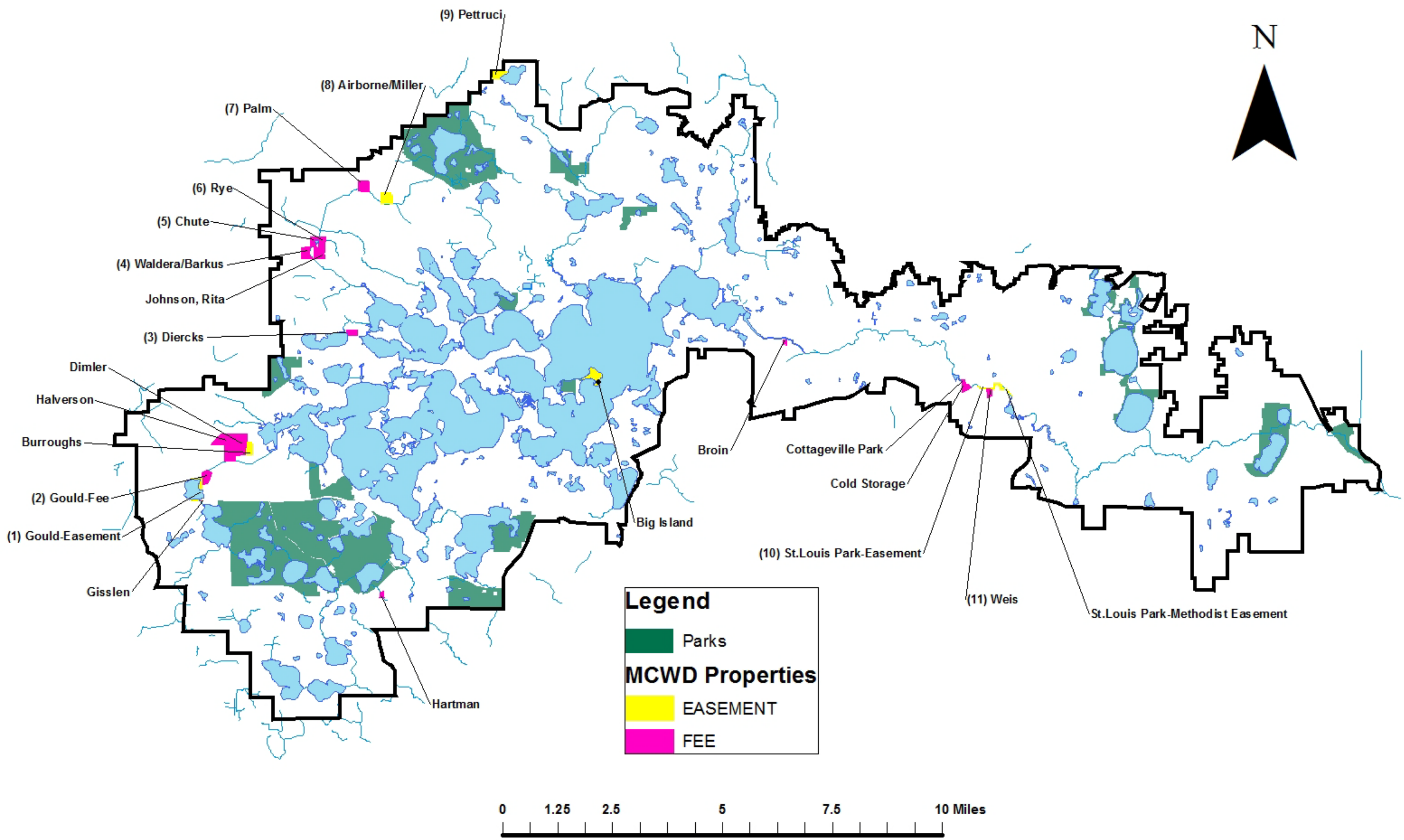
Natural Resource Inventory of District Lands

Operations and Programs Committee, April 3, 2014

OUTLINE

- Summarize last Operations and Programs Committee meeting
- Goal of Management Plans
- Natural Resource Inventory and Recommendations
- Next Steps

District Properties: Fee title and Easements



Property #1 and #2
Gould Easement and
Fee Parcels

Figure 2
Topographic Features
Parcels and Conservation Areas

MCWD NRMP
8251State Hwy.7 &
4500 Six Mile Creek Rd.
Minnetrista, MN

0 250 500 1,000 Feet

Property #1
Gould Easement Parcel

MU	NPC or Cover Type	Quality	Restoration Target	Acres
A	Northern Mixed Cattail Marsh (MRn83)	CD	Northern Mixed Cattail Marsh (MRn83)	17.88
G	Disturbed Deciduous Woodland	NA	Southern Dry-Mesic Oak Woodland (FDs37)	0.08
H	Southern Mesic Oak-Basswood Forest (MHs38)	D	Southern Mesic Oak-Basswood Forest (MHs38)	1.17
I	Residential Home Site/ Southern Mesic Oak-Basswood Forest (MHs38)	NA	Residential Home Site/ Southern Mesic Oak-Basswood Forest (MHs38)	1.61
J	Northern Wet Meadow/Carr – Willow-Dogwood Shrub Swamp (WMn82a)	C	Northern Wet Meadow/Carr – Willow-Dogwood Shrub Swamp (WMn82a)	1.56
NA	Lake (Open Water)	NA		59.38

Figure 6
Management Units

MCWD NRMP
4500 Six Mile Creek Road
Minnetrista, MN

Property #2
Gould Fee Parcel

MU	NPC or Cover Type	Quality	Restoration Target	Acres
A	Northern Mixed Cattail Marsh (MRn83)	CD	Northern Mixed Cattail Marsh (MRn83)	23.37
B	Disturbed Deciduous Woodland	NA	Southern Dry-Mesic Oak Woodland (FDs37)	0.60
C	Old Field	NA	Southern Dry-Mesic Oak Woodland (FDs37)	1.10
D	Northern Wet Meadow/Carr – Willow-Dogwood Shrub Swamp (WMn82a)	CD	Northern Wet Meadow/Carr – Willow-Dogwood Shrub Swamp (WMn82a)	3.31
E	Old Field-Juniper Woodland	NA	Southern Mesic Oak Savanna (Ups24a)	1.68
F	Old Field-Planted to Prairie	NA	Southern Mesic Oak Savanna (Ups24a)	1.15
G	Disturbed Deciduous Woodland	NA	Southern Dry-Mesic Oak Woodland (FDs37)	1.94

Property #3
Diercks Parcel

MU	NPC or Cover Type	Quality	Acres
A	MHs49 – wet-mesic hardwood forest	D	1.7
B	MHs39a – mesic maple-basswood (bitternut hickory) forest	CD	9.7
C	MHs49 – wet mesic hardwood forest	C	2.2
D	MRn83 – mixed cattail marsh	CD	1.1
E	Mhs38 – mesic oak-basswood forest	CB	1.3
F	ephemeral pool/drainageway (reed canary grass)	NA	1.2
G	Former residential home site	NA	1.7

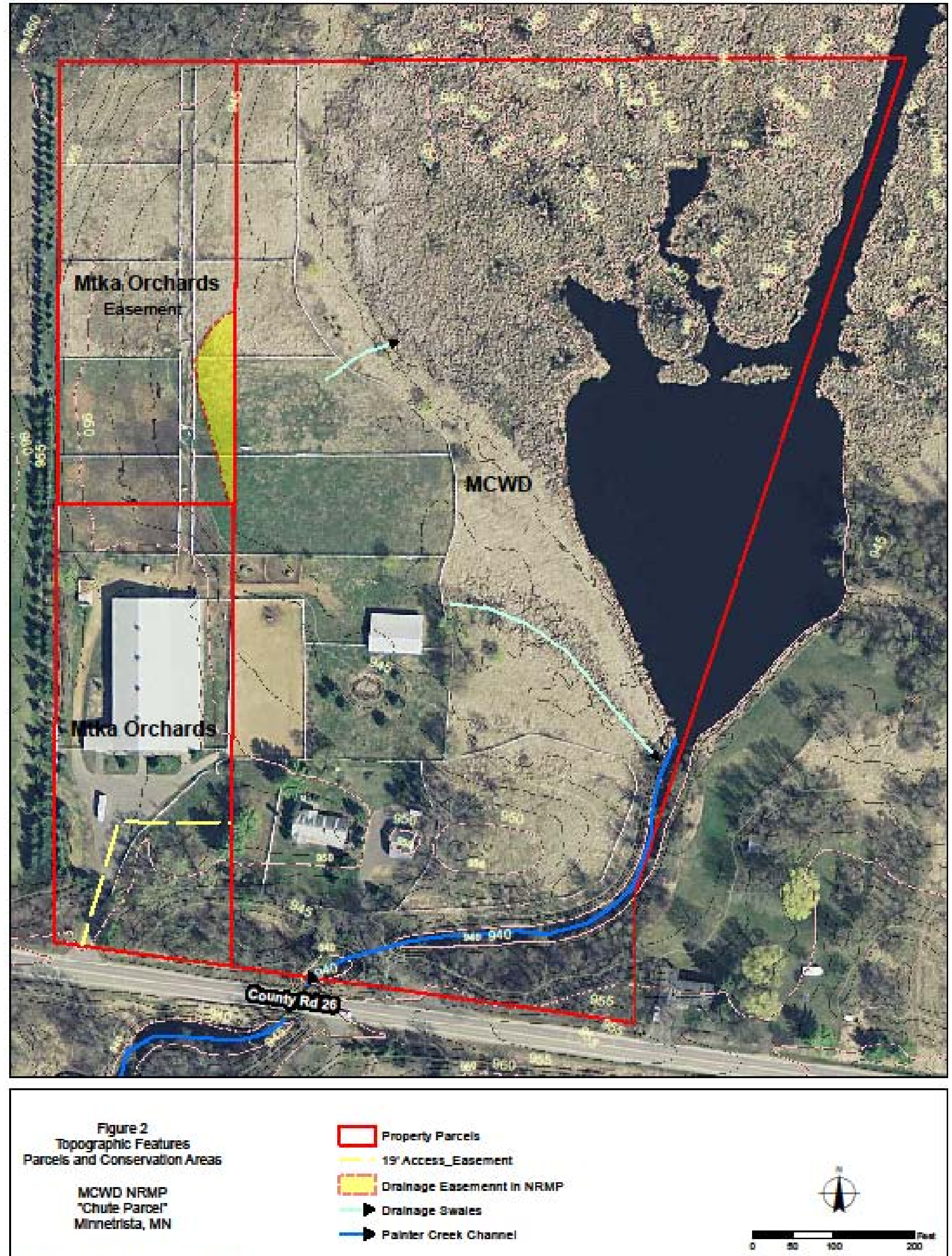
Property #4
Waldera/Barkus Parcels

MU	NPC or Cover Type	Quality	Restoration Target	Acres
A	Disturbed Deciduous Forest	NA	Southern Wet-Mesic Hardwood Forest	1.3
B	Northern Wet Meadow/Carr (WMn82)	C	Northern Wet Meadow(WMn82)	7.3
C	Northern Wet Meadow/Carr – Willow-Dogwood Shrub Swamp (WMn82a)	C	Northern Wet Meadow/Carr – Willow-Dogwood Shrub Swamp (WMn82a)	3.6
D	Northern Mixed Cattail Marsh (MRn83)	CD	Northern Mixed Cattail Marsh (MRn83)	8.7
E	Sugar Maple Basswood - Bitternut Hickory Forest (MHs39a)	C	Sugar Maple Basswood - Bitternut Hickory Forest (MHs39a)	3.7
F	Northern Mixed Cattail-Sedge Marsh (MRn83a)	C	Northern Mixed Cattail-Sedge Marsh (MRn83a)	2.4
G	Sugar Maple Basswood - Bitternut Hickory Forest (MHs39a)	BC	Sugar Maple-Basswood - Bitternut Hickory Forest (MHs39a)	2.0
H	Red Oak-Sugar Maple-Basswood-Bitternut Hickory Forest (MHs38c)	D	Southern Dry/Mesic Oak-Maple Woodland (FDs37)	2.8
I	Access Driveway	NA	Northern Wet Meadow(WMn82)	0.9

Figure 5
Management Units

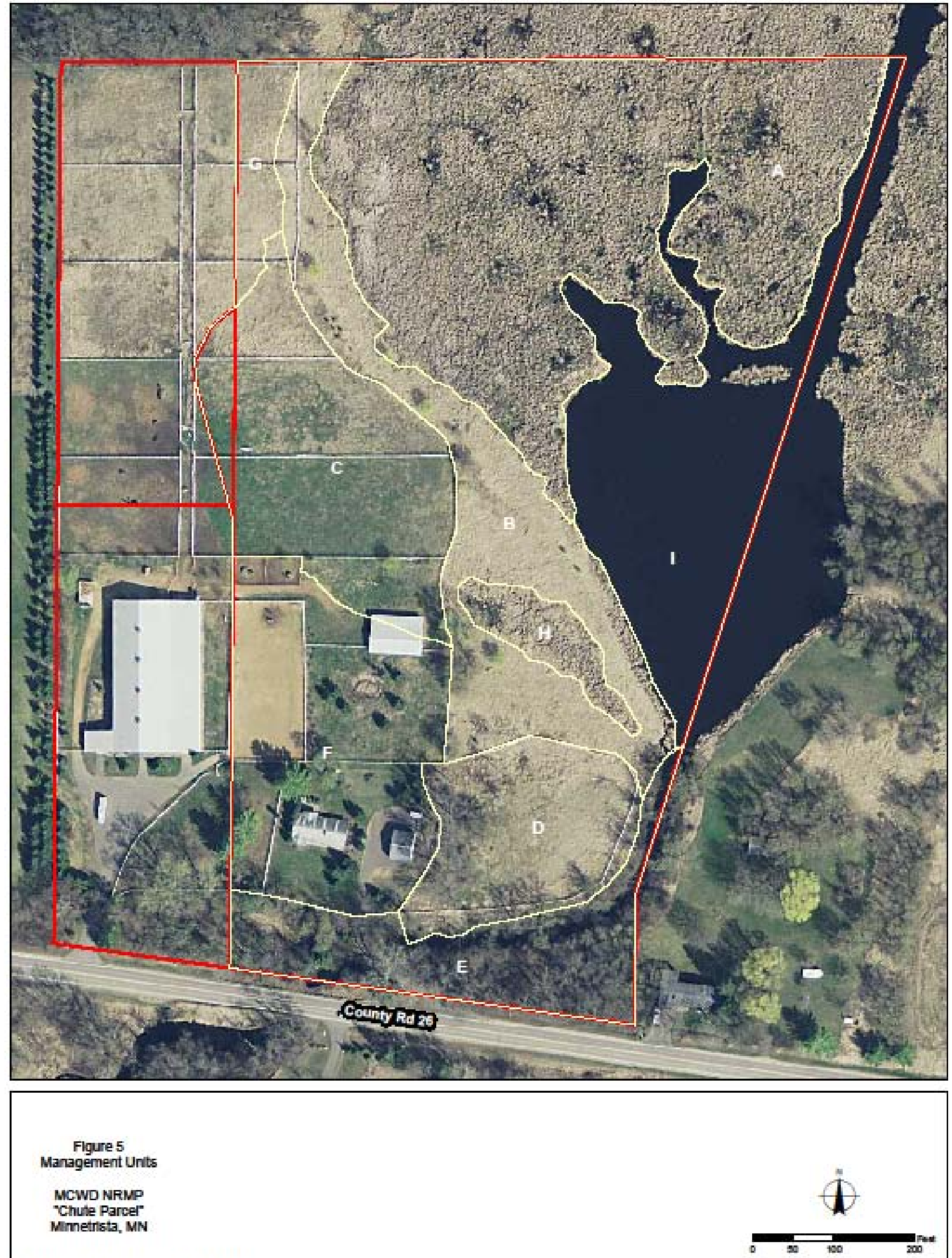
MCWD NRMP For:
6485, 6495 and 6525
County Road 26
Minnetrista, MN

Property #5
Chute Parcel
(Easement and Fee)



Property #5
Chute Parcel
(Easement and Fee)

MU	NPC or Cover Type	Quality	Restoration Target	Acres
A	Northern Mixed Cattail Marsh (MRn83)	D	Northern Mixed Cattail Marsh (MRn83)	5.30
B	Wet Meadow (Reed Canary)	NA	Northern Wet Meadow(WMn82)	2.11
C	Pasture (hydric soils)	NA	Southern Seepage Meadow/Carr (WMs83)	2.05
D	Pasture (upland)	NA	Mesic Oak Savanna (Ups24a)	1.20
E	Disturbed Deciduous Forest	NA	Southern Mesic Oak-Basswood Forest (MHs38)	1.30
F	Former Residential Home Site	NA	Mesic Oak Savanna (Ups24a)	2.22
G	Pasture (upland)	NA	Mesic Oak Savanna (Ups24a)	0.34
H	Mixed Emergent Marsh/Stormwater Pond	NA	Northern Wet Meadow(WMn82)	0.33
I	Water Quality Pond/Open Water	NA	Water Quality Pond/Open Water	2.34



Property #6
Rye Parcel

MU	NPC or Cover Type	Quality	Restoration Target	Acres
A	Planted Prairie	NA	Mesic Oak Savanna (Ups24a)	3.8
B	Wet Meadow (Reed Canary)	NA	Northern Wet Meadow(WMn82)	6.6
C/G	Disturbed Deciduous Woodland	NA	Mesic Oak Savanna (Ups24a)	2.9
D	Northern Mixed Cattail Marsh (MRn83)	D	Northern Mixed Cattail Marsh (MRn83)	7.0
E	Disturbed Deciduous Forest	NA	Southern Wet-Mesic Hardwood Forest (MHs49)	1.6
F	Willow-Dogwood Shrub Swamp (WMn82a)	D	Willow-Dogwood Shrub Swamp (WMn82a)	1.0
H	Northern Mixed Cattail Marsh (MRn83)	C	Northern Mixed Cattail Marsh (MRn83)	0.4

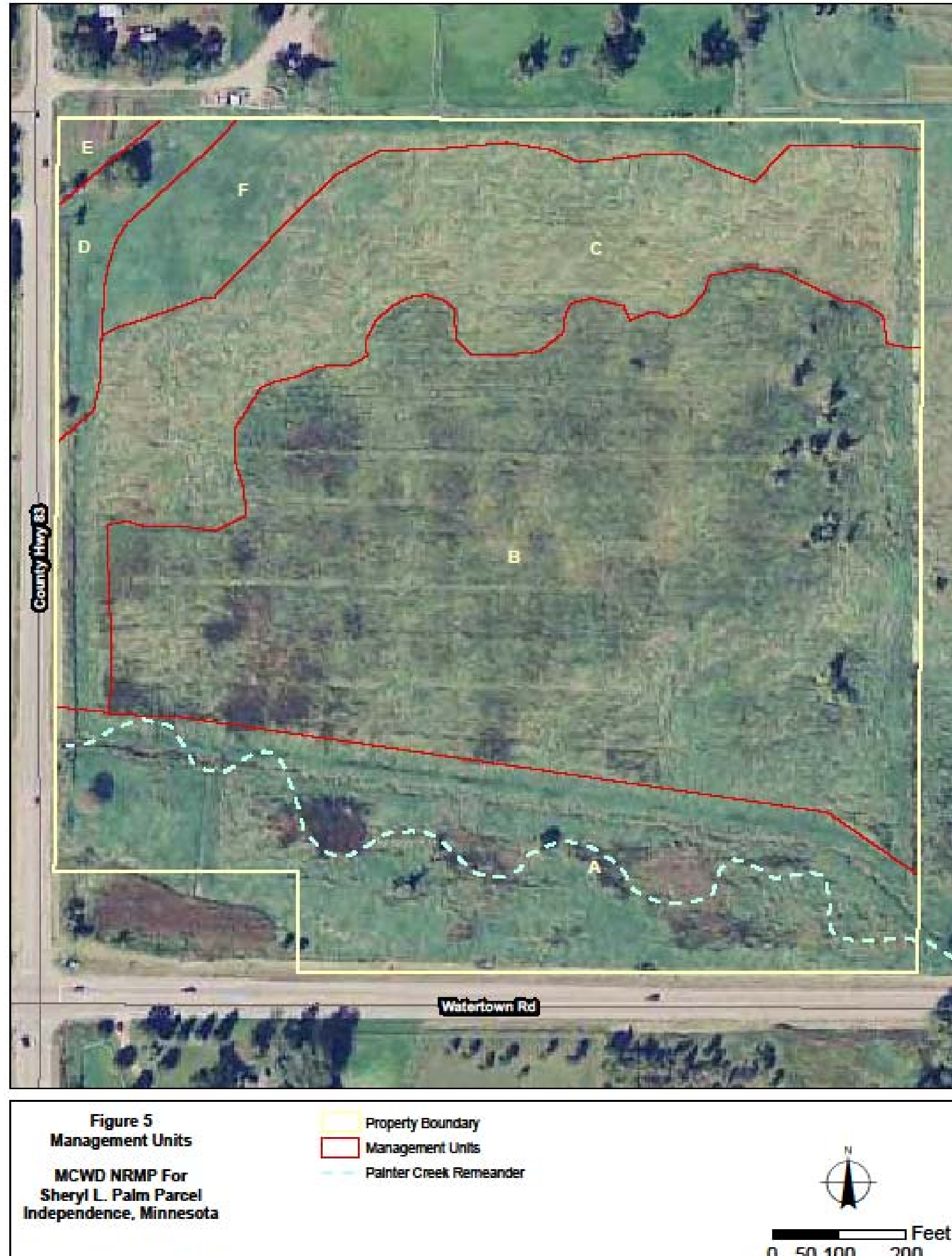
Property #7
Sheryl L. Palm Parcel

Figure 2
Topographic and Drainage Features

MCWD NRMP For
Sheryl L. Palm Parcel
Independence, Minnesota

Property #7
Sheryl L. Palm Parcel

MU	NPC or Cover Type	Quality	Restoration Target	Acres
A	Northern Mixed Cattail Marsh (MRn83)/Wet Meadow (reed canary dominated)	D	Northern Mixed Cattail Marsh (MRn83)/Wet Meadow/Carr (WMn82)	7.88
B	Northern Mixed Cattail Marsh (MRn83)	D	Northern Mixed Cattail Marsh (MRn83)	17.12
C	Wet Meadow (reed canary dominated)	NA	Sedge Meadow (WMn82b)	7.84
D	Wet Meadow (reed canary dominated)	NA	Sedge Meadow (WMn82b)	0.94
E	Garden/Lawn	NA	Southern Mesic Prairie (Ups23)	0.24
F	Wet Meadow (reed canary dominated)	NA	Seepage Meadow/Carr (WMs83a)	2.40



Property #8
Airborne/Miller Parcels

MU	NPC or Cover Type	Quality	Restoration Target	Acres
A	Cattail-Sedge Marsh (MRn83a)	C	Cattail-Sedge Marsh (MRn83a)	0.9
B	Northern Wet Meadow/Carr (WMn82)	CD	Northern Wet Meadow (WMn82)	1.5
C	Northern Mixed Cattail Marsh (MRn83)	CD	Tamarack Swamp-Southern (FBs63a)	5.0
D	NA	NA	Tamarack Swamp-Southern (FBs63a)	1.1
E	Southern Mesic Prairie (UPs23)	C	Southern Mesic Prairie (UPs23)	0.3
F	Northern Wet Meadow/Carr (WMn82)	C	Tamarack Swamp-Southern (FBs63a)	1.1
G	Northern Mixed Cattail Marsh (MRn83)	CD	Northern Mixed Cattail Marsh (MRn83)	10.7
H	Northern Wet Meadow/Carr (WMn82)	CD	Northern Wet Meadow/Carr (WMn82)	4.1
I	Disturbed Deciduous Woodland	NA	Mesic Oak Savanna (Ups24a)	1.3
J	Mown Grass	NA	Northern Wet Meadow/Carr (WMn82)	1.5
K	Disturbed Deciduous Woodland	NA	Mesic Oak Savanna (Ups24a)	0.5
L	Northern Wet Meadow/Carr (WMn82b4 – Lake Sedge Subtype)	B	Northern Wet Meadow/Carr (WMn82b4 – Lake Sedge Subtype)	2.3
M	Northern Mixed Cattail Marsh (MRn83)	CD	Tamarack Swamp-Southern (FBs63a)	1.9
N	Northern Wet Meadow/Carr (WMn82b4 – Lake Sedge Subtype)	BC	Northern Wet Meadow/Carr (WMn82b4 – Lake Sedge Subtype)	5.1

Property #9
Pettruci Parcels

Figure 2
Easement Parcels

MCWD NRMP For
2910, 2920 &2930 Parkview Dr.
Medina, MN

Parcel Boundaries
MCWD Easement Boundaries

N

0 250 500 1,000 Feet

Property #9
Pettruci Parcels

MU	NPC or Cover Type	Quality	Restoration Target	Acres
A	Disturbed deciduous woodland	NA	Southern Mesic Oak Savanna (Ups24a)	0.86
B	Wet Meadow/Old Field	NA	Southern Seepage Meadow-Carr (WMs83)	3.23
C	Northern Mixed Cattail Marsh (MRn83)	C/D	Northern Mixed Cattail Marsh (MRn83)	3.08
D	Unnamed Lake	NA	Unnamed Lake	20.90

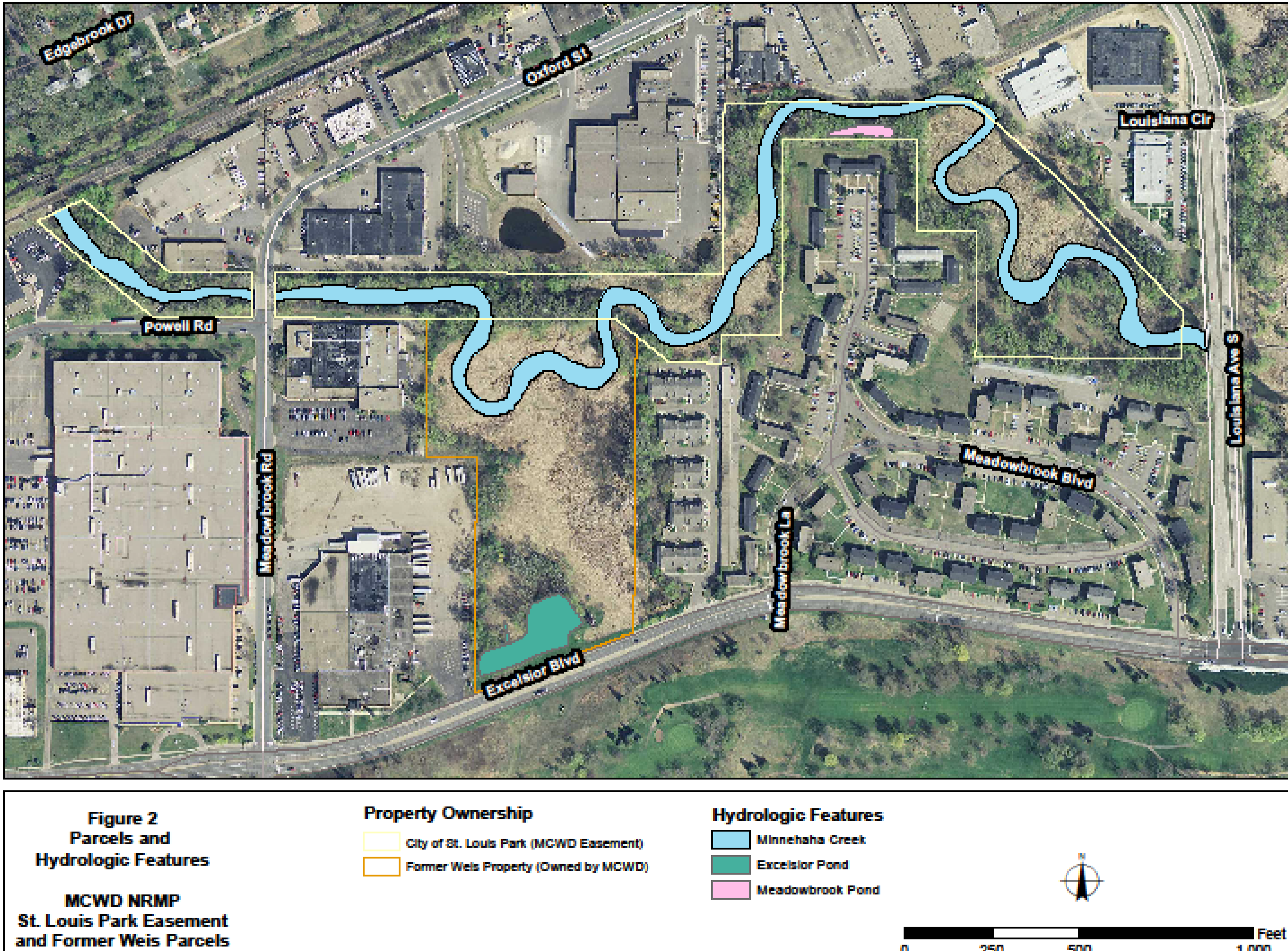
Figure 6
Management Units

MCWD NRMP For
2910, 2920 &2930 Parkview Dr.
Medina, MN

N

Feet
0 50 100 200

Property #10
St. Louis Park-Easement Parcel



Property #10
St. Louis Park-Easement Parcel

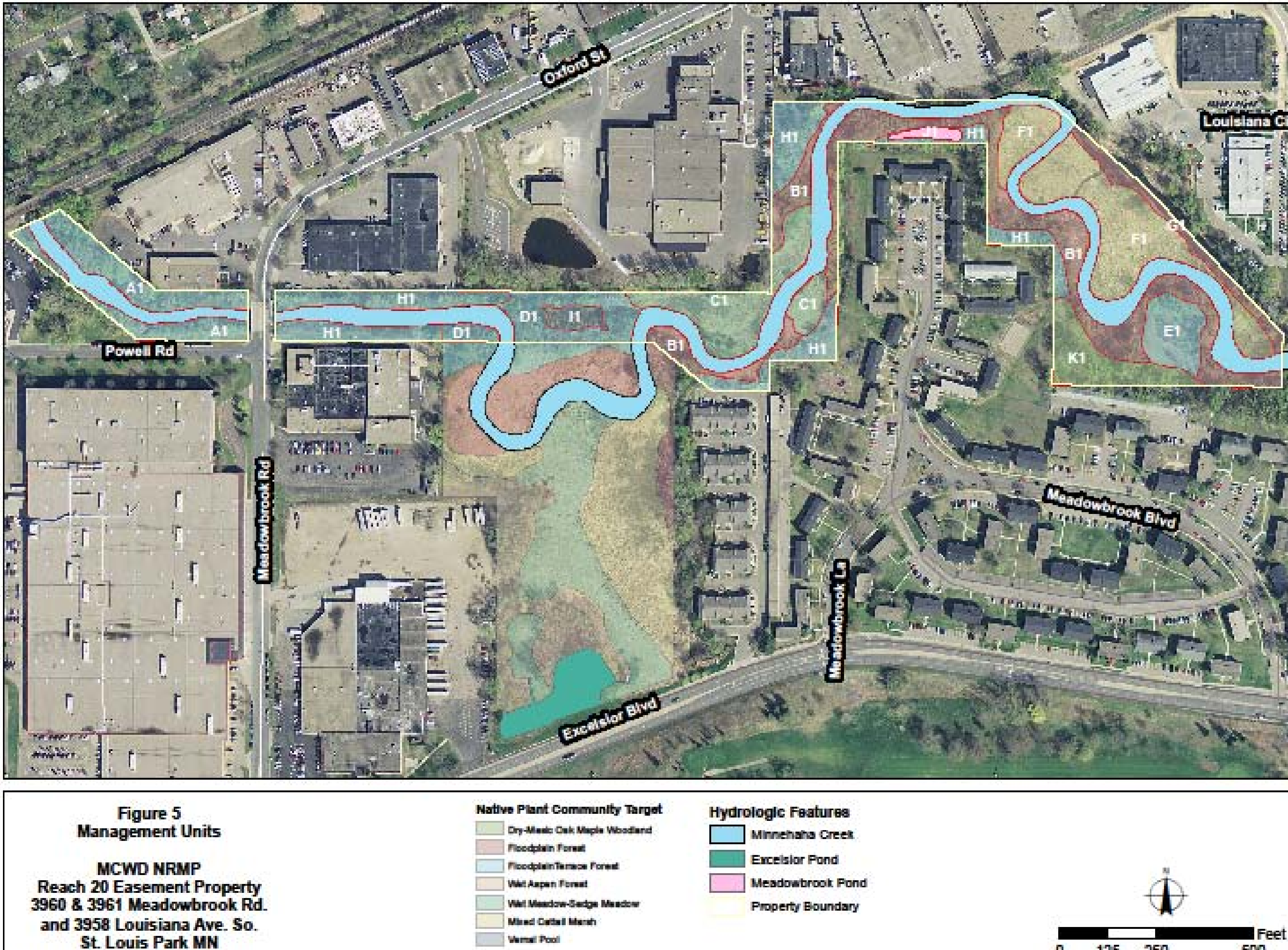


Figure 5
Management Units

MCWD NRMP
Reach 20 Easement Property
3960 & 3961 Meadowbrook Rd.
and 3958 Louisiana Ave. So.
St. Louis Park MN

Property #10
St. Louis Park-Easement Parcel

SLP Easement						
MU_ID	NPC Class	NPC Target	Quality	Acres	Hydro Class	Soils
A1	Southern Terrace Forest (FFs59)	Southern Terrace Forest (FFs59)	D	1.36	FT	Silty Clay Loam, Cut/Fill
B1	Southern Floodplain Forest (FFs68)	Southern Floodplain Forest (FFs68)	D	2.84	FD	Silty Clay Loam
C1	Northern Wet Meadow-Carr (WMn82	Northern Wet Meadow-Carr (WMn82	CD	1.38	FS	Mucky Mineral/Peat
D1	Former Channel (Filled)	Southern Floodplain Forest (FFs68)	NA	0.91	FT/FD	Fill/Silty Sand with High Organic
E1	Disturbed Deciduous Woodland	Southern Terrace Forest (FFs59)	NA	0.61	FT	Sandy Loam
F1	Northern Mixed Cattail Marsh (MRn83)	Northern Mixed Cattail Marsh (MRn83)	CD	2.36	FS/FP	Mucky Peat
G1	Former Channel (Filled)	Southern Floodplain Forest (FFs68)	NA	0.50	FD	Fill/Silty Sand with High Organic
H1	Southern Terrace Forest (FFs59)	Southern Terrace Forest (FFs59)	D	2.40	FT	Sandy Loam, Cut/Fill
I1	Former Channel	Vernal Pool	NA	0.19	SW/FP	Fill/Silty Sand with High Organic
J1	Southern Floodplain Forest (FFs68)	Meadowbook Pond	NA	0.11	SW	NA
K1	Southern Dry Mesic Oak Woodland (FDs37)	Southern Dry Mesic Oak Woodland (FDs37)	D	0.80	UP	Sandy Loam
				13.45		

Hydrologic Class	
UP	Upland
FT	Floodplain Terrace
FD	Floodplain (Seasonally Dry)
FS	Floodplain (Saturated)
FP	Floodplain (Ponded)
SW	Stormwater

Property #11
Weis Parcels

Figure 5
Management Units

MCWD NRMP
Former Weis Parcel
7200, 7202, 7250 & 7252 Excelsior Blvd
St. Louis Park MN

Native Plant Community Target
- Dry-Mesic Oak Maple Woodland
- Floodplain Forest
- Floodplain/Terrace Forest
- Wet Aspen Forest
- Wet Meadow-Sedge Meadow
- Mixed Cattail Marsh
- Vernal Pool

- Property Boundary
- Minnehaha Creek
- Excelsior Pond
- Meadowbrook Pond

Feet: 0, 100, 200, 400

Property #11
Weis Parcels

Weis						
MU ID	**NPC Class**	**NPC Target**	**Quality**	**Acres**	**Hydro Class**	**Soils**
A2	Constructed Stormwater Pond	Constructed Stormwater Pond	NA	0.72	SW	Silty Clay Loam/Fill
B1	Southern Floodplain Forest (FFs68)	Southern Floodplain Forest (FFs68)	D	0.40	FD	Silty Clay Loam
B2	Southern Wet Aspen Forest (WFs55)	Southern Wet Aspen Forest (WFs55)	CD	2.01	FT	Silty Clay Loam
C2	Northern Wet Meadow-Carr (WMn82	Northern Wet Meadow-Carr (WMn82	CD	2.31	FS	Mucky Mineral/Peat
D1	Southern Terrace Forest (FFs59)	Southern Terrace Forest (FFs59)	D	0.50	FT/FD	Silty Sand Over Gravel
D2	Northern Mixed Cattail Marsh (MRn83)	Northern Mixed Cattail Marsh (MRn83)	D	2.29	FP	Mucky Peat
E2	Channel Edge/Recently Graded	Southern Floodplain Forest (FFs68)	NA	1.39	FS	Silty Sand Over Gravel
F2	Northern Mixed Cattail Marsh (MRn83)	Northern Mixed Cattail Marsh (MRn83)	CD	0.31	FP	Mucky Mineral/Peat
G2	Northern Wet Meadow-Carr (WMn82)	Northern Wet Meadow-Carr (WMn82)	NA	0.33	SW/FS	Mucky Mineral/Peat
			TOTAL ACRES	10.25		

Hydrologic Class	
UP	Upland
FT	Floodplain Terrace
FD	Floodplain (Seasonally Dry)
FS	Floodplain (Saturated)
FP	Floodplain (Ponded)
SW	Stormwater

NEXT STEPS

- Synthesize the natural resource inventory, land use, water quality opportunities, goals, access, etc. for each focused geography

- Develop Management Plans that provide recommendations and identify the opportunities for the focused geography

NATURAL RESOURCE MANAGEMENT PLAN

FOR

SIX MILE MARSH PRAIRIE RESTORATION

MINNETRISTA, MINNESOTA

Prepared by:

Applied Ecological Services, Inc.
21938 Mushtown Road
Prior Lake, MN 55372
(952) 447-1919

Submitted to:

MINNEHAHA CREEK WATERSHED DISTRICT

18202 Minnetonka Boulevard
Deephaven, MN 55391
(952) 471-0590

Kim Alan Chapman, PhD
Douglas M. Mensing, MS

FINAL January 17, 2013

12-0078

TABLE OF CONTENTS

APPENDICES

EXECUTIVE SUMMARY

The 2007 Minnehaha Creek Watershed District (MCWD) Comprehensive Water Resource Management Plan (WRMP) identifies Six Mile Marsh as a key conservation area. The WRMP lays out the need for the MCWD Land Conservation and Restoration Program to create connections between ecosystems within the Six Mile Marsh and Lake Minnetonka subwatersheds to improve water quality, preserve natural conveyances, facilitate the movement and proliferation of native species, and enhance recreational opportunities. Further, the WRMP calls out goals for substantial nutrient load reductions from the Six Mile Marsh subwatershed. In an effort to accomplish these needs and goals, the Land Conservation and Restoration Program has acquired approximately 230 acres of uplands and wetlands on the north side of Six Mile Creek, through fee title and a conservation easement.

For the Six Mile Marsh Prairie Restoration Project, MCWD intends to restore previously row-cropped lands to a natural vegetative cover and hydrologic regime, which is estimated to reduce pollutant loading by up to 380 lbs/year. This project is also intended to increase infiltration; to reduce runoff volumes carrying pollutant loads to wetlands and waters of the MCWD; to promote groundwater recharge; to restore and protect wetland and upland resources in the Six-Mile Marsh subwatershed; to protect and improve existing conservation corridors; and to reduce existing flows and negative effects from agricultural drainage on aquatic resources within the MCWD.

During the design of this project, MCWD completed a comprehensive restoration design in coordination with community stakeholders, the City of Minnetrista, and Three Rivers Park District to meet additional community goals for the area. MCWD also coordinated design aspects with the Minnesota Board of Soil and Water Resources, Minnesota Department of Transportation, University of Minnesota, Hennepin County Environmental Services and through a partnership with the U.S. Fish and Wildlife Service.

1 INTRODUCTION

Applied Ecological Services, Inc. (AES) was retained by the Minnehaha Creek Watershed District (MCWD) to prepare this Natural Resource Management Plan (NRMP) for the Six Mile Marsh Prairie Restoration site, located on Halstead Drive in Minnetrista, Hennepin County, Minnesota. A NRMP is a site-specific document that helps to ensure that the conservation goals and aesthetic vision of a project are realized. This NRMP is designed to guide ecological restoration, enhancement and management of uplands and wetlands at the site. In addition, design and construction of a bituminous, ADA-compliant spur trail will provide access to the site from the Dakota Rail Trail. Through this work, the MCWD will significantly improve the ecological integrity of the site and downstream resources, as well as provide the public with opportunities for low-impact recreation, education, and enjoyment.

Goals

This NRMP is guided by the following goals, which the MCWD project team defined and prioritized with the assistance of AES:

1. **Restore moderate to high quality native plant communities and habitats**. The short term goal is to establish moderate quality native habitats, which over time will be managed to achieve high quality habitats. Restoration of the site will result in a mosaic of prairie and savanna, with patches of wetland and native woodland. This complex of native plant communities will provide valuable habitat for a broad diversity of wildlife.
2. **Manage invasive vegetation**. Invasive species present at the site will be removed and controlled as part of native plant community restoration. Perpetual stewardship will be required to manage these aggressive species.
3. **Protect and improve surface water**. The MCWD's Land Conservation and Restoration Program is founded on the knowledge that conservation and restoration of natural areas benefit watersheds. In turn, water quality protection helps maintain healthy ecosystems. Implementation of this project (located in the Minnehaha Creek watershed's headwaters) will improve local ecosystem functions and benefit surface water resources downstream.
4. **Develop opportunities for education, interpretation, and public enjoyment**. The MCWD recognizes the importance of education and outreach to convey the importance of conservation and environmental stewardship. The site offers valuable opportunities for such activities, given its size, proposed restoration program, and accessibility. The spur trail leading from the existing Dakota Rail Trail will allow trail users an opportunity to access and enjoy the site. There are also opportunities for sensitive, site-appropriate, passive recreation (e.g., birding).
5. **Build healthy soils.** Through native plant community restoration, site soils will be restored and their ecological functions improved. Conversion of much of the site from annual row crops to deep-rooted native perennial vegetation and enhancement of existing semi-natural areas will build healthier soils, improving infiltration capacity, increasing moisture retention, and enhancing carbon sequestration across the site.

These goals were considered throughout the design of this restoration program and are discussed further in Section 4 of this NRMP. Conscientious project implementation, management, and perpetual stewardship will be important to achieve these goals and maximize the project's benefits for the District and the greater community.

This NRMP is organized around these major topics:

- Benefits of ecological restoration
- Restoration and management philosophy
- Site description and existing conditions
- Conservation goals and opportunities
- Target native plant communities
- Restoration and management approach
- Restoration and short-term management
- Perpetual management
- Opinion of probable cost
- Other restoration and management considerations

Project specifications are included in Appendix A of this NRMP, and the project plan set (*Six Mile Marsh Prairie Restoration Project*, sealed January 11, 2013) provides detailed maps for construction.

Benefits of Ecological Restoration

The MCWD has a long history and strong dedication to the conservation and enjoyment of Minnehaha Creek and its greater watershed. The MCWD recognizes the critical role that natural resources play in healthy and sustainable watersheds, and the importance of ecological restoration and perpetual stewardship. Simply defined, ecological restoration is the art and science of improving the natural environment by stabilizing and enhancing its diversity, resilience, and natural functions. This is typically accomplished by restoring diverse native plant communities, which quickly provide important habitats, and over time rebuild healthy soils. These improvements in turn support the delivery of ecosystem services, such as water and air purification, stormwater management, groundwater recharge, erosion control, and carbon sequestration. Restoration of a diversity of native plant species in the site's woodlands, grasslands, and wetlands will also enhance populations of breeding birds, insects and other invertebrates, amphibians, mammals and other wildlife. The construction of the regional trail spur off of the adjacent Dakota Rail Trail will provide convenient access for people to visit and enjoy the site.

Restoration and Management Philosophy

The philosophy of ecological restoration focuses on creating healthy and sustainable ecosystems, often in the context of a developed or disturbed landscape. The composition, structure, and function of restored ecosystems are similar to that of native ecosystems. As a result, a moderate level of management is sufficient to maintain these ecosystems in perpetuity. Restored ecosystems are recognizable by a diversity of native plant species. Restored aquatic ecosystems typically have a natural hydrological regime, with seasonal high and low water levels and slowly rising waters after storms.

The site's regional context, its position in the watershed, the original vegetation (pre-1850), and current conditions all informed this NRMP. This NRMP is designed to restore plant communities native to the site and greater region. However, changes in the larger landscape and in local conditions usually prevent the re-creation of natural conditions from 150 years ago; those historical conditions simply provide insight into what natural conditions may be possible at the site. More importantly, the goals for the site will dictate the level of effort expended and the eventual condition of the ecosystems. Not all of the natural environment will be restored to exceptional native plant communities, but all will be restored and managed to meet the MCWD's goals. As healthy and sustainable ecosystems are established here, wildlife populations, ecological functioning, and human enjoyment will be enhanced.

Restoration and management plans need to be flexible. Restoration programs experience variability in the response of the ecosystems to restoration work, changing management needs, and cycles of funding. At times, programs need to respond to new scientific data and insights. For these reasons, this NRMP should be viewed as a starting point in a process of restoring the biodiversity and natural processes of the site. It should guide major restoration and management efforts and projects. As more detailed data are gathered, it is expected that restoration and management activities may be refined. The most successful restoration programs use regular monitoring and reporting as feedback on the program's effectiveness. Monitoring also generates information to justify changes in the restoration and management program. Adaptive management—a cycle of implementation, monitoring, evaluation, adjustment, and implementation—is central to the best restoration programs and should begin with the restoration work and continue indefinitely as part of the stewardship of the site.

2 SITE DESCRIPTION

The Six Mile Marsh Prairie Restoration site consists of approximately 230 acres of uplands and wetlands, and lies within U.S. Public Land Survey Sections 28, 29, and 33 of Township 117 North, Range 24 West. The site consists of four recorded addresses: 7901, 7701, and 8015 Halstead Drive and a conservation easement located at 7475 Farmhill Drive in Minnetrista, Minnesota. In 2007, these sites were identified by the MCWD as a priority for acquisition due to their location within the Six Mile Creek watershed, their restoration potential, and their adjacency to the Dakota Rail Trail, managed by Three Rivers Park District (TRPD).

3 EXISTING CONDITIONS

The site's existing conditions were assessed with a variety of data. In addition to AES' site reconnaissance and wetland delineation work, we compiled and reviewed existing published data (e.g., conservation corridors, rare natural features). Additionally, we reviewed project-specific data collected by Hennepin County Environmental Services, U.S. Fish and Wildlife Service, Cross River Consulting, Board of Water and Soil Resources, Minnesota Department of Transportation, the University of Minnesota, Otto Associates, and Wenck Associates.

Anthropogenic features on the site include a barn, pole shed, farmstead, two driveways, overhead power lines, agricultural drain tiles, a farm drive connecting the main, northern portion of the site to the "southeast peninsula," a fenced-in watering hole on the edge of Six Mile Marsh, and an underground natural gas pipeline. Existing site conditions are shown on Plan Sheet 2.1.

Regional Context

The site is located in the City of Minnetrista, Hennepin County, Minnesota, in the Big Woods Ecological Subsection, as defined by the Minnesota Department of Natural Resources (MnDNR). The western half of the Twin Cities metropolitan area (and beyond) lies in this ecoregion.

The site is located within a MCWD Key Conservation Area, a Metro Conservation Corridor, and a Regional Ecological Corridor. These factors, in conjunction with the site's location in the headwaters of the Minnehaha Creek watershed, provide a unique opportunity for conservation, ecological restoration and water quality protection.

The site is located in a rural residential area, with the Turtle Creek residential subdivision located adjacent to the southwest. The City of St. Bonifacius lies approximately ½ mile southwest of the site, and Six Mile Creek (flowing eastward along the south edge of the site) flows approximately 1.5 miles into Halsted Bay of Lake Minnetonka. Halsted Bay is considered impaired for its high nutrient content. The MCWD has been pursuing conservation and restoration efforts along Six Mile Creek to help improve water quality in Halsted Bay.

Glacial History, Landforms and Soils

The Wisconsinan glaciation (which ended here about 11,000-12,000 years ago) created the landforms visible at the site. Moderate to steep slopes are throughout the site and are generally concentrated at the edges of wetlands.

After the glacier retreated, the region was colonized by taiga and spruce-fir vegetation. During the Hypsithermal (a warm, dry period 6,000-8,000 years ago) prairie flora made a significant advance eastward, then prairie retreated as the climate became wetter. The Little Ice Age of about 350 years ago accelerated that retreat, especially in the Big Woods region of Minnesota. As a result, upland soils in the region developed primarily under forest conditions, but periods of savanna and prairie occupancy before the Little Ice Age may have influenced the soil's overall evolution.

USDA/NRCS soil mapping for the site (USDA/NRCS 2012) indicates uplands dominated by well-drained Lester loam and the Lester-Kilkenny complex. Lowland soils in the site are mapped as Hamel, overwash-Hamel complex, with the lowest and wettest containing Muskego, Blue Earth, and Houghton soils. Hamel soils are generally poorly drained, and the remaining lowland soils are predominantly wet, organic soils.

Hydrology

Most of the site drains to the south into Six Mile Marsh, which drains to Six Mile Creek, and eventually flows into Halsted Bay of Lake Minnetonka. A portion of the site's northwest corner (including Wetlands 1, 2, and 10) drains northward, through a culvert under Halstead Drive, and eventually flows into Halsted Bay. Lake Minnetonka flows into the Minnehaha Creek, which eventually enters the Mississippi River in Minneapolis. A small area in the site's northeast corner appears to be a landlocked depression. A culvert under Halstead Drive may exist in this area, but was not confirmed.

Historical Vegetation

MnDNR data and research by F.J. Marschner (1974) indicate that the site's northern portion is located in an area that, prior to about 1850, was dominated by Big Woods Hardwood Forest. This forest was a community of oak, maple, basswood, hickory, and elm. It was protected from the frequent fires that swept over the landscape by its rough topography and numerous wetlands and lakes. These features reduced the intensity of fires that reached the area. The southern portion of the site was dominated by Wet Prairie. In 1850, this southern area likely consisted of an intermittently flowing, sluggish wetland slough as opposed to the current, well-defined, free-flowing Six Mile Creek and its associated wetlands.

Existing Land Cover

The Six Mile Marsh Prairie Restoration site consists of approximately 230 acres of uplands and wetlands. Site uplands are dominated by cropfields, most recently (2012) in soybeans. Additionally, site uplands contain patches of woodland, forest, planted native grasses, hayfields, and former farmsteads. The expansive Six Mile Marsh lies in the southern portion of the site, and eight depressional wetlands were confirmed on the site during recent wetland delineation activities (AES 2012). Existing land cover is shown on Plan Sheet 2.1, and a brief description of the site's natural and semi-natural communities follows.

<u>Woodlands & Forests</u>

Four groupings of woodlands and forests currently exist on the site.

- A patch of second-growth trees exists on a relatively steep slope in the western portion of the site. The dominant woody species in this woodland patch include American elm (*Ulmus americana*), and boxelder (*Acer negundo*), with the invasive, non-native shrub common buckthorn (*Rhamnus cathartica*) in the shrub layer.
- A mixed stand of upland and wetland woodlands and forest is present on the north and west edges of the site's large western wetland (Wetland 9, Plan Sheet 2.1). Some of the trees in the northeast portion, including several large planted conifers, are associated with the former farmstead. The remainder of this wooded stand contains lowland forest. The dominant woody

species in this forest include Eastern cottonwood (*Populus deltoides*), American elm, boxelder, and black willow (*Salix nigra* or a hybrid). Common buckthorn has invaded most of the upland portions of this forest.

- In the south and central portions of the site, along the edge of Six Mile Marsh, a relatively narrow band of remnant bur oaks (*Quercus macrocarpa*) remain. Some of these oaks have broad canopies, suggesting their development in more open, savanna-like conditions. A few large basswoods (*Tilia americana*) and scattered ironwood (*Ostrya virginiana*) trees were observed in the northern portion of this woodland patch, while black maple (*Acer nigrum*) were observed in the southern portion (including numerous saplings). In addition to oaks, basswood and black maple were also common savanna species in Minnesota. Much of this woodland, especially the edges, has been invaded by Eastern red cedar (*Juniperus virginiana*), prickly ash (*Zanthoxylum americanum*), common buckthorn, and Tartarian honeysuckle (*Lonicera tatarica*). The groundlayer is often dominated by non-native, agronomic grasses, such as smooth brome (*Bromus inermis*) and the invasive, non-native reed canarygrass (*Phalaris arundinacea*).
- The peninsula extending into Six Mile Marsh (in the far southeast portion of the site) contains patches of degraded forest and woodland. The forest is dominated by relatively young green ash (*Fraxinus pennsylvanica*) in the canopy, and a dense layer of invasive, non-native common buckthorn in the shrub/sapling layer. Both common buckthorn seedlings and young shrubs were abundant, and few other shrub species were observed. Other species in this forest included large bur oak and red oak (*Quercus rubra*), common hackberry (*Celtis occidentalis*), American elm, Eastern red cedar, and the invasive, non-native glossy buckthorn (*Rhamnus frangula*) and Tartarian honeysuckle. The native but aggressive prickly ash is present, primarily along woodland edges. Also present on this peninsula are several large (approximately 40-50 inch dbh), isolated oaks, including bur and red.

<u>Grasslands</u>

Several patches of grassland exist within the site.

- Two small patches of planted native grasses exist along Halstead Drive, on the northern edge of the site. These plantings contained good cover by native grasses (especially the eastern patch), but they lacked forb cover and diversity, and some non-native species were present.
- Strips of planted grasses exist in the northeast portion of the site. These areas contained only low cover by natives, and some consisted entirely of agronomic grasses. These areas have presumably been used for hay production.
- The site's southeast peninsula contains planted grasslands (hayfield) as well as wildlife food plots (corn). Agronomic grasses and common weeds were observed in this area, including smooth brome, Kentucky bluegrass (*Poa pratensis*), and reed canary grass. Portions of these non-native grasslands are being invaded by woody species, including prickly ash, buckthorn, and green ash saplings.
- The east-central edge of the site consists of a non-native grassland. It appears that prairie plantings have occurred in portions of this area in the past, but a combination of poor site

preparation and/or lack of management has resulted in old field conditions, dominated by Kentucky bluegrass, smooth brome, and Canada goldenrod (*Solidago canadensis*).

Wetlands

The site's most significant wetland is Six Mile Marsh, occupying approximately 77 acres in the southern and eastern portions of the site. This marsh consists of a mosaic of native Cattail Marsh and disturbed wetlands, often dominated by invasive narrowleaf cattail (*Typha angustifolia*) and hybrid cattail (*Typha* x *glauca*).

The eight additional site wetlands vary significantly. They range in size from 0.3 acre (Wetland 1) to 2.76 acres (Wetland 9), they range in hydrology from temporarily flooded to semipermanently flooded, and they possess a variety of vegetation, mostly non-native and/or invasive species such as reed canary grass and narrowleaf cattail. The hydrology of several of these wetlands (i.e., Wetlands 1, 2, 6, and 9) may be affected by existing agricultural drain tiles. Detailed descriptions of each of these eight depressional wetlands can be found in AES' wetland delineation report (AES 2012).

Existing Wildlife

A wildlife survey was not conducted at the site; however, it would be expected that a moderate diversity of rural wildlife use the site for nesting and/or foraging due to the variety of upland and wetland habitats and the secluded nature of much of the site. During field work, AES observed what appeared to be a raptor nest in the site's western-most woodland patch, and MCWD staff has spotted Sandhill Cranes on the site.

Rare Natural Features

The MnDNR's Natural Heritage Database tracks endangered, threatened, and special concern plant and animal species and animal congregations (e.g., heron rookeries). As of July 2012, no records of rare plants or animals were documented on or near the site.

Species of Greatest Conservation Need

Species of Greatest Conservation Need (SGCN) is a wildlife classification for regional conservation purposes. It includes state-listed species and non-listed species that are regionally rare or in decline, often as a result of habitat loss. The MnDNR publication, *Tomorrow's Habitat for the Wild and Rare: An Action Plan for Minnesota Wildlife, Comprehensive Wildlife Conservation Strategy* (MnDNR 2006) presents a statewide analysis of SGCN species, organized by ecological subsection. The Big Woods Subsection, where the site is located, contains 7 mammals that are SGCN species, 58 birds, 14 reptiles, 1 amphibian, 16 fish, 2 spiders, 3 invertebrates, and 24 molluscs.

Providing a refuge for certain SGCN species would be an appropriate long-term objective for the site. The site's size, regional setting, variable habitats, and restoration potential raise the likelihood that that

SGCN species use or could use the site. Restoration and management of the site would be expected to attract some of the region's upland and wetland SGCN species, but not river-dependent species.

Invasive Species

Invasive vegetation exists throughout most of the site, with the least present in active cropfields (due to annual tilling and regular herbicide use). Invasive species thrive in disturbed habitats and often dominate and out-compete native plants, reducing habitat and species diversity, and lessening an ecosystem's resilience in the face of disturbances and environmental change. Of the plant species observed by AES at the site, several are a concern with regard to ecological restoration and management of native plant communities. A list of invasive species is provided in the project specifications (Appendix A, Herbaceous Species Removal Section). Controlling these species will be essential for restoration work to succeed.

Invasive animals (e.g., non-native earthworms) also cause ecological harm to soils and vegetation. Unfortunately, control of invasive animals is usually difficult and costly; being aware of their presence and not facilitating their spread can slow infestations.

The MnDNR has developed guidelines to minimize the introduction and movement of invasive species (Appendix B). These guidelines should be followed at all times in the site to prevent new introductions as well as the spread of invasive species within the site.

4 CONSERVATION GOALS AND OPPORTUNITIES

The MCWD, assisted by AES, developed four goals to guide this NRMP. These goals represent a combination of short and long term goals, were prioritized by MCWD staff, and each goal is discussed below in priority order.

1. **Restore higher quality native plant communities and habitats**

Aside from portions of Six Mile Marsh, the site contains few native plant communities, and most are of poor to moderate quality. However, the site represents an opportunity to restore complex mosaic of native plant communities, including significant blocks of core habitat for area-sensitive species. Converting the site's croplands and non-native grasslands to native prairie and savanna, restoring more natural hydrology and native vegetation to site wetlands, and enhancing existing woodlands and forests will result in a diversity of native habitats. Implementation of this NRMP will result in the restoration of moderate quality native habitats in most portions of the site within a few years. Continued ecological management at the site will result in higher quality native plant communities over time. The site's location within several identified conservation corridors makes habitat restoration even more beneficial to regionally rare wildlife. The MCWD is committed to carrying out ecological restoration and management, exemplified by their past work and this NRMP.

2. Manage invasive vegetation

Removal of invasive vegetation is often the most important step in ecological restoration, and continued management of invasive species is critical to a successful project. The site's cropfields, recently planted in Roundup Ready® soybeans, provide a relatively weed-free base from which to install native seed. This should result in good initial weed control, but management will still be important, especially during the initial establishment period of the prairie (usually about three years). Non-native grasslands will require more aggressive site preparation, likely consisting of three treatments of broadcast herbicide and possibly tilling.

Most of the site's wetlands are dominated by a combination of non-native, invasive reed canary grass and/or narrowleaf cattail. Aggressive removal and control efforts are required to enable native vegetation to become established through seeding and planting. Once natives are established, invasive control efforts can usually be reduced; however, depending on weed pressure, perpetual management is almost always necessary. Invasive vegetation in Six Mile Marsh will not be managed as part of this project.

The first and most important step in enhancing most degraded woodlands and forests is selective removal and control of invasive woody brush - often common buckthorn and Tartarian honeysuckle. Both of these species are present on the site, and buckthorn is abundant in some of the site's woodlands and forests, especially in the southeast portion of the site. Selective thinning of aggressive native woody species (e.g., boxelder, elms, prickly ash) is sometimes advantageous to restore target plant communities.

3. Protect and improve surface water

The site's surface waters include Six Mile Creek, Six Mile Marsh, and various depressional wetlands. While the site's upland and wetland vegetation communities provide some surface water management functions (e.g., filtration, low-diversity habitats), they do not provide the functions and benefits of healthy native ecosystems. Through establishing deep-rooted, perennial, native vegetation throughout the site, soils will be more stable, resulting in less opportunity for sediment and nutrient transport to Six Mile Marsh and downstream to Halsted Bay. Removing/abandoning existing agricultural drain tiles (Plan Sheet 3.0), restoring more natural hydrology, and restoring native wetland vegetation will provide better wetland habitats while also increasing infiltration, evapotranspiration, filtration and adsorption of sediment and phosphorus, storage and rate control, and downstream stream bank stabilization. Restoration activities will help reduce the stress placed upon Six Mile Creek due to past (and presumably future) development of land upstream.

The site's kettle and kame topography ensures that most of the site's depressional wetlands are isolated basins with small watersheds and little input from drainageways. This helps maintain higher water quality than is typical in many developed areas, and will facilitate restoration and reduce management requirements for site wetlands.

4. **Develop opportunities for education, interpretation, and public enjoyment**

The site offers myriad opportunities for education and interpretation of natural resources, ecological restoration and management. These opportunities tie directly in the public's ability to access and enjoy the site. Some education/interpretation opportunities follow:

- Exhibit healthy Minnesota native plant communities.
- Demonstrate the process of ecological restoration & management.
- Demonstrate the control of invasive species.
- Illustrate how to increase wildlife habitat quality & diversity.
- Install interpretive signs/kiosks to convey project goals and benefits as well as the process of ecological restoration.
- Partner with conservation non-profits to lead natural history hikes and other events.
- Partner with nearby schools to use the site for field study and experiments. A curriculum could be developed around restoration of the site.
- Provide opportunities for restoration volunteers (e.g., native seed collection, brushing).
- Provide opportunities for citizen science (e.g., conducting field surveys, collecting other data).

The site is also intended for sustainable, low-impact public use, including passive recreation. Human activities consistent with these goals include walking on designated trails, wildlife observation, and other non-consumptive, non-disruptive recreation. Currently, only the spur trail from the Dakota Rail Trail is proposed (Plan Sheet 7.0). If additional trails will be introduced to the site, they should be soft-surfaced (e.g., or mown, non-aggressive grasses) to discourage high-speed and/or loud uses (e.g., bicycles, skateboards). Trails should be designed sensitively in terms of their alignment and drainage. The MnDNR's publication, *Trail Planning, Design, and Development Guidelines* (MnDNR 2007), should be consulted to assist with sensitive trail design and construction. Trails should be restricted to the site's uplands unless a sensitively-designed boardwalk or pier is desired to cross or access wetlands.

5. **Build healthy soils**

Over time, restored and managed native plant communities will rebuild the site's soils. The majority of the site has been tilled annually, with nutrient-demanding crops being harvested each year and subsequent sheet and rill erosion occurring in the crop fields, resulting in sedimentation in farmed depressions (including historical wetlands) and downstream water resources. Healthy, deep-rooted, perennial vegetation will help anchor site soils, reducing erosion from the site's uplands and improving soil health. Most native prairie and savanna vegetation grows its roots deep into the soil, and some of these roots die back annually as part of the plant's natural life cycle. This root material (consisting largely of carbon) increases soil organic matter, rebuilding healthy soil and improving infiltration capacity, increasing moisture retention, and enhancing carbon sequestration across the site. Healthy soils result in improved ecosystem services, including reduced erosion and improved surface water and groundwater resources.

5 TARGET NATIVE PLANT COMMUNITIES

Target native plant communities were selected through discussions with the MCWD. Based on the site's environmental conditions and project goals, the following native plant communities will be restored to the site:

- Dry-Mesic Oak Forest (2.88 ac)
- Lowland Hardwood Forest (1.42 ac)
- Mesic Oak Savanna (17.35 ac)
- Mesic Prairie (114.22 ac)
- Wet Prairie (9.14 ac)
- Wet Meadow (5.71 ac)
- Marsh (1.95)

Note: Acres are approximate.

Existing forests will be transitioned to Dry-Mesic Oak Forest (in drier uplands) or enhanced Lowland Hardwood Forest (in lower areas). While Maple-Basswood Forest was the region's dominant upland plant community prior to European settlement, Mesic Prairie restoration was chosen as the target plant community for the majority of the site's uplands (including the expansive croplands as well as the old field on the east-central edge of the site). Prairie restoration is considerably easier, faster, and more affordable than forest restoration. The intent is for portions of the restored prairie to be transitioned to Mesic Oak Savanna over time. As open prairies transition into lower, moister elevations, Wet Prairie will be restored. Consistently wet/saturated wetlands will be restored to Wet Meadow, and regularly inundated, shallow wetland areas will be restored to Marsh. The expansive Six Mile Creek wetlands will not be addressed as part of this restoration plan.

For the majority of the site, wholesale restoration will occur, such as converting a cropfield to a native prairie. Most of the site's wetlands have either been partially drained by agricultural tiles and/or are dominated by invasive wetland species, namely reed canarygrass, narrowleaf cattail, and/or hybrid cattail. Restoring these wetlands will entail restoring more natural hydrology to the basins (by removing/abandoning tiles where they exist) and replacing invasive vegetation with appropriate native plants.

Plant species lists for restoration of native plant communities are provided in the project specifications (Appendix A). Native plant materials should have a source-origin within 150 miles of the site whenever possible, and only native, wild-type (non-cultivar) species should be used. Substitutions for specified seed and plant materials may be necessary due to the rapidly changing availability and pricing of native plant materials. Every effort should be made to match the ecological purpose of species that are unavailable in the selection of substitution species.

6 RESTORATION AND MANAGEMENT

Restoration and Management Stages and Implementation Phasing

Ecological restoration and management occurs in two stages, discussed below.

Restoration and Short-Term Management

This initial stage is the most intensive and costly. Significant effort is often necessary to reestablish native vegetation and plant community structure. Actions include tasks such as selective woody brush removal, spraying invasive species with herbicide, native seeding and planting, and using bio-control techniques when available. After invasive plants are removed and native seed and plants are installed, short-term management is critical. The period of time required to complete this restoration and short-term management stage varies depending on the condition of the ecological system, its response to restoration efforts, as well as the size of the site and intensity and scope of the of the restoration work. Typically this initial stage requires about three years, after which the perpetual management stage begins.

Perpetual Management

After achieving initial restoration goals within a management unit, the restoration process shifts to a reduced-intervention, lower-cost perpetual management stage. The perpetual management stage is critical for maintaining the value of the investment, perpetuating healthy plant communities, and maximizing the ecological and aesthetic benefits of the native plant communities. This perpetual management provides long-term control of invasive species, remedial seeding/planting as necessary, and maintains necessary disturbance patterns (e.g., fire) within the management units.

To carry out these two stages in the site, work tasks are listed and scheduled over a multi-year period. Once work begins, it is important that all tasks be completed in sequence, or the restoration targets may not be achieved.

It is important that the restoration and management program and schedule be flexible. Flexibility is necessary because some tasks require suitable weather conditions or are dependent on the completion of preceding tasks. Flexibility is also necessary because feedback from the monitoring program may result in changes of strategy, techniques, and timing in order to meet restoration goals.

Ecological Monitoring & Reporting

Throughout both stages of ecological restoration and management, ecological monitoring provides important data about the effectiveness of the program. Initial baseline monitoring provides important information against which future monitoring data can be compared. Monitoring assesses the response of native plant communities by measuring ecological indicators of plant community recovery. Effectiveness is judged against the objectives of the project design (i.e., performance standards), and goals can be modified over time as a result of this feedback. High quality native plant communities in conservation lands (e.g., MnDNR Scientific and Natural Areas) and nearby parks can be useful as reference sites to assist with the design and assessment of site restorations.

Fixed photo-reference points should be established in the site for repeat photography of representative plant communities. Photo documentation throughout the entire restoration and management process (including baseline photographs, taken prior to initial restoration tasks) will provide a valuable record of restoration progress.

The results of annual monitoring are used to direct the restoration and management activities for the upcoming year. Annual ecological monitoring reports, usually completed at the end of a year, provide the locations and dates of all restoration and management efforts undertaken, site photographs, and future work that needs to be completed to address restoration goals. Monitoring reports are useful for documenting progress, assessing the need for modifications to the restoration and management program (i.e., adaptive management), informing MCWD staff and visitors of the status of the program, and informing municipalities and regulatory agencies about progress towards achieving conservation goals.

Within a given management unit, detailed ecological monitoring and reporting should be done annually for at least the first four years following initial restoration activities. This level of effort is warranted during initial restoration work and the critical establishment period of native plantings. Quantitative or semi-quantitative monitoring and reporting is useful for guiding adaptive management and is necessary to evaluate achievement of performance standards. Less intensive monitoring and reporting should then continue in perpetuity, but frequency and level of effort should be based on site conditions, recent restoration and management activities, pressure by invasive species, etc.

Ecological Monitoring Protocol

Ecological monitoring is critical to inform adaptive management at the site and to insure the investments made in the site's restoration. Monitoring should be conducted throughout initial restoration activities, at least twice annually for the first four years, followed by a minimum of annual inspections in subsequent years. Issues that should be assessed and documented include:

- Native vegetation (document species and percent cover by ecological restoration zone; compare with seeding/planting lists);
- Invasive vegetation (document species and percent cover by ecological restoration zone; include map of populations);
- Erosion Areas (map areas of erosion, denoting severity as well as type, such as sheet, rill, shoreline, stream bank, mass wasting, etc.);
- Hydrology (document hydrologic regime of wetlands and aquatic systems, depths of standing water; visual assessment of water clarity, etc.);
- Document any incompatibilities with the site's conservation easement or conservation goals (e.g., dumping, unsanctioned mowing, etc.)

The MCWD may be interested also in documenting the soil restoration process, through assessment and documentation of soil cores throughout the site's different restoration zones. Following site assessment, recommendations should be made regarding necessary corrective actions. Recommendations may include special herbicide and/or mowing treatments, overseeding, interplanting, re-planting, erosion control techniques, protection of plantings, etc. Monitoring reports should be prepared, summarizing work completed since the previous report, monitoring findings, and recommended corrective actions.

Specialized Training

Specialized training (often involving licensing or certification), oversight, and guidance are required of personnel before implementation of this NRMP. Personnel and volunteers involved in prescribed burning, brush control, monitoring, seed collection, etc. should receive training commensurate with the activity in which they would be involved. Training is especially important for those activities that may have risk and safety implications, such as prescribed burning and herbicide application. However, even misidentification of plant species (e.g., mistaking native cherry shrubs for common buckthorn, mistaking native grasses for invasive reed canary grass) can have adverse effects on restoration implementation and management.

Restoration and Short-Term Management

Restoration and short-term management of the site's plant communities will require a variety of tasks, many of which vary depending on specific, local environmental conditions. Restoration and management tasks are described in detail in the project specifications (Appendix A). Implementation of this restoration project is anticipated to begin in Spring 2013, addressing all restoration zones simultaneously. The recommended restoration and short-term management schedule follows.

Table 1. Schedule for Restoration and Short-Term Management

Task	Description/Subtask	Year 1				Year 2				Year 3			
		Spring	Summer	Fall	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall	Winter
Grading, Clearing & Grubbing and Removals	Break & seal tiles, scrape swale sediment, construct berm, clear/grub specified trees and other removals per plans	■											
Seeding & Planting (croplands being restored to prairie and wetlands)	Install native seed	■											
	Install live herbaceous plants					■							
Weed Control (croplands being restored to prairie and wetlands)	Spot spray, broadcast herbicide, wick apply herbicide and/or spot mow		■	■		■	■			■	■		
Site Preparation (all zones except previous croplands)	Spot spray, broadcast herbicide, wick apply herbicide and/or spot mow	■	■	■									
Brushing & Thinning (all zones with invasive woody vegetation)	Cut & stump treat invasive woody plants				■								
	Selectively thin aggressive native woody plants				■								
Weed Control (all zones except previous croplands)	Spot spray, broadcast herbicide, wick apply herbicide and/or spot mow					■	■			■	■		
	Foliar herbicide non-native woody re-growth							■				■	
	Prescribed burn (where fuel is sufficient)											■	
Seeding & Planting (all zones except croplands already seeded/planted)	Install native seed			■									
	Install live herbaceous plants					■							
Ecological Monitoring & Reporting (all zones)	Assess/document site, and prepare summary report	■	■	■	■	■	■	■	■	■	■	■	■

* Installation of oak seedlings/saplings into Mesic Oak Savanna Expansion areas will occur at a later date. Exact timing of these live plantings will be determined based on the site's response to prairie restoration, natural recruitment of volunteer oak trees, availability and size of oak seedlings/saplings, and other factors.

Management Units

After the initial stage of restoration and management is complete, perpetual management tasks will be implemented by management units. Following project implementation, management units will be delineated considering property boundaries, existing roads, topography, trails, reasonable-sized areas to manage, similar management needs (e.g., use of prescribed fire), the need for wildlife refugia (e.g., nearby alternate habitat for prairie invertebrates and other wildlife during and after prescribed fires), and proposed site uses. Additional native plantings (e.g., entry plantings and building foundation plantings) may be completed as part of a separate landscape plan for the site and are not included in this NRMP.

The following sections outline restoration and management tasks to be performed throughout the site as well as within each individual management unit. When possible, implementation of this NRMP should proceed sequentially, beginning with tasks conducted throughout the entire site, then proceeding to individual management units. Management units have been numbered for identification purposes only; they do not represent a prioritization or sequence. While management units can be combined, split, and implemented in almost any order, the issues listed above (property boundaries, management needs, etc.) should be considered when developing an implementation schedule.

General Restoration and Management Tasks for the Entire Site

Restoration and management tasks that should be carried out throughout the entire site include:

1. Biological Inventory

    - As soon as scheduling allows, conduct a thorough plant inventory to inform future restoration planning and identify any rare plants that may be present on site. Establishment of permanent relevé plots would provide a valuable and standardized method of documenting existing vegetation and monitoring change. The MnDNR has published a handbook to assist with implementation of this method (MnDNR 2007), and MnDNR staff may available for on-site training.
    - As soon as scheduling allows, conduct a thorough wildlife inventory to better understand the desirable and undesirable wildlife using the site. This will help refine selected indicator species and inform habitat management strategies to favor rare or uncommon species in or near the site.
    - A "bioblitz[1]" is a cost-effective way to leverage regional technical expertise and involve area residents to inventory a site's biological resources.

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[1] A bioblitz is a concentrated period (usually 24-hours) of documenting all living species within a given area, such as a public park. Bioblitzes are useful for gathering important baseline data on plants and animals in a specific area, while also providing an opportunity for environmental education and biodiversity appreciation.

2. Deer Herd Management

    - Evidence of deer browsing on native shrubs was observed at the site. Deer herd management and/or deterrence may be necessary to prevent over-browsing of the herbaceous and shrub layers. Without protection, restoration of diverse native ground layer vegetation may be impeded or prevented, and planted or desirable volunteer tree and shrub seedlings may not survive. As has been done in regional parks, a deer control program may be considered for the site if over-browsing warrants a control program. An appropriate deer removal can be explored in partnership with the non-profit, volunteer-run organization, Metro Bow Hunters Resource Base. Through this program, experienced volunteer archers may assist in deer control efforts.

3. Annual Ecological Monitoring & Reporting

    - Each year, walk the site's natural areas and document response to native seeding/planting, survivorship, invasive species presence, problems with vegetative cover, and observations of herbivory, erosion, or illicit activities (e.g., dumping).
    - Establish fixed photo-reference points and take photos annually, including landscape photos as well as oblique downward photos to capture ground layer vegetation.
    - Prepare annual ecological monitoring report that summarizes findings and provides recommendations for future management.
    - Conduct flora and fauna surveys (e.g., indicator species) to assess and monitor biological response to ecological restoration and management activities.

Recommendations for Native Seed Collection by Volunteers

Volunteer seed collection is an effective way of educating participants and helping to build an appreciation for conservation and restoration ecology. Differing phonologies for native species provides the opportunity for seed collection at multiple times each year, enabling volunteers to experience the site during different seasons.

Volunteer seed collection may be conducted through simple hand-collection or using a variety of hand-held harvesters. The best native seed collecting methods vary by species. For many native species, seed is beaten, cut, or stripped from a plant using gloved hands. Simple tools are all that are needed. Larger cutting tools, such as sickles and scythes, are not recommended for volunteer use.

It is important to develop a site-appropriate seed collection program in order to maximize the benefits for both the MCWD as well as volunteers. Elements of a successful volunteer seed collection program include:

- Identification of priority native species and/or species that lend themselves to volunteer collection
- Volunteer coordinator
- Simple seed collection tools and equipment (e.g., gloves, badminton rackets for beating seeds off plants, lightweight fabric hoppers for holding collected seed, clippers for cutting stems)
- Adequate training and supervision of volunteers
- Safety plans
- Documentation of seed collection efforts (to quantify the ounces, pounds, and value of collected seed)
- Plans for using collected seed

A typical volunteer seed collection event can result in hundreds if not thousands of dollars worth of native seed. This valuable product may be used on site for restoration or enhancement overseeding, on other MCWD conservation lands, or sold or traded with others to meet their ecological restoration needs. The benefits of volunteers interacting – hands-on – with nature cannot be quantified in monetary terms.

Recommendations for Transition from Prairie to Savanna

Over time, portions of the site's prairie will be transitioned to Mesic Oak Savanna, one of Minnesota's most endangered native plant communities. This will be accomplished through a variety of strategies, including:

- Protection of desirable woody vegetation (e.g., oak seedlings) from prescribed fire, deer and rodent browse, and other damage. Adjacent vegetation, including grasses and woody plants, may require control to reduce competition for sunlight and resources (e.g., water, nutrients).
- Live plants can be purchased and installed. Herbaceous plants can be purchased as live plugs, and woody plants can be purchased as bare root, ball and burlap, or containerized stock. Acorns can be collected from the site (and other nearby areas) and grown-out at a nursery for later installation as seedlings/saplings. This approach will preserve the site's actual genetics, and would be expected to result in well-adapted specimens that thrive under the site's specific conditions (e.g., soils, climate, pests). The size, location, and spacing of installed oak seedlings/saplings needs to consider protection from prescribed fire and browse.
- An on-site nursery could be established to propagate oaks and other savanna species to facilitate the restoration of this native plant community.

Plan Sheet 6.0 depicts hatched Mesic Oak Savanna Expansion areas, which capitalize on existing oak and other tree seed sources. These expansion areas will initially be restored to and managed as Mesic Prairie in the short term, followed by planting and protection of oak seedlings/saplings to connect and expand existing site woodlands. Over time, the District may wish to establish additional Mesic Oak Savanna Expansion areas, such as along the site's northwest edge along the Dakota Rail Trail treeline.

AES recommends that the MCWD consider field-testing a variety of the savanna restoration techniques listed above to determine which best meets project goals. Test plots on the site could be established and monitored in order to determine cost-effectiveness and other benefits gained from these various techniques.

Perpetual Management Tasks

Perpetual management is essential to restoring and maintaining the composition, structure, and function of healthy native ecosystems. The two primary perpetual management tasks are:

1. *Weed Control*
   - Control invasive non-native herbaceous vegetation, primarily with appropriate spot herbicide applications. Cutting of invasive woody vegetation may also be necessary in some areas. Plant communities targeted for prairie restoration may employ haying or mowing if prescribed burning is not feasible. Mowing is less effective than haying because it does not remove plant material; over time the accumulated organic matter results in nutrient enrichment, which can favor invasive plants.
2. *Prescribed Burning*
   - Prescribed burning is a very cost-effective management tool for many native plant communities, including not only prairies but also savannas and some woodlands and forests. Generally, perpetual management burns are conducted on a rotational basis, burning only a portion of the site (e.g., one or a subset of the management units) each year and beginning with the fall or spring following the third full year of growth after seeding. In order to mimic natural fire regimes, burns should extend across habitat gradients (e.g., burning from prairies into adjacent savannas, woodlands, and wetlands) when feasible.

Perpetual management tasks (Table 2) are repeated at different intervals for different plant communities to ensure that healthy restored plant communities are maintained over the long term.

Table 2. Perpetual Management Schedule & Average Annual Costs

	Task Frequency (once every X years)				
Target Native Plant Community	**Prescribed Burning**	**Weed Control (Spot Herbicide)**	**Remedial Seeding/Planting**	**Detailed Monitoring & Reporting**	**Average Annual Perpetual Cost**
Dry-Mesic Oak Forest	5-10	3-4	5	1	$400/ac
Lowland Hardwood Forest	NA	3-4	5	1	$300/ac
Mesic Oak Savanna	2-3	2-3	2-3	1	$500/ac
Mesic Prairie	3-4	1-2	3-5	1	$300/ac
Wet Prairie, Wet Meadow & Marsh	3-4	1-2	3-5	1	$300/ac

Notes: NA = not applicable
Schedule assumes that prescribed burning will be employed as a restoration and management technique. If prescribed burning is not employed, haying should be used in prairie areas to prevent accumulation of plant material.

7 OPINION OF PROBABLE COST

Restoration, enhancement, short-term management, and perpetual management of the site's natural areas will require a substantial commitment of resources. However, phased and budgeted appropriately, this stewardship is achievable over time. While there are unknowns regarding the response of the site's natural areas to interventions, actual scheduling of activities, and whether activities will be conducted by MCWD staff, volunteers, and/or contractors, we offer the following summary of costs likely involved in the initial restoration and short-term management stage.

Table 3. Opinion of Probable Cost (construction and 3 years of management)

Item	Description	Quantity	Unit	Unit Cost	Line Item Cost Subtotal	Remarks
1	**Site Preparation**					
1.1	Mobilization	1	LS	$ 5,000	$ 5,000	
1.2	Clearing/Grubbing	1	LS	$ 2,500	$ 2,500	
1.3	Rock/Wood/Debris/Fence Removal	1	LS	$ 2,000	$ 2,000	
1.4	Herbiciding	35	AC	$ 200	$ 7,000	restoration areas not recently in crops or not being graded
1.5	Discing/Tilling	25	AC	$ 150	$ 3,750	restoration areas currently with dense, non-native vegetation
				Site Preparation Subtotal	**$ 20,250**	
2	**Earthwork**					
2.1	Sediment Scrape from Swales & Respread	3,200	CY	$ 5.00	$ 16,000	
2.2	Erosion Control	1	LS	$ 4,500	$ 4,500	construction entrance, straw bioroll, geotextile, and erosion control blanket
				Earthwork Subtotal	**$ 20, 500**	
3	**Utilities**					
3.1	Remove Existing Tile (50 ft of each, upper end)	450	LF	$ 10	$ 4,500	
3.2	Plug Tile Outlet (50 lbs concrete)	9	EA	$ 100	$ 900	
				Utilities Subtotal	**$ 5,400**	
4	**Native Seed with Cover Crop (material only)**					
4.1	Dry-Mesic Oak Forest	2.88	AC	$ 0	$ 0	no seed in this zone
4.2	Lowland Hardwood Forest	1.42	AC	$ 0	$ 0	no seed in this zone
4.3	Mesic Oak Savanna	17.35	AC	$ 580	$ 10,065	
4.4	Mesic Prairie	114.22	AC	$ 375	$ 42,835	
4.5	Wet Prairie	9.14	AC	$ 810	$ 7,405	
4.6	Wet Meadow	5.71	AC	$ 610	$ 3,485	
4.7	Marsh	1.95	AC	$ 500	$ 975	assume seed ½ zone
				Native Seed Subtotal	**$ 64,765**	

Item	Description	Quantity	Unit	Unit Cost	Line Item Cost Subtotal	Remarks
5	**Live Plant Plugs (material only)**					
5.1	Marsh	1,000	EA	$ 3.50	$ 3,500	assume plug ½ zone
				Live Plant Plugs Subtotal	**$ 3,500**	
6	**Ecological Restoration & 3 Years Management**					
6.1	Dry-Mesic Oak Forest (brushing/thinning)	2.88	AC	$ 2,500	$ 7,200	
6.2	Lowland Hardwood Forest (brushing/thinning)	1.42	AC	$ 1,500	$ 2,130	
6.3	Mesic Oak Savanna (brushing/thinning, broadcast seed)	17.35	AC	$ 2,500	$ 43,375	
6.4	Mesic Prairie (drill seed, straw mulch & crimp)	114.22	AC	$ 1,000	$ 114,220	
6.5	Wet Prairie (drill seed, straw mulch & crimp)	9.14	AC	$ 1,000	$ 9,140	
6.6	Wet Meadow (install seed & straw mulch)	5.71	AC	$ 1,000	$ 5,710	
6.7	Marsh (broadcast seed up to water's edge and install plugs in shallow water)	1.95	AC	$ 850	$ 1,660	
6.8	Short-Term Management (all zones, Year 1)	152.67	AC	$ 500	$ 76,335	mow & spot spray
6.9	Short-Term Management (all zones, Year 2)	152.67	AC	$ 500	$ 76,335	mow & spot spray
6.10	Short-Term Management (all zones, Year 3)	152.67	AC	$ 500	$ 76,335	spot spray & burn
				Ecological Restoration & 3 Years Mgmt Subtotal	**$ 412,440**	
7	**Alternative - Bituminous Spur Trail**					
7.1	Mobilization	1	LS	$ 35,000	$ 35,000	
7.2	Topsoil Strip/Stockpile/Respread	50	CY	$ 15	$ 750	
7.3	8' Trail (6" section, subgrade, Class V)	2,100	CY	$ 40	$ 84,000	
7.4	Trail Culverts	24	LF	$ 20	$ 480	
7.5	Benches	2	EA	$ 2,500	$ 5,000	
				Alternative - Bituminous Spur Trail Subtotal	**$ 125,230**	
8	**Subtotal (including Alt. Trail costs)**				**$ 652,085**	
9	Contingency	10.00%			$ 65,210	
10	**Total Construction Estimate (including Alt. Trail costs)**	**(2012 Dollars)**			**$ 717,295**	

8 CONCLUSION

The majority of the site has been significantly altered through historical land use. However, the restoration, enhancement, and management tasks described in this NRMP will help achieve the conservation goals for the MCWD. Execution of these restoration and management tasks by qualified restoration specialists in conjunction with ecological monitoring and adaptive management will help to ensure a legacy of healthy ecosystems at the site. These restored and enhanced native ecosystems will provide aesthetically pleasing landscapes for the community, passive recreational opportunities, and ecosystem services that benefit the entire region.

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Appendix A. Specifications for Natural Resource Management Plan for Halverson-Dimler Restoration Project

SPECIFICATIONS FOR
NATURAL RESOURCE MANAGEMENT PROGRAM

FOR

HALVERSON-DIMLER RESTORATION PROJECT
MINNETRISTA, MINNESOTA

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January 15, 2013 (select sections only)

TABLE OF CONTENTS

SITE WORK

SITE WORK
SECTION – NATIVE PLANT SEEDING

PART 1. GENERAL

1.1 DESCRIPTION

A. This section includes installation of native plant seed in areas to be restored or enhanced to native plant communities. This work shall occur in the areas designated as Mesic Oak Savanna, Mesic Prairie, Wet Prairie, Wet Meadow, and Marsh on the project plans.

1.2 RELATED SECTIONS

A. Soil preparation; Herbaceous perennial planting.

1.3 QUALITY ASSURANCE

A. Qualifications of workers: provide at least one person who shall be present at all times during execution of this portion of the work, and who shall be thoroughly familiar with the type and operation of equipment being used. Said person shall direct all work performed under this section.

B. Standards: all materials used during this portion of the work shall meet or exceed applicable federal, state, county and local laws and regulations, including those of the Minnehaha Creek Watershed District. All seed shall be free from insects and disease. Species shall be true to their scientific name as specified.

1.4 SUBMITTALS

A. Materials: Prior to delivery of any materials to the site, submit to the Owner a complete list of all seed to be used during this portion of the work. Include complete data on source, quantity and quality. This submittal shall in no way be construed as permitting substitution for specific items described on the plans or in these specifications unless approved in writing by the Owner.

B. Equipment: Prior to commencement of any work, submit to the Owner a written description of all mechanical equipment and its intended use during the execution of the work.

C. After the work is complete, submit to the Owner formal “as-built” plans. As-builts shall be prepared in AutoCAD or comparable drafting software and shall delineate areas seeded with natives and a listing of all species installed and quantities installed. Any field changes or deviations from the original plans shall be clearly marked on the as-builts. Hand-edited design plans are not acceptable as as-builts.

PART 2. PRODUCTS

The following seed lists represent species that are appropriate for the target native plant communities. Some of these species may not be available at the time of seeding, and other appropriate native species may be added and/or substituted with approval in writing from the Owner.

"Restoration" generally refers to re-creating a native plant community from scratch, such as converting an old field to native prairie. The assumption is that most if not all existing vegetation must be removed prior to installation of native plant materials. "Enhancement" refers to the converting an existing semi-natural community, such as a degraded woodland, to a native plant community, such as a Mesic Oak Savanna. Variable rates of seed and live plant material are warranted for these two strategies, and appropriate rates may vary across an individual restoration zone depending on local conditions.

2.1 DRY-MESIC OAK FOREST SEED LIST

No seed proposed for this zone.

2.2 LOWLAND HARDWOOD FOREST SEED LIST

No seed proposed for this zone.

2.3 MESIC OAK SAVANNA SEED LIST

For Areas with No or Little Canopy Cover (<20%):

Use Minnesota State Seed Mix 36-211 (Woodland Edge South & West). For bidding purposes, assume <20% canopy cover area constitutes 50% of Mesic Oak Savanna acreage.

For Areas with Existing Canopy Cover (>20%):

For bidding purposes, assume >20% canopy cover area constitutes 50% of Mesic Oak Savanna acreage.

SCIENTIFIC NAME	**COMMON NAME**	**Rate**
GRAMINOIDS		**(lb/ac)**
Bromus pubescens	Hairy woodland brome	0.30
Carex sprengellii	Long-beaked sedge	0.10
Elymus hystrix	Bottlebrush grass	0.20
Elymus virginicus	Virginia wild rye	3.40
	Total Grasses	**4.00**

SCIENTIFIC NAME	**COMMON NAME**	**Rate**
FORBS		**(lb/ac)**
Anemone cylindrica	Long-headed thimbleweed	0.10
Aquilegia canadensis	Canada columbine	0.20
Arisaema triphyllum	Jack-in-the-pulpit	0.20
Eurybia macrophylla	Large-leaved aster	0.03
Campanula rotundifolia	Harebell	0.04
Desmodium glutinosum	Pointed-leaved tick-trefoil	0.05
Smilacina racemosa	Common false Solomon's seal	0.20
Solidago flexicaulis	Zig zag goldenrod	0.05
Symphyotrichum cordifolium	Heart-leaved aster	0.03
Symphyotrichum oolentangiense	Sky blue aster	0.05
Thalictrum dioicum	Early meadow-rue	0.05
	Total Forbs	**1.00**

SCIENTIFIC NAME	**COMMON NAME**	**Rate**
COVER CROP (select ONE)		**(lb/ac)**
Avena sativa (Oct 15 – Aug 1)	Oats	**15.00**
Triticum aestivum (Aug 1 – Oct 15)	Winter wheat	**15.00**

2.4 MESIC PRAIRIE SEED LIST

Use Minnesota State Seed Mixe 35-241 (Mesic Prairie General).

2.5 WET PRAIRIE SEED LIST

Use Minnesota State Seed Mix 34-262 (Wet Prairie).

2.6 WET MEADOW SEED LIST

Use Minnesota State Seed Mix 34-271 (Wet Meadow South & West).

2.7 MARSH SEED LIST

Use Minnesota State Seed Mix 34-181 (Emergent Wetland Mix). Seed should be broadcast onto wet to moist soil (not over open water). Live plants will be installed in areas of standing water.

2.8 MATERIALS

A. Grass species to be supplied as pure live seed include, at a minimum: *Andropogon gerardii* (Big bluestem), *Bouteloua curtipendula* (Side-oats grama), *Elymus canadensis* (Canada wild rye), *Elymus virginicus* (Virginia wild rye), *Panicum virgatum* (Switchgrass), *Schizachyrium scoparium* (Little bluestem grass), and *Sorghastrum nutans* (Indian grass). Submit to the Owner lab germination test results.

B. Origin of all seed shall be from within a 150-mile radius of the project site and native to Minnesota. Species shall be true to their scientific name as specified.

C. Straw or hay for erosion control shall be clean, seed-free hay or threshed straw of wheat, rye, oats, or barley. Marsh hay shall not be used on the site.

PART 3. EXECUTION

3.1 METHOD

A. Native plant seeding shall occur in restoration zones designated on plans after Soil preparation (previous section).

B. Seeding shall be preferentially conducted as a late fall dormant seeding (after November 1) or in early spring (as soon as the soil is free of frost and in a workable condition but no later than June 30).

C. Seeds shall have proper stratification and/or scarification to break seed dormancy if planting in spring.

D. All legumes shall be inoculated with proper rhizobia at the appropriate time prior to planting.

E. Thoroughly mix all seed by hand or machine before sowing.

F. Grass seed shall be preferentially installed with a rangeland type grain drill or no-till planter, such as by Truax, or equivalent as approved in writing by the Owner. Forb seed can be installed by a rangeland type grain drill or no-till planter; however, if this equipment is used, it shall be modified to drop small, flowable seed on the ground surface.

G. If soil is too wet or areas too small to install by a rangeland type grain drill or no-till planter, a mechanical broadcast seeder, such as by Cyclone, shall be used. Hand broadcasting of seed may also be employed.

H. Seed that is to be sown by hand shall be divided into two equal parts. The entire area shall be sown with first half before spreading second half. All seed shall be broadcast evenly throughout seeding zones after seedbed has been prepared.

I. Seeding shall be conducted on exposed soil or water <2" deep.

J. Within 24 hours, or as soon as site conditions permit, broadcast seeded areas shall be rolled with a cultipacker perpendicular to the slope. Cultipacking may not be possible or practical in wetlands or in areas where soil preparation was non-intensive; therefore, gentle raking of seeded areas should be conducted to ensure good seed-to-soil contact.

K. Hydroseeding and mulching onto a lightly disced soil surface is also an acceptable method. Contractor shall provide specifications on the nature of the equipment, mulching system, and tackifier that would be used if hydroseeding/mulching is the chosen method.

L. Within seven days of seeding, crimp 2,000 pounds per acre of straw or hay onto flat areas and slopes up to three feet horizontal to one foot vertical (3:1). If straw/hay crimping is not possible or not practical (e.g., in wetlands or in areas where soil preparation was non-intensive), machine or hand spread straw/hay at a rate of <=2,000 pounds per acre (depending on existing cover of desirable native vegetation, slopes, soil erodibility, etc.).

M. If area to be seeded was treated with herbicide, seeding shall occur no less than 14 days after herbicide application.

3.2 CLEAN-UP, REMOVAL AND REPAIR

A. Clean up: The Contractor shall keep the work area free of debris. After seed installation is complete, clean up any remaining materials, debris, trash, etc. Avoid driving over seeded areas to minimize disturbance

B. Removal: After work has been completed remove any tools, equipment, empty containers, and all other debris generated by the Contractor

C. Repair: Repair any damages caused by the Contractor during completion of the work described in this section.

3.3 INSPECTION

A. After completion of seeding, the Contractor shall schedule with Owner a provisional acceptance inspection of the work.

3.4 ACCEPTANCE AND GUARANTEE

A. Provisional acceptance: The work shall be considered 90% complete after all seed has been installed and the Contractor has completed all required clean up, removal, and repair as described in 3.2 of this section.

B. Final acceptance: The work shall be considered 100% complete after the Contractor has met or exceeded the performance standards given in 3.4C of this section, and completed all required clean up, removal, and repair as described in 3.2 of this section.

C. Guarantee: The Contractor shall guarantee seeded areas will meet or exceed the following performance criteria one full growing season after installation and provisional acceptance: 70% total plant cover (including cover crop), seedlings of 2 planted grass/sedge species present and widely dispersed, and seedlings of 4 planted forb species present and widely dispersed.

END OF SECTION

SITE WORK
SECTION – HERBACEOUS PERENNIAL PLANTING

PART 1. GENERAL

1.1 DESCRIPTION

A. This section includes installation of live herbaceous perennial plants, tubers, bulbs, and dormant rootstocks of herbaceous perennial plants. This work shall occur in the areas designated as Marsh on the project plans.

1.2 RELATED SECTIONS

A. Soil preparation; Native plant seeding.

1.3 QUALITY ASSURANCE

B. Qualifications of workers: provide at least one person who shall be present at all times during execution of this portion of the work, and who shall be thoroughly familiar with the type and operation of equipment being used. Said person shall direct all work performed under this section.

C. Standards: all materials used during this portion of the work shall meet or exceed applicable federal, state, county and local laws and regulations. All live herbaceous perennial plants, tubers, bulbs, and dormant rootstocks of herbaceous perennial plants shall be free from insects and disease.

1.4 SUBMITTALS

A. Materials: Prior to delivery of any materials to the site, submit to the Owner a complete list of all live herbaceous perennial plants, tubers, bulbs, and dormant rootstocks of herbaceous perennial plants to be used during this portion of the work. Include complete data on source, quantity and quality. This submittal shall in no way be construed as permitting substitution for specific items described on the plans or in these specifications unless approved in writing by the Owner.

B. Equipment: Prior to commencement of any work, submit to the Owner a written description of all mechanical equipment and its intended use during the execution of the work.

C. After the work is complete, submit to the Owner formal "as-built" plans. As-builts shall be prepared in AutoCAD or comparable drafting software and shall delineate areas planted with live herbaceous plants and a listing of all species installed and quantities installed. Any field changes or deviations from the original plans shall be clearly marked on the as-builts. Hand-edited design plans are not acceptable as as-builts.

PART 2. PRODUCTS

2.1 MARSH PLANT LIST

SCIENTIFIC NAME	COMMON NAME	TOTAL # PLANTS
GRAMINOIDS		
Carex lacustris	Lake sedge	100
Carex stricta	Tussock sedge	100
Eleocharis palustris	A species of spike-rush	50
Bolboschoenus fluviatilis	River bulrush	100
Schoenoplectus tabernaemontani	soft stem bulrush	100
Spartina pectinata	Prairie cordgrass	50
	GRAMINOID TOTAL:	**500**

SCIENTIFIC NAME	COMMON NAME	TOTAL # PLANTS
FORBS		
Acorus calamus	Sweet flag	100
Iris versicolor	Blue flag	100
Sagittaria latifolia	Broad-leaved arrowhead	200
Sparganium eurycarpum	Giant bur-reed	100
	FORB TOTAL:	**500**

2.2 MATERIALS

A. All plants must be ASTM standards for specified size and condition.

B. Origin of all live herbaceous perennial plants, tubers, bulbs, and dormant rootstocks of herbaceous perennial plants shall be from within a 150-mile radius of the project site and native to Minnesota. Species shall be true to their scientific name as specified.

PART 3. EXECUTION

3.1 METHOD

A. Planting of all live herbaceous perennial plants, tubers, bulbs, and dormant rootstocks of herbaceous perennial plants (herein referred to as "live herbaceous plants") shall occur in restoration zones designated on plans after soil preparation, cover crop seeding, native plant seeding, and installation of erosion control blanket.

B. Planting of all live herbaceous plants shall be completed after May 15 but no later than July 15 without written approval by the Owner.

C. All live herbaceous plants shall be potted, two-year or equivalent nursery grown stock, size "38" or equivalent (i.e., 2.5-inch pot) unless approved in writing by the Owner.

D. All live herbaceous perennial plants shall be approved by the Owner prior to installation.

E. Provide healthy, vigorous live herbaceous perennial plants; provide freshly dug tubers, bulbs, and dormant rootstocks of herbaceous perennial plants. Do not use materials that have been in cold storage for longer than 45 days.

F. Deliver live herbaceous perennial plants, tubers, bulbs, and dormant rootstocks of herbaceous perennial plants to project site after preparations for planting have been completed.

G. Live herbaceous plants shall be transported and stored in such a manner as to insure adequate protection against wind damage, desiccation, and other physical damage.

H. If planting is delayed more than four hours after delivery, keep plants in refrigerated container or set plants in shade protected from weather and mechanical damage, and keep moist and cool.

I. Plant layout and locations of all live herbaceous plants shall be conducted by the Contractor and approved by the Owner before excavation of plant pits. The Owner reserves the right to make minor adjustments to plant material locations without additional cost to the Owner.

J. When conditions detrimental to plant growth are encountered during excavation such as rubble, fill or other obstructions, notify the Owner immediately before planting.

K. Before planting, biodegradable pots shall be split, and non-biodegradable pots shall be removed. Root systems of all potted plants shall be split at base of plug with 1" cuts in a crisscross pattern with a sharp blade.

L. Emergent live herbaceous plants shall be installed in 0"-2" depth of water.

M. Live herbaceous plants shall be clustered into groups of 5 to 10 individuals of the same species. Emergent Wetland plants should be installed on approximate 2-foot centers.

N. All live herbaceous plants shall be adequately healed in to prevent desiccation.

O. The soil around the roots shall be lightly compacted and free of air pockets to prevent desiccation.

P. Thoroughly water all plants within 12 hours of planting if plants are not submerged or not in saturated or very moist soil.

Q. In order to achieve the performance standards listed in 3.4C below, if the Contractor deems it necessary, all groupings of live herbaceous emergent wetland plants shall be protected from wildlife herbivory on all four sides by wildlife exclusion cages. The Contractor shall submit shop drawings, including a materials list, to the Owner for approval prior to installation. Said cages shall be removed by the Contractor one full growing season after installation or as otherwise directed by the Owner.

R. If planting into an area treated with herbicide, plant materials shall be installed no less than 14 days after herbicide treatment.

3.2 CLEAN-UP, REMOVAL AND REPAIR

A. Clean up: The Contractor shall keep the work area free of debris. After the work is complete, clean up any remaining materials, plant containers, debris, trash, etc. Avoid driving or walking over planted areas to minimize disturbance.

B. Removal: After work has been completed remove any tools, equipment, empty containers, and all other debris generated by the Contractor.

C. Repair: Repair any damages caused by the Contractor during completion of the work described in this section.

3.3 INSPECTION

A. After completion of planting and wildlife exclusion cages, the Contractor shall schedule with the Owner a provisional acceptance inspection of the work.

3.4 ACCEPTANCE AND GUARANTEE

A. Provisional acceptance: The work shall be considered 90% complete after initial planting, and after the Contractor has completed all required clean up, removal, and repair as described in 3.2 of this section.

B. Final acceptance: The work shall be considered 100% complete after the Contractor has met or exceeded the performance standards given in 3.4C. of this section, completed all required clean up, removal, and repair as described in 3.2 of this section, and removed cages as described in 3.1Q. of this section.

C. Guarantee: The Contractor shall guarantee planted areas will meet or exceed the following performance criteria one full growing season after provisional acceptance: survivorship of 4 planted species widely dispersed throughout the planted areas.

END OF SECTION

MINNEHAHA CREEK WATERSHED DISTRICT
QUALITY OF WATER QUALITY OF LIFE

MEMORANDUM

To: MCWD Board of Managers

From: Telly Mamayek, Communications Director; Becky Christopher (Houdek), Planner

CC: James Wisker, Planning Director

Date: November 6, 2014

Re: Community Outreach for the 2017 Comprehensive Plan

Purpose:

- To provide a status report on community outreach for the District's 2017 Comprehensive Water Resources Management Plan as requested at the October 23, 2014 meeting of the MCWD Board of Managers.

History/Recent Board Action/Discussion:

- Discussions about the process and timeline for developing the District's 2017 Comprehensive Water Resources Management Plan (Plan) began in the fall of 2013. In a memo to the Planning and Policy Committee for its meeting on October 3, 2013, staff outlined the steps that were taken to develop the 2007 Plan to facilitate discussion on the development of the 2017 Plan. During discussion, the Committee noted that communities would be adopting their comprehensive plans in 2018, allowing opportunity for collaborative planning/outreach efforts. The Committee discussed that different outreach strategies may be needed in different geographies based on land use, projected change over time and the diversity of local government units.
- A Request for Board Action was presented to the Board of Managers at its February 13, 2014 meeting to authorize staff to work with Himle Rapp to conduct a district-wide public opinion survey in the spring of 2014. The purpose of the survey was to measure the effectiveness of the District's communications efforts and inform the process for developing the District's 2017 Plan. The request was approved by a unanimous vote and advanced to the consent agenda for the February 27, 2014 meeting, during which it was approved by a unanimous vote.
- At the Board workshop on March 13, 2014, Himle Rapp led a discussion with the Board of Managers on the role of engaging the District's target audiences in formulating the 2017 plan. During discussion, Managers noted the importance of using the public opinion survey findings to inform the 2017 Plan development and engaging policymakers in addition to technical staff. By a unanimous vote, the Board directed staff to continue to define the planning process and the outreach plan.

- On March 25, 2014, Himle Rapp conducted a scoping session with the MCWD program managers to identify information desired from the public opinion survey.
- A follow-up input exercise was done with the entire staff on April 21, 2014 and results of that discussion were sent to Himle Rapp.
- At the June 19, 2014 meeting of the Planning and Policy Committee, staff presented a comprehensive framework for the 2017 Plan update which included an outreach and engagement plan, including objectives, key messages, target audiences, outreach strategies, process and schedule.
- A Request for Board Action was presented to the Board of Managers at its July 31, 2014 meeting to adopt the framework for the 2017 Plan update. There was considerable discussion on the proposed approach - remaining responsive to Districtwide concerns while focusing on specific geographies – and the proposal to continue addressing the long-range issues identified in the 2007 Plan. The request was approved by a 4-1 vote.
- Additional meetings were held with Himle Rapp on August 27, 2014 and October 21, 2014 to further refine the outreach process.

Current Status:

- In coordination with Himle Rapp, staff has continued to refine the components of the outreach plan for the 2017 Plan and will be providing an update at the November 6, 2014 joint meeting of the Operations and Programs and Policy and Planning Committees.

Next Steps/Board Meetings:

- At the December 11, 2014 Board workshop, staff will present a Request for Board Action to approve a contract for a self-assessment to gain insight on the performance of the District's current programs, identify potential new initiatives and emerging concerns and evaluate feedback from committees. This assessment is expected to occur in early 2015.
- In early 2015, staff will present a Request for Board Action to approve a contract for development of a database to track project information and progress toward load reduction goals.
- In January 2015, a kickoff meeting will be held to introduce the District's stakeholders to the 2017 Plan outreach process and invite them to participate.
- In early 2015, the Districtwide public opinion survey will be conducted.

Attachments:

- Memo to 10-3-13 Planning & Policy Committee
- 2-27-14 RBA authorizing Himle Rapp to conduct Districtwide public opinion survey
- Memo for 3-13-14 Board workshop discussion on 2017 Comprehensive Plan outreach
- 7-31-14 Draft 2017 Comprehensive Plan Framework
- 7-31-14 RBA adopting the 2017 Comprehensive Plan Framework

If there are questions in advance of the meeting, please contact: Becky Christopher, Planner at bhoudek@minnehahacreek.org; 952-641-4512 or Telly Mamayek, Communications Director at tmamayek@minnehahacreek.org; 952-641-4508.

MINNEHAHA CREEK WATERSHED DISTRICT
QUALITY OF WATER QUALITY OF LIFE

DATE: October 3, 2013

TO: Planning and Policy Committee

FROM: James Wisker, Director of Planning, Projects and Land Conservation

CC: Eric Evenson, Administrator
Louis Smith, District Counsel

RE: Review of the Development of the 2007 Comprehensive Water Resource Management Plan

Introduction:

The purpose of this memorandum is to summarize the development and structure of the 2007 update of its Comprehensive Water Resource Management Plan (Plan) to facilitate Committee discussion on the process and timeline for developing the 2017 Plan.

Executive Summary:

In developing the 2007 Plan, the District utilized extensive analysis of the watershed to identify causes of water quality degradation and corresponding implementation strategies to address the issues. Mirroring Total Maximum Daily Load (TMDL) implementation frameworks the 2007 Plan's implementation strategy relied on a performance based management strategy that encompassed a revised regulatory program, shared watershed and LGU requirements, and a coordinated effort between the District's capital improvements, land conservation, education-communication and hydrodata programs. As such, the District's 2007 Plan includes both nonstructural solutions to the problems such as public information and education, and regulation of land and water use; and structural solutions encompassing the District's capital project initiatives.

The development of the 2007 Plan was a substantial undertaking and a significant step forward for MCWD. Preceding the development of the Plan, the District completed a number of specialized studies, including detailed analyses of the condition of lakes, streams, and wetlands in the watershed, and an extensive hydrologic and hydraulic analysis of existing and expected future hydrologic and water quality conditions. Through extensive stakeholder engagement the 2007 Plan then consolidated the findings and recommendations from these studies into a comprehensive implementation framework, focused on water resource and divided into subwatersheds, which set forth holistic hydrologic, water quality and ecological integrity goals for the lakes, streams and wetland within the watershed.

Overall Plan Development Process:

The MCWD's 2007 Plan was the culmination of a several-year planning effort that incorporated an extensive public and technical planning process. As detailed in Section 4.1 of the Plan, in preparation for drafting the 2007 Plan, the District completed analyses of all its major hydrologic systems, including surface water quantity and quality modeling; water quality goal setting; stream assessments for Minnehaha Creek and the primary streams of the upper watershed; functions and values assessments of the wetland resources of the District; and a Visioning process to identify options and public preferences for the future management of Minnehaha Creek. In addition, specialized studies on specific water resources have been conducted, including the Painter Creek Feasibility Study, the Stubbs Bay Feasibility Study, and the Gleason Lake Management Plan.

Most of these past planning efforts included an extensive public participation process. The 2007 Plan integrated these past planning efforts into a long-range Management Plan for the watershed and the eleven subwatershed planning units.

The Hydrologic/Hydraulic and Pollutant Loading Study, or HHPLS, used an extensive public input process involving nearly 100 public meetings across the watershed to share modeling results, identify problems and gain input on appropriate approaches to addressing problems. Participants in these Regional Teams included city staff, agency representatives, and citizens. Most significantly, these public input sessions resulted in the development of new or refinement of existing water quality goals for 62 lakes or bays within the District. That planning process and those goals form the foundation of the 2007 Plan.

As work began on the 2007 Plan, the Board of Managers met in a series of workshops to discuss various policy issues. The Managers convened a Technical Advisory Committee (TAC) of City representatives and state and other agency staff to review and comment on these policy questions, assumptions, methods, and initial recommendations of the plans. The TAC met seven times between May 2005 and January 2006, and discussed:

- Performance Management Approach
- Regulatory Integration
- Land Conservation Program
- Wetland Management Planning
- Method for Calculating Ultimate Development
- Method for Calculating LGU Phosphorus Load Reductions
- Individual Subwatershed Plans

The Board of Managers also convened a Citizens Advisory Committee (CAC) of interested citizens appointed by their cities of residence to review and comment on policy questions and to provide advice and perspective on prioritizing resources. This CAC was a separate body from the Board's standing CAC, although there was overlap between members. The CAC met initially five times to obtain background information on topics similar to those covered by the TAC, then met several more times to review the draft subwatershed plans and to prioritize the water resources and issues in each subwatershed.

District staff also periodically sent email updates to an extensive email correspondence list advising interested parties as to the status of the planning process and how they could provide input. Planning drafts of the subwatershed plans were also posted on the District's Web site for public review and comment.

Formal Review Process:

Minnesota State Statute 103B.231 provides a specific formal review process that included the following milestones for the 2007 Plan:

1. 60-day release of the DRAFT Comprehensive Water Resources Management Plan for review and comment to counties, the Metropolitan Council, State review agencies, the Minnesota Board of Water & Soil Resources, Soil & Water Conservation Districts, towns and statutory and home rule charter cities.
2. Response in writing to comments received from the organizations noted above within 30-days of close of comment period
3. Watershed District public hearing on the DRAFT Comprehensive Water Resources Management Plan
4. Revision of DRAFT Comprehensive Water Resources Management Plan and release of the FINAL Plan to Metropolitan Council, State review agencies and the Minnesota Board of Water & Soil Resources
5. Final approval by the Minnesota Board of Water & Soil Resources

6. Adoption of the FINAL Comprehensive Water Resources Management Plan by Watershed District

On September 21, 2006 the MCWD Board of Managers approved the draft 2007 Plan for release. The draft Plan was submitted directly via electronic copy on compact disc to fifty-three different public and private organizations, posted on the MCWD website for download and a hard copy was made available for the public review at the MCWD offices. Individuals requesting personal copies of the draft Plan were also forwarded CD copies.

During the 60-day review period between September 21, 2006 and November 21, 2006, MCWD held four informational briefings at different locations throughout the watershed including Minneapolis, Minnetonka, Mound, and the MCWD offices. Meetings consisted of a presentation by MCWD staff providing an overview of the draft Plan components followed by a question and answer period. Meetings were generally well attended and hosted approximately 90 individuals representing various organizations as well as members of the community. As follow-up to the briefing meetings, MCWD provided presentations to two cities within the watershed at the request of city staff.

MCWD officially closed the 60-day review period following November 21, 2006. In total, MCWD received comments from thirty-two different organizations and individuals, nineteen of which were statutory review organizations (State review, agencies, cities, counties, etc.). MCWD provided response to all comments received by December 21, 2006.

On December 21, 2006, MCWD held a public hearing to allow for direct input from the general public on the draft Plan and to discuss changes to the Plan as a result of the comments received during the review period. Unfortunately, this meeting, while well-attended, coincided with a bout of bad winter weather and the MCWD Board of Managers resolved to continue the public hearing until January 18, 2007 to allow those unable to attend the meeting an opportunity to be present at a future public hearing. On January 18, 2007, the MCWD Board of Managers reopened the public hearing to hear comment and testimony regarding the draft Plan. Upon closing of the public hearing and a discussion by the Board, it was resolved to authorize the release of a final 2007 MCWD Comprehensive Water Resources Management Plan conditional upon updating the draft Plan with a list of specific changes.

Upon competing that update, the final MCWD Comprehensive Water Resources Management Plan was submitted to the Board of Water & Soil Resources (BWSR) for its final, 45-day review. The BWSR transmitted copies to the state review agencies for final review. On June 11, 2007 the BWSR Metro Water Planning Committee reviewed the final Plan and recommended to the full BWSR Board that it be approved. On June 27, 2007, the Board of Water & soil Resources reviewed and approved the final 2007 Plan.

Integration of Past Planning Efforts:

As outlined above, prior to drafting and formal public process, the District invested in a significant planning effort beginning in 2000, completing systematic analyses of all its major hydrologic systems, including surface water quality and quantity modeling; water quality goal setting, stream assessments for Minnehaha Creek and the primary streams of the upper watershed; functions and values assessments of the wetland resources of the District; and a Visioning process to identify options and public preferences for the future management of Minnehaha Creek.

In addition, specialized studies on specific water resources were conducted, including the Painter Creek Feasibility Study, the Stubbs Bay Feasibility Study, and the Gleason Lake Management Plan. Most of these past planning efforts also included an extensive public participation process. The 2007 Plan integrated these past planning efforts into a long-range Management Plan for the watershed and the eleven subwatershed units. Below is a brief summary of some of the major planning efforts:

Hydrologic and Hydraulic Pollutant Loading Study:

In 2003 the District completed a two year effort to compile existing and new information on the water resources in the District, to identify existing water management issues, define the impact of future land changes, and recommend how the District could address those changes. The most ambitious watershed study ever undertaken by a watershed district in Minnesota, the *Hydrologic/Hydraulic and Pollutant Loading Study*, or HHPLS, was initiated to:

- Document the nature of the physical and biological characteristics of the watershed;
- Quantify the amount of water moving through the watershed, and the quantity of that water as it moved and as it gathered in various receiving waters;
- Gather public input to assist in problem identification and solution definition;
- Formalize management programs on a subwatershed basis; and
- Provide the study results to implementation partners in an easily understood manner.

The overarching goal of the HHPLS was to improve and maintain the surface water, groundwater, and associated natural resources of the District. The study included detailed modeling of the current and 2020 hydraulic and hydrologic conditions in the subwatershed as well as the current and projected future water quality expected to result from those conditions and future land use change.

The extensive public input process used nearly 100 public meetings across the watershed to share these results, identify problems and gain input on appropriate approaches to addressing problems. Most significantly, these public input sessions resulted in the development of new or refinement of existing water quality goals for 62 lakes or bays within the District.

The findings of the HHPLS serve as the basis for the 2007 Plan. Some of the results have been refined or further developed; for example, the 2020 modeling has been extrapolated to hypothetical Ultimate Development conditions. The Implementation Plan in the 2007 Plan extends from the problem identification and public input gained through the HHPLS development.

Functional Assessment of Wetlands:

In 2001-2003 the District undertook a *Functional Assessment of Wetlands* (FAW) on all wetlands greater than one-quarter acre in size. This assessment used a variant of the Minnesota Routine Assessment Method (MnRAM) developed in partnership with the Hennepin Conservation District (HCD) to assess wetland functions and values. The intent of completing this analysis was to provide a comprehensive inventory and assessment of existing wetland functions and values, both for District management purposes and to assist the municipalities within the District by providing consistent, comprehensive wetland resources data.

Using the results of that analysis, individual wetlands were assigned to one of four categories – Preserve, and Manage 1, 2, or 3. Wetlands that were evaluated as Exceptional or High on certain ecological or hydrologic values were assigned to the Preserve category. The balance of evaluated wetlands were assigned to a category based on this assessment of current functions and values, with Manage 1 wetlands exhibiting higher values and Manage 2 and 3 moderate or lower values. These management classifications will be used in regulating and protecting wetlands based on their function and existing condition.

Stream Assessment:

In 2003 the District assessed the physical and biological condition of Minnehaha Creek and five principle upper watershed streams – Long Lake Creek, Gleason Creek, Classen Creek, Painter Creek, and Six Mile Creek. The Minnehaha Creek stream assessment included a fluvial geomorphic investigation to evaluate the stability of the creek as well as evaluation of creek conditions using the standard assessment tools Stream Visual Assessment Protocol and Pfankuch Channel Stability. Both the upper and lower watershed stream assessments included a channel inventory, identification of erosion problem areas, and evaluation of the macroinvertebrate and fish communities.

The assessments were intended to characterize the general conditions of these streams and to provide baseline information to assist the District in developing management strategies to improve and protect these streams. Stream assessment findings are reported in the respective subwatershed plan and form the basis for Implementation Plan activities.

Creek Visioning:

In 2005 the District undertook a joint partnership with the United States Army Corps of Engineers (USACE) to develop a large-scale, long-term Vision for Minnehaha Creek to serve as guidance for organizations that share Creek corridor management responsibilities. A Citizen Advisory Committee (CAC) of community representatives and a Technical Advisory Committee (TAC) of agency representatives through a lengthy community input process developed a common vision and management recommendations.

The 2005 MCWD *Minnehaha Creek Visioning Partnership Final Report* presents the results of that process and summarizes the Partnership's recommendations for future Creek management. Erosion control and support of aquatic life were overall the highest ranked priorities for improvement. However, when considered reach by reach, support and maintenance of recreation were the highest priority for the reaches upstream of the Browndale dam, followed by improvement of aquatic life and erosion control. Erosion control and streambank stabilization was the highest priority for the reach downstream of the Browndale dam. The Partnership recommended specific management options for the District and its partners.

An important part of the Visioning process was the discussion of several streamflow management scenarios developed by the Corps to model what would happen with changes to the operation of the Grays Bay Dam. The Dam is managed to discharge water from Lake Minnetonka into the Creek only when the DNR-established runout elevation of the lake is exceeded. During dry periods the lake level falls and there is minimal discharge; flow in the creek falls to minimal flow-related aquatic habitat conditions and canoeing is not possible. The Corps developed a number of scenarios that would provide targeted releases for recreation or habitat purposes, and then modeled the resulting impact on water level in Lake Minnetonka; the percent of time creek flow fell within optimal conditions for aquatic habitat and recreation; the percent of time potentially erosive flows could be expected; and resulting estimated water quality. Each scenario attempted to balance these often competing interests; in the end the Partnership recommended that further study be completed to find a way to optimize and balance year round minimum flows and moderated extreme flows with recreational and lake uses.

Hydrologic Data Program:

The Minnehaha Creek Watershed District's (MCWD) annual Hydrologic Data Program is designed for the collection of background water quality and quantity data. This data is used for the following purposes:

- Long term trend analysis
- Calibrating the Hydraulic, Hydrologic and Pollutant Load Models
- Developing Stage-Discharge relationships
- Diagnosing subwatersheds for implementation efforts

The program is a collaborative effort between the Three Rivers Park District (TRPD), the Minneapolis Park and Recreation Board (MPRB), the Metropolitan Council (Met Council), the Minnesota Pollution Control Agency (MPCA), the Lake Minnetonka Conservation District (LMCD), and the Minnesota Department of Natural Resources (DNR). Data collected is used to identify water quality trends, track progress, and analyze water related problems. The program began in 1968. The District undertook an expanded monitoring program in 1997 to provide a comprehensive view of water quality and to focus improvement projects in the areas with the most need.

The annual program includes precipitation monitoring; lake water quality and lake level monitoring; streamflow and stream water quality monitoring; and groundwater well level tracking. Lake and stream data are summarized on easy to understand Report Cards for the general public, while the complete report is published annually. Data is uploaded to the national water quality database STORET where it is available for public use.

Basic Plan Assumptions:

In addition to synthesizing data from across the watershed and undertaking extensive public process to identify issues and implementation strategies, the 2007 Plan was formulated around several key assumptions. Those assumptions are summarized below:

What is Water Quality?:

Individuals have different opinions about how good surface water quality is defined. Some focus on water clarity; some on whether there are obvious signs on pollution such as trash or oil sheen; some on the presence or absence of algae. Most water resource plans focus primarily on the concentration of Total Phosphorus (TP) in lakes, although the MPCA has adopted numeric limits for 126 EPA Clean Water Act priority pollutants. Very few water bodies are monitored for these priority pollutants because:

- Most are rarely detected in lakes;
- When detected, it is even more rare to find concentrations that pose a health risk by ingestion;
- Even if one is detected at a concentration above standard, it rarely affects use (contact recreation and aesthetics); and
- One priority pollutant sample scan is about $1000.

For regulatory purposes, the EPA and the MPCA define acceptable water quality as that which supports the designated beneficial-use of the water resource. For lakes, those designated uses are recreation and aesthetics; for wetlands it is aquatic life. Eutrophic conditions are the most common and likely problems impacting use of lakes, and excess nutrients are usually the cause. The EPA and MPCA regulatory focus is therefore on nutrients, specifically Total Phosphorus concentration, as a means to classify lakes relative to support of their designated use. Lakes are determined to be Impaired Waters if their TP concentration exceeds a certain average concentration; in the North Central Hardwood Forest ecoregion in which the District is located, that threshold is 40 ug/L for deep lakes, 60ug/L for shallow lakes.

Phosphorus impacts algal and macrophyte productivity, water clarity, fish habitat, aquatic life support, odor, and appearance (aesthetics). All these factors may be part of an individual lake user's perception or definition of water quality. By cost-effective statistical assessments of TP, the "health" of the lake can be measured in terms of nutrient and sediment loads, internal cycling of nutrients, oxygen depletion, macrophyte types and support, aquatic life habitat and aesthetic conditions such as clarity, odor and frequency and types of algal blooms. In other words, TP is an indicator of water quality as well as a driver of water quality.

This Plan assumes that good water quality is achieved when the physical, chemical, biological and aesthetic characteristics of a waterbody support its full designated use (recreation, aesthetics and/or aquatic life) and when the ecological integrity of the environment is supported. Because water quality in lakes is regulated mainly by the TP concentration, the water quality focus of the Plan is on reducing phosphorus loads to the lakes to achieve regulatory TP standards. However, each subwatershed plan sets forth an integrated set of goals, policies, and actions intended to address other aspects of water quality such as aquatic vegetation, buffer management, biological management, water clarity, and public information and education.

Integrated Resource Management:

A guiding principle of this Plan is Integrated Resource Management (IRM). Integrated Resource Management is an interdisciplinary approach to water resources management that focuses on specific water resource, subwatershed, or watershed outcomes rather than on processes such as wetland regulation, runoff rate control, or *BMP* selection. This approach recognizes that water resources are complex, dynamic systems that require integrated decisions about water quality, water quantity, ecologic integrity, and land use and regulation to achieve complex and multi-dimensional end goals. Thus, for example, rather than simply focus on a numerical water quality objective for a lake, the end goal would be a lake that meets water quality and clarity objectives intended to sustain an appropriate fishery and associated aquatic vegetation and support swimming and other recreational uses. Accomplishing those end goals might require managing internal and external phosphorus and sediment loads, improving upstream water resources such as streams and wetlands, conserving upstream upland resources that serve to buffer human-induced impacts, and restoring degraded resources. An integrated program of capital projects, operations and maintenance, education, conservation, public and private property improvements, and regulation of land use and land use change may be required to achieve those objectives.

Ultimate Land Use:

The 2007 Plan provides management strategies both for the period of the Plan – 2007-2017 – and also for the long term. Impacts to water resources accumulate over long periods of time, and improvements may take long periods to achieve. This Plan takes a long term vision that takes into account long-term change. To that end, the modeling and resource planning in the subwatershed plans uses Ultimate Land Use as the planning condition, considering that Ultimate development could be considered the "worst-case scenario" for predicting impacts of development on water resources.

Land use change impacts downstream water quality by increasing the volume of runoff and the concentration and load of nutrients and sediment transported to receiving waters. Each subwatershed plan includes a table predicting how land use change such as the expected conversion of vacant land to other uses could be expected to ultimately impact water quality in the watershed's lakes. The table also illustrates the role of the regulatory program in managing these impacts.

“Ultimate Development” for this planning and modeling purpose is defined as the conversion to development of all agricultural lands and one-half of the other upland area that remains undeveloped in the 2020 local government land use plans. This conversion may take place by 2030 or require significantly more time; but it is assumed that at some point in the future these conversions will occur. This fully developed condition would be expected to generate the greatest downstream water quality impacts. Each subwatershed plan then includes a plan for reducing the impacts of that Ultimate Development condition through regulation, LGU requirements, operating programs, and capital projects.

2007 Plan Structure:

While the 2007 Plan includes, for the watershed as a whole, all elements required by Minnesota statute and administrative rule, the eleven subwatershed plans set forth problems, issues and solutions in detail at a water resource specific level.

Overall, the 2007 Plan adopted a performance-based management strategy to meet specific water resource goals that utilized a proverbial three legged management stool including:

- A revised regulatory program to achieve no degradation
- LGU requirements enforced through Local Water Management Plans
- MCWD capital projects and programs

In this regard, the 2007 Plan mirrors Total Maximum Daily Load (TMDL) implementation frameworks. For example, where a waterbody has been designated by the Minnesota Pollution Control Agency (MPCA) and Environmental Protection Agency (EPA) as an Impaired Water, the regulatory requirements required by the Clean Water Act govern, and the District’s implementation plan is integrated into the TMDL Implementation framework. Where a waterbody does not meet District goals and has not been designated as an Impaired Water, then the District’s implementation plan still guides. Where a waterbody does not have a numeric goal for water quality, or where the resource meets its water quality goals, the District’s Implementation Plan is focused on minimizing future degradation.

The overall Plan and its subwatershed components are divided into the following sections:

Introduction:
Provides a general overview of the Minnehaha Creek Watershed District, the purpose of the Surface Water Management Act and the components of this watershed management plan.

Land and Natural Resources Inventory:
A physical inventory of the watershed, it includes a profile of the watersheds’ existing environmental conditions. This profile contains descriptions of the area's geology, topography, soils, biological and human environment, and current land use and projected land use to the year 2020.

Hydrologic Systems:
Contains information necessary to understand the hydrologic system. Information includes historic precipitation, the drainage system and watershed and subwatershed boundaries, wetlands, waterbodies, conveyance systems, and floodplains. Surface water quality information and groundwater characteristics are included in this section.

Issues Identification:
Provides an overview of priority issues identified in the planning process. These generalized watershed issues are developed in more subwatershed-specific detail in each of the subwatershed plans.

Goals and Policies:
The 2007 Plan presents an overview of the 17 goals and associated policies developed by the Board of Managers to guide the plan. These 17 goals provide the framework for the development of performance goals and standards in each of the subwatershed plans.

Implementation Program:
Sets forth a plan of action for managing water resources in the watershed that included proposed amendments to the regulatory program (completed); expansion of operating programs including Land Conservation, Education, Communications and Hydrodata programs (amended to include LID, Cost Share and AIS); and a Capital Improvement Program.

Impact on Local Government:
Discusses requirements of Local Surface Water Management Plans, annual reporting, and impact of this Plan on local governments.

Amendments:
Identifies the procedures for amending this plan. Amendments since 2007 include:

- Cost Share and LID Programs
- Various Capital Projects
- Local Water Management Plan Implementation
- AIS Management
- Minnehaha Creek Subwatershed Approach

Summary:

Leading up to the adoption of the 2007 Comprehensive Plan the District integrated past planning efforts and undertook an extensive stakeholder engagement process in order to identify target water quality goals for specific water resources and develop a coordinated implementation strategy relying on expanding regulation, all of its other programs, and LGU efforts. The 2007 Plan acknowledged that achieving these established goals was a long term effort and would span into future plan generations.

Conclusion:

This document is intended to provide background information to facilitate a preliminary discussion on the scope of the 2017 Plan update process.

MEETING DATE: February, 27, 2014

TITLE: Authorization to Execute a Contract with Himle Rapp, Inc. to Conduct a District-wide Public Opinion Survey

RESOLUTION NUMBER: 14-015

PREPARED BY: Telly Mamayek

E-MAIL: tmamayek@minnehahacreek.org **TELEPHONE:** 952-641-4508

REVIEWED BY: ☒Administrator ☐ Counsel ☐ Program Mgr. (Name):______________________
☐ Board Committee ☐ Engineer ☐ Other

WORKSHOP ACTION:

☒ Advance to Board mtg. Consent Agenda. ☐ Advance to Board meeting for discussion prior to action.

☐ Refer to a future workshop (date):________ ☐ Refer to taskforce or committee (date):_______________

☐ Return to staff for additional work. ☐ No further action requested.

☐ Other (specify): _________________________________

PURPOSE or ACTION REQUESTED:
Authorize District Administrator to execute a contract with Himle Rapp, Inc. (HRC) to conduct a District-wide public opinion survey for an amount not to exceed $42,000.

PROJECT/PROGRAM LOCATION:
The process of conducting a public opinion survey will be a District-wide activity.
As outlined in the District's Strategic Communications Plan, this survey will help measure the effectiveness of the District's communications efforts and inform the process for developing the District's next 10-year comprehensive water resources management plan.
A random sample of 600 residents will be selected for the phone survey which will identify current attitudes relating to protecting water and water quality issues, test attitudes, perceptions and awareness of MCWD and its projects, and help shape the strategy and overall positioning for the District's next 10-year plan.

PROJECT TIMELINE:
The survey will take approximately three months to complete. Pending board approval in February, the process could begin in March 2014 and proceed according to the following timetable:

February 13, 2014	Proposal presented at Board Workshop
February 27, 2014	Proposal on Consent Agenda at Board Meeting
March 1 – 31, 2014	HRC conducts scoping session with MCWD to identify issues to test, develop and finalize survey questionnaire and order sample
April 1 – 22, 2014	HRC's vendor conducts telephone survey interviews and tabulates data

April 23 – May 13, 2014	HRC analyzes data, prepares report of findings, conclusions and recommendations
May 15, 2014	HRC presents findings to MCWD Board Workshop

PROJECT/PROGRAM COST:

Fund name and number:	Communications, 2303
Current budget:	Not to exceed $42,000
Expenditures to date:	$0
Requested amount of funding:	$0
Is a budget amendment requested?	No
Is additional staff requested?	No

PAST BOARD ACTIONS:

The MCWD Strategic Communications Plan was included in the 2013 Communications Work Plan, which the MCWD Board of Managers approved on July 26, 2012.
The District-wide public opinion survey is included in the District's Strategic Communications Plan, which the MCWD Board of Managers approved on December 19, 2013.

SUMMARY:

A key goal of the District's communications program, as outlined in the Strategic Communications Plan for 2014 and 2015, is increasing awareness of MCWD, its mission and its programs. To assess the effectiveness of the District's effort to reach that goal, the plan includes a random-sample survey of District residents. The MCWD last conducted a District-wide public opinion survey in 2003.

An integral component in the process of developing the District's next 10-year comprehensive water resources management plan is outreach to individuals and organizations that have a vested interest in community and water resource planning and management. In preparation for those outreach efforts, it's important for the District to have an assessment of residents' attitudes, perception and awareness of water quality issues, the MCWD and its projects and programs.

Recognizing the need for this updated information, MCWD staff proposes a District-wide public opinion survey by Himle Rapp Inc., as outlined in the District's Strategic Communications Plan for 2014 and 2015. Under the proposal, a random sample of 600 District residents will be interviewed by telephone (cell phone and landline) during the spring of 2014. The data collected from this quantitative survey will not only measure knowledge of and support for MCWD and its water quality work, but will also test potential new initiatives the District could take in its efforts to manage and protect the water resources within its boundaries.

Himle Rapp Inc. is uniquely qualified for this project based on its history of work for the District, including the development of the District's two-year Strategic Communications Plan, the 2013 "Weigh in on Clean Water" outreach campaign, the 2010 audit of the District's communications and educations programs, its deep knowledge of the District's programs and activities, and its familiarity with the District's board, stakeholders and communities.

The District-wide public opinion survey will measure the effectiveness of the District's communications efforts and help inform the process for developing the District's next 10-year comprehensive water resources management plan.

RESOLUTION

RESOLUTION NUMBER: 14-015

TITLE: Authorization to Execute a Contract with Himle Rapp Inc. to Conduct a District-wide Public Opinion Survey

WHEREAS, A key goal of the District's communications program, as outlined in the Strategic Communications Plan for 2014 and 2015, is increasing awareness of MCWD, its mission and its programs; and

WHEREAS, To assess the effectiveness of the District's efforts to reach that goal, the plan includes a random-sample survey of District residents; and

WHEREAS, The MCWD last conducted a District-wide public opinion survey in 2003; and

WHEREAS, An integral component in the process of developing the District's next 10-year comprehensive water resources management plan is outreach to individuals and organizations that have a vested interest in community and water resource planning and management; and

WHEREAS, In preparation for those outreach efforts, it's important for the District to have an assessment of residents' attitudes, perception and awareness of water quality issues, the MCWD and its projects and programs; and

WHEREAS, In recognition of the need for this updated information, MCWD staff proposes a District-wide public opinion survey by Himle Rapp Inc., as outlined in the District's Strategic Communications Plan for 2014 and 2015; and

WHEREAS, The data collected from this quantitative survey will not only measure knowledge of and support for MCWD and its water quality work, but will also test potential new initiatives the District could take in its efforts to manage and protect the water resources within its boundaries; and

WHEREAS, Himle Rapp Inc. is uniquely qualified for this project based on its history of work for the District, including the development of the District's two-year Strategic Communications Plan, the 2013 "Weigh in on Clean Water" outreach campaign, the 2010 audit of the District's communications and educations programs, its deep knowledge of the District's programs and activities, and its familiarity with the District's board, stakeholders and communities; and

WHEREAS, The District-wide public opinion survey will measure the effectiveness of the District's communications efforts and help inform the process for developing the District's next 10-year comprehensive water resources management plan.

NOW, THEREFORE, BE IT RESOLVED that the Minnehaha Creek Watershed District Board of Managers hereby authorizes the District Administrator to execute a contract with Himle Rapp Inc. to conduct a District-wide public opinion survey for an amount not to exceed $42,000.

Resolution Number 14-015 was moved by Manager ______________, seconded by Manager _____________.
Motion to adopt the resolution ___ ayes, ___ nays, ___abstentions. Date: ________________.

____ Date:_______________________

Secretary

Memo

To: MCWD Board of Managers

From: Telly Mamayek, MCWD Communications Director

Date: March 10, 2014

Re: Water Resource Plan Community Engagement Process

As the District begins the process of developing its next 10-year Comprehensive Water Resources Management Plan, an integral part of that process is to determine the level of public outreach and engagement to employ.

While the District-wide public opinion survey this spring is the first step in identifying residents' concerns, the District would also benefit from engaging directly with constituent groups including elected officials, government staff, citizen leaders, developers, business owners, and others. Among the possibilities to consider is how the District can use innovative tools (i.e. social media) and channels (i.e. Master Water Stewards) to involve as many people as possible in the process.

At the Board workshop on March 13, John Himle, CEO of Himle Rapp Inc. will lead a conversation about the potential role of engaging the District's target audiences in formulating the next 10-year plan. As part of the discussion, Himle will explore the benefits of public outreach, the best tactics for reaching the District's target audiences and when to engage them, key messages and desired outcomes.

MINNEHAHA CREEK WATERSHED DISTRICT
QUALITY OF WATER QUALITY OF LIFE

MEMORANDUM

To: MCWD Planning and Policy Committee

From: Becky Houdek, Planner

CC: James Wisker, Director of Planning, Projects, and Land Conservation

Date: June 19, 2014

Re: Framework for 2017 Comprehensive Plan Update

Purpose:
At the July 31, 2014, Board Meeting staff will request Board approval of a framework for developing the 2017 Comprehensive Plan. Staff will summarize previous discussions and present an outline for public process and outreach.

Background:
Over the past several months, there have been a number of discussions and presentations to the Board of Managers relating to the development of the next generation Comprehensive Water Resources Management Plan (CWRMP or Plan). The revised Plan is due ten years from the date that the Board of Water and Soil Resources approved the current plan, giving the District a deadline of June 27, 2017.

At the June 19, 2014 Planning and Policy Committee meeting a cohesive framework for developing the 2017 Plan was discussed. The framework discussed by Committee was generally divided into two parts:

1. An overarching scope and structure for the 2017 Plan
2. A commensurate process and schedule

The materials presented and discussed, (1) connected and incorporated all past discussions; (2) defined a high level scope; (3) outlined a drafting structure; (4) established a preliminary list of tasks and work products; and (5) mapped a process and schedule, including roles for advisory committees, the Board, and broader public.

On the understanding that that the first step in developing the 2017 Plan requires approval of a framework and process, the Committee unanimously forwarded this framework to the full Board for adoption, with suggested edits included.

As previously established at Committee, and summarized to the Board of Managers, the framework, and associated process and outreach plan is predicated on the understanding that the 2017 Plan revision will be an update, not a major rewriting, that focuses on developing policies and processes that improve implementation and service delivery. Also discussed at Committee were the following principles that have emerged out of previous Board discussions:

- Improve the integration of land-use and water planning;
- Utilize the strategic asset value of water to create environmental, social and economic value;
- Sustain and intensify geographic focus;
- Improve collaboration and partnership through deeper understanding and recognition of external, non-water resource objectives;
- Maximize innovation and flexibility in pursuit of creative new solutions to emerging issues;
- Broaden ecosystem understanding of water in relation to the built and natural environments;
- Increase alignment of programs and initiatives around capital investments;
- Recognize and utilize the value of regulation in furthering larger, more comprehensive partnership driven solutions.

These principles will inform the overarching policies and structure of the 2017 Plan, as well as the process, communications and outreach.

Packet Materials:
The following materials are included in the packet and numbered as shown:

<u>Framework for Developing 2017 Plan</u>

1. Summary of past Board discussions
2. Purpose, Principles, and Scope
3. Structure
4. Tasks and work products
5. Outreach Plan
6. Process, Roles, and Schedule
    a. 2007 process flowcharts
    b. 2017 process flowchart
    c. 2017 preliminary schedule

Appendix – Materials referenced in Section 1

<u>1. Summary of Past Board Discussions:</u>

Below is a summary of documents and presentations the Board has seen over the past several months related to the development of the next generation Comprehensive Water Resources Management Plan (CWRMP). Information and Board feedback from these past discussions has been incorporated into the following framework. Each of the referenced documents are included in an Appendix at the back of this packet.

A. **Review of the Development of the 2007 CWRMP** (October 2013 PPC)
   - Memo from James Wisker summarizing the process used to develop the 2007 CWRMP to facilitate Committee discussion on the process and timeline for developing the 2017 CWRMP.

B. **CWRMP Process Outline** (October 2013 PPC)
   - Document from Louis Smith providing a general process and timeline for updating the CWRMP.

C. **Policy and Planning Committee Meeting Minutes** (October 2013 PPC)
   - Minutes summarizing Committee's discussion of items A and B above.

D. **In Pursuit of a Balanced Urban Ecology in the Minnehaha Creek Watershed** (January 2014 Board Meeting)
   - Resolution 14-009 adopting Board policy framework to guide future planning and District initiatives.

E. **Preliminary Needs Analysis and Review of 2007 Plan Goals and Priorities** (February 2014 PPC)
   - Presentation by Diane Spector providing a high-level overview of expectations, new data, data gaps, plan layout, and process.

F. **Policy and Planning Committee Meeting Minutes** (February 2014 PPC)
   - Minutes summarizing Committee's discussion of item E

G. **Alternatives for Organizing the 17 Goals in the 2007 CWRMP** (March 2014 PPC)
   - Memo from Craig Dawson providing a recommendation for the reorganization of the District's goals to improve clarity and understanding.

H. **Policy and Planning Committee Meeting Minutes** (March 2014 PPC)
   - Minutes summarizing Committee's discussion of item G

I. **Planning for the 2017 Management Plan** (March 2014 Board Retreat)
   - Presentation by Diane Spector providing a high-level overview of expectations, approach, new data, data gaps, plan layout, and process. Minutes from the Board retreat could not be located.

J. **CWRMP Community Engagement Process** (March 2014 Workshop)
   - Presentation by John Himle providing draft objectives and outline for a public engagement process (no attachment).

K. **Board Workshop Meeting Minutes** (March 2014 Workshop)
   - Minutes summarizing Board discussion of item J

L. **Identifying Six Mile Creek Subwatershed as a Priority District Focus** (May 2014 Board Meeting)
   - Resolution 14-047 identifying Six Mile Creek as a priority subwatershed and directing staff to reflect this focus in the District's planning activity, work plans, budgets, and in coordination with subwatershed partners.

2. Purpose, Principles, and Scope:

Purpose:
The District's Comprehensive Plan serves four primary purposes:

1. Fulfill statutory requirements outlined in 103D.401 and 405
2. Provide authorities for District programs and projects
3. Guide the integration and alignment of District projects and programs
4. Communicate District's mission and plans to communities and general public

Principles:
Over the last year the Board of Managers has engaged in several discussions and adopted policies that provide overarching guidance for the 2017 Plan update.

During the 2013 Annual Board Retreat, the MCWD Board of Managers prioritized discussion around its desire to *"express commitment to complement the effort of cities and private development"*, *"move away from regulatory focused relationships"*, and "*institutionalize the conversation*" regarding the District's efforts to integrate its *"work into the plans and works of others."* Subsequent discussions around the academic and policy mandate to improve the integration of land and water planning lead to the adoption of the policy, *In Pursuit of a Balanced Urban Ecology.*

This policy identified the opportunity to improve land-use and water integration by leveraging, in public and private partnerships, the strategic asset value of natural systems to create social and economic value within the built environment. Partnerships, geographic focus and flexibility were identified as principles to guide the implementation of this policy.

Through the development of the *Balanced Urban Ecology* policy, the Board also identified the need to evolve a more strategic, targeted use of its regulatory authorities to facilitate the aforementioned partnerships. Specifically, the Board established that while the District is not entertaining relaxing its regulatory presence or authorities, regulation has proven to be a valuable asset in the identification and development of larger, more comprehensive water resource partnerships.

Also in 2013, the Board of Managers adopted a recommended monitoring and data collection framework to complement an increased geographic focus for program and project delivery. This Ecosystem Evaluation Program (EEP) builds on the District's understanding that aquatic systems are part of a larger ecosystem (built and natural), creating a larger ecological emphasis.

Based on these recent discussions and decisions, the following have emerged as principles to guide the 2017 Plan:

- Improve integration of land-use and water planning;
- Utilize the strategic asset value of water to create environmental, social and economic value;
- Sustain and intensify geographic focus;
- Improve collaboration and partnership through deeper understanding and recognition of external, non-water resource goals;
- Maximize innovation and flexibility in pursuit of creating new solutions to emerging issues;
- Broaden ecosystem understanding of water in relation to built and natural land;
- Increase alignment of programs and initiatives around capital investments;
- Recognize and utilize function and value of regulation in furthering larger, more comprehensive partnership driven solutions.

Scope:
In addition to developing agreement on the purpose and guiding principles, formal consensus on the scope of the Comprehensive Plan is required before developing a process and advancing work product.

At the October 2013 Planning and Policy Committee meeting, staff provided an overview of the process used for development of the 2007 Plan (see Attachment 1.A in the Appendix). The Committee reviewed the extensive stakeholder engagement process used for the 2007 Plan to identify water quality goals, and develop a coordinated implementation strategy relying on expanded regulation, capital improvement projects, District programs, and Local Government Unit (LGU) efforts.

Based on the knowledge that achieving the 2007 Plan objectives would span into future plan generations, the Committee noted that the framework and goals established for the 2007 Plan generally remain relevant and effective. Therefore, the Planning Committee established that the 2017 Plan revision should be an update, preserving much of the structure and content of the 2007 Plan, while updating and improving elements of it based on new data and lessons learned through implementation over the past decade.

Understanding the general purpose, guiding principles and update nature of the 2017 Plan revision, on the following page is a table that compares and contrasts the scope for the 2007 Plan and the proposed scope for the 2017 Plan update.

Element	2007 Scope	2017 Scope
Outreach and Engagement	▪ Extensive stakeholder process focused on issue identification, goal-setting and development of 3-pronged approach to achieve nutrient goals	▪ Outreach will focus on maximizing effectiveness of proposed implementation framework and identifying local problems, priorities, and plans
	▪ Process included: - Subwatershed Management Teams - Regional Teams for HHPLS Study (9 teams, approx. 72 meetings) - Minnehaha Creek Visioning Partnership (12 meetings) - Technical Advisory Committee (7 meetings) - Citizen Advisory Committee (20 meetings)	▪ Process will include: - Board - Technical Advisory Committee - Policy Advisory Committee - Citizen Advisory Committee - Six Mile Steering Committee - Public opinion survey ▪ Fewer meetings, focused on implementation model ▪ Will also utilize District's ongoing communications through annual LGU meetings, annual review of CIP, TMDL development, project partnerships, EEP
Goal Setting	▪ Board established 17 policy goals	▪ Generally preserve policy goals but clarify long-term goals vs. strategies vs. tactics
	▪ Lake-specific nutrient goals were set by Regional Teams for HHPLS Study	▪ Align nutrient goals with approved TMDLs
Studies and Data Collection	▪ Numerous data collected and studies completed for 2007 Plan: - USACE Feasibility - Hydrodata - Hydrologic, Hydraulic, and Pollutant Loading Study (HHPLS) - Stream Assessment - Functional Assessment of Wetlands - Strategic Education and Communications Plan - Land Conservation Plan	▪ Incorporate data and studies completed since 2007: - Hydrodata and trend analysis - AIS data - Stream Assessment Update and 1st Order Inventory - Six Mile Diagnostic and Carp Assessment - TMDLs - Baseflow Study - Atlas 14 ▪ Continue to update data and studies on ongoing basis through Ecosystem Evaluation Program ▪ Complete self-assessment: - Evaluate program effectiveness and alignment - Develop database to track progress toward nutrient goals
Implementation Plan	▪ Mirrored TMDL framework and established 3-pronged approach to achieve nutrient goals: regulation, LGU requirements, capital projects	▪ Preserve 3-pronged approach and align nutrient goals and LGU requirements with approved TMDLs
	▪ Equal priority placed on all areas of District	▪ Identify priority subwatersheds based on need and opportunity ▪ Develop strategies and process for remaining responsive outside of priority areas
	▪ Strong emphasis on regulation and LGU requirements	▪ Will emphasize District's focus on partnerships and integration of land-use and water planning
	▪ 10-yr CIP with high project-specificity	▪ 5-yr CIP focused on priority geographies ▪ Goal-oriented allowing for opportunity-driven projects
	▪ Nutrient focused	▪ Broader ecological/ecosystem focused
	▪ Programs generally functioned independently	▪ Align programs around capital investments while maintaining baseline operations throughout District
	▪ Primarily financed through ad valorem tax levy	▪ Will explore range of funding sources

3. Plan Structure:

As has been discussed at previous meetings, staff is proposing to structure the Plan in three volumes, as follows:

1. Executive Summary
    a. A concise summary for policymakers, technicians, and the public that provides a high level framework for how the 4th Generation Plan is organized.
    b. Focused on the District's approach to carrying out its mission in partnership with its communities as described in the Board-adopted policy framework *In Pursuit of a Balanced Urban Ecology*.

2. Data and Issue Identification
    a. A synthesis and integration of all pertinent data will be used to identify specific issues that need to be addressed in order to achieve MCWD's broad definition of water quality.

3. Goals and Implementation Plan
    a. An outline of measurable goals associated with the District's policy goals (e.g. water quality, water quantity, ecological integrity, public engagement) and strategies for achieving them.
    b. An implementation framework that includes:
        i. Priority geographies and planning model used to develop implementation plans
        ii. Strategies and process for remaining responsive outside priority areas
        iii. Description and alignment of programs around capital investment
        iv. Administrative details

4. Tasks and Work Products:

Following Board adoption of a 2017 Plan framework, work product will be developed. Below is a list of the primary tasks that will need to be completed as part of the development of the next generation Plan. These are not ordered sequentially, and many tasks will be completed concurrently as shown in the schedule in Section 6 of this packet.

Outreach and Engagement

- Refine outreach plan and develop messaging and materials
- Establish advisory groups (Technical Advisory Committee, Policy Advisory Group, Citizen Advisory Group, and Six Mile Steering Committee) and develop meeting schedule and agendas
- Public opinion survey

Data and Issue Identification

- Incorporate new data:
    - Hydrodata and trend analysis
    - AIS data
    - TMDLs
    - Six Mile Creek Diagnostic and Carp Assessment
    - Stream Assessment Update and 1st Order Stream Inventory
    - Baseflow Study
    - Atlas 14
- Update issue identification for each subwatershed based on new data and community input

Self-assessment

- Evaluate program effectiveness and alignment
- Create database to track project information and progress toward nutrient goals

Goals

- Complete reorganization of policy goals as discussed at the March 2014 PPC meeting (see attachment 1.F. in Appendix).
- Review and update as needed to ensure clear identification and connection of long-term goals with near-term strategies and tactics (e.g. baseflow)
- Update nutrient goals and LGU requirements to align with approved TMDLs
- Incorporate new goals related to ecological integrity and the District's new Ecosystem Evaluation Program

Implementation Framework

- Board policy discussions (e.g. subwatershed prioritization, model for remaining responsive, financing options)
- Differentiate management approach for different subwatersheds based on need and opportunities:
    - Identify priority subwatersheds for District focus in the 2017-2027 Plan cycle and schedule for rotation
    - Establish strategies and process for remaining responsive outside of priority subwatersheds (e.g. cost share grants, opportunity-based partnership projects)

- Update program descriptions to show how programs align around priority subwatersheds while maintaining base level of operations throughout District
- Develop 5-year CIP for priority subwatersheds and outline process for amendment as District moves to a new priority subwatershed(s)
- Develop project priority lists for non-focal geographies

Plan Drafting

- Incorporate new implementation framework and program updates
- Other updates as needed: reorganization, procedural, clarifying
- Draft executive summary section of the Plan

5. Outreach Plan:

Below is an outreach plan outline that includes: outreach objectives, key messages, target audiences, and engagement tactics. This preliminary outline will be refined and used to develop and implement a comprehensive communications plan with Himle Rapp.

Outreach Objectives:

- Obtain broad support for the implementation framework, including:
  - Geographic focus
  - Integration of land-use and water resource planning
  - Model for District responsiveness

- Focus stakeholder input on:
  - Maximizing the effectiveness of the proposed implementation framework
  - Identifying local problems, priorities, plans and partnership opportunities

- Fulfill statutory requirements

Key Messages:

Below is an outline of preliminary messages, consistent with discussion to date and established principles. These will be refined and incorporated into the formal communications and outreach plan with Himle Rapp.

- The Plan is an update to the 2007 Plan, not a major overhaul.
  - 2007 Plan was developed with significant input from communities and provides strong foundation of data, issues, and long-term goals that will carry over into 2017 Plan
  - Not founded on need for major revision to existing rules
  - 2017 Plan update will focus on improving effectiveness and service delivery

- Optimized implementation model that creates environmental, social and economic value.
  - Reinforced by Policies:
    - In Pursuit of a Balanced Urban Ecology
    - TMDL Policy
    - Regulatory Offset Policy

  - Emphasis on Partnership:
    - Opportunities are best identified through the development of strong relationships, sharing of technical expertise, and integrated planning
    - We aim to develop a deeper understanding of the needs and desires of communities in order to design projects that enhance social and economic viability as well as environmental benefit

  - Geographic Focus and Responsiveness:
    - Addressing all impairments District-wide is the long-term goal
    - We are more effective when we focus (example of Urban Corridor)
    - We will remain responsive to all communities as opportunities arise

  - Innovation and Flexibility
    - Results-oriented approach to improve effectiveness through innovation in partnerships, financing, and management strategies

        - Plan is a living document and can be amended to adapt to new information and emerging issues (5-year vs. 10-year CIP)

- No new major requirements for communities. Focus on added value and collaboration.
    - No new load reduction requirements, just aligning with TMDLs for consistency
    - More emphasis on collaboration and adding value to communities:
        - Sharing of resources/services for more effective use of public funds
        - Helping LGUs meet MS4 requirements (education, regulation)
        - Collaboration on planning and projects to meet multiple goals
    - We will be focused but remain responsive to needs and opportunities District-wide

- Balanced schedule and process to allow involvement without burden.
    - District will engage local technical staff, policymakers and general public throughout the process to obtain input on local priorities and better understand how the District can add value to its communities.

Target Audiences and Outreach Tactics:
Below is a preliminary list of target audiences and possible outreach tactics for each. These will be finalized through the development of a communications and outreach plan with Himle Rapp.

- City, county, and other local technical staff (Minneapolis Park and Recreation Board, Three Rivers Park District, Lake Minnetonka Conservation District):
    - Introduce to municipal staff at upcoming LGU annual meetings
    - Invite to serve on Technical Advisory Committee (see Section 6 for more detail on TAC)
    - Invite to subwatershed meetings (smaller group meetings used to identify local priorities)

- City and county policymakers:
    - Invite to serve on Policy Advisory Committee (see Section 6 for more detail on PAC)
    - Invite to subwatershed meetings
    - Send liaisons to council meetings as desired/requested
    - Communicate through newsletters and at District events

- Metro plan review agencies (Board of Water and Soil Resources, Met Council, Pollution Control Agency, Dept. of Natural Resources, Dept. of Transportation, Dept. of Health, Dept. of Agriculture):
    - Invite to serve on TAC

- Interested public (CAC, Lake and Creek Associations, Neighborhood/Homeowner Associations):
    - Invite to serve on Citizen Advisory Committee (see Section 6 for more detail on CAC)
    - Invite citizen group representatives to subwatershed meetings

- General public:
    - Obtain input through public opinion survey
    - Inform through Splash, website, Facebook

6. Process, Roles and Schedule:

Process:
As described in earlier sections, the development of the 2007 Plan was a substantial undertaking that involved numerous studies, a complex modeling effort, and an extensive stakeholder engagement process. The 2007 Plan development effort is summarized in the attached flow diagrams that include (1) the Plan components; (2) the process used to develop the Hydrologic, Hydraulic, and Pollutant Loading Study (HHPLS); and (3) the Plan approval process, including the involvement of the various advisory groups.

A comment heard frequently regarding the 2007 process was that participants serving on the various advisory groups became fatigued with the number of meetings and the depth and breadth of the process. The Board and advisory groups were very involved in analyzing the data and issues for each subwatershed and setting goals for all the major waterbodies. Acknowledging this feedback and consistent with the update nature of the 2017 Plan, the Planning Committee agreed that the 2017 Plan writing should be substantially less involved than the process used in 2007.

Building on the strong technical foundation provided by the 2007 Plan, recently adopted TMDLs, updated Stream Assessments, the Six Mile Diagnostic, and various other studies completed since 2007, the MCWD has a firm understanding of the water resource issues across the District. Therefore, as discussed and agreed upon by the Planning and Policy Committee, it is recommended that the 2017 Plan focus less on revising issue identification and goal-setting in favor of updating and improving the District's implementation model. This includes policies, plans, program alignment, local priorities, integration with land-use, responsiveness, financing, partnership models, etc.

A process diagram is attached to help illustrate the different tasks and key points of involvement for the various advisory groups which are defined below.

Roles:
The development and drafting of the 2017 MCWD Comprehensive Plan will include the involvement of several internal and external groups. A District Team of Board, staff and consultants will provide overarching policy direction, draft and assemble the plan, and facilitate advisory group meetings. Advisory groups, including a policy committee, technical committee, citizen advisory committee and a Six Mile steering committee, will all play various roles in the development and review of the 2017 Comprehensive Plan.

Below is an outline of the respective roles of each of these groups.

DISTRICT TEAM:

The District's 2017 Comprehensive Plan Team will be comprised of the Board, staff, and consultants. These groups will (1) provide overarching policy direction and structure for the Plan; (2) prepare for, facilitate and respond to advisory groups; and (3) draft and assemble the Plan for approval.

Below is a brief summary of roles and responsibilities for members of the District's Internal Team:

- Becky Houdek, District Planner:
  - Principal Project Manager responsible for coordinating all elements of plan development, including scope, schedule, budget, Board, staff, consultants, and advisory groups.

- Administrator and Management Team:
  - Provide ongoing guidance, support and review to Project Manager.

- Program Staff:
  - Provide work-product and support services at the direction of the Project Manager and/or Management Team. Program staff will specifically provide input regarding opportunities for improvement in program function and alignment through the Self-Assessment.

- Board/Committees:
  - Provide policy direction focused on improving the District's implementation model. Attend and chair the Policy Advisory Committee Meetings. Provide communications support to external policy makers. Provide iterative review and feedback on Plan drafts at major milestones.

- Consultants:
  - Develop work-product and provide support services, under contract, and as directed by the Project Manager. Primary consultants will include:
    - Wenck – technical services and engineering
    - Smith Partners – legal services and policy development
    - Himle Rapp – communications services

ADVISORY GROUPS:

A number of advisory groups may play a role in the development of the District's 2017 Comprehensive Plan. Advisory groups will serve to (1) provide feedback on policy direction and structure of the Plan; (2) provide input and guidance focused on improving the District's implementation model; (3) provide iterative review and comment on Plan drafts.

Below is a brief summary of recommended roles and responsibilities for possible advisory groups:

- Policy Advisory Committee (PAC):
  - Public policy makers will convene quarterly, or more frequently as needed, to discuss and provide feedback on the policy direction and structure of the Plan.
  - The PAC will focus on policies and overarching structure of the Plan focused on improving the District's implementation model, responsiveness, and integration with land-use and outside interests.
  - The PAC will provide direction to the Technical Advisory Committee (TAC) to gather information and develop work-product on specific areas of policy interest.
  - Policy makers appointed to the PAC will serve as a conduit to their representative agencies and organizations.

- Technical Advisory Committee (TAC):
  - Meet as needed, working at the direction of PAC and District staff, to develop work-product and technical recommendations focused on improving the District's implementation model, responsiveness, and integration with land-use and outside interests.
  - Provide input and feedback throughout the development of the implementation framework. Specific areas of focus including strategies for improving collaboration with communities and remaining responsive while focused in priority geographies.
  - Provide iterative review and feedback on Plan drafts at major milestones.

- Citizen Advisory Committee (CAC):
  - Meet as needed, working at the direction of the Board of Managers and staff, to assist in policy identification and development; provide feedback and advice on proposed implementation framework; and provide external communications support.

- Six Mile Steering Committee (SMSC):
  - Working in parallel and concurrent with Comprehensive Plan Development.
  - Comprised of a subset of the PAC and TAC, meeting throughout 2015, focused on implementation planning for the Six Mile Creek priority subwatershed, specifically included the development of multi-jurisdictional integrated capital investment plan.
  - Resulting subwatershed implementation plan will be integrated into the 2017 Comprehensive Plan.

<u>Schedule:</u>
Below is a preliminary outline of a draft schedule. A Gantt chart providing additional detail is attached.

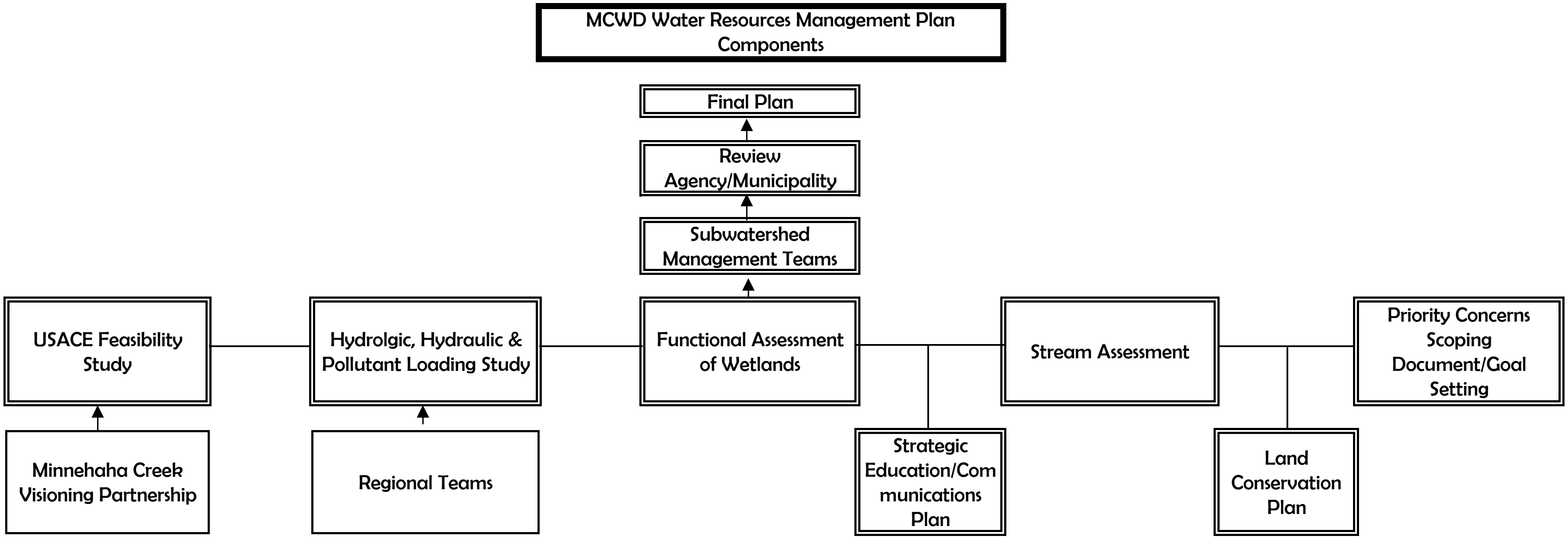
- 2014 – Plan Scoping and Preparation
  - Board adopts framework for plan revision
  - Develop necessary scopes and execute consultant contracts for elements including:
    - Self-assessment
    - Technical data updates
    - Communications and outreach implementation
  - Initiate outreach to communities regarding scope of update, schedule, and key messages
  - Obtain letters of understanding and/or resolutions of support from communities
  - PAC and TAC appointments

- 2015 – Plan Development and Stakeholder Engagement
  - Initiate PAC, TAC, CAC, SMSC meeting schedule
  - Identify areas of policy focus, develop work-product and draft various plan elements for review by District Team and Advisory Groups.

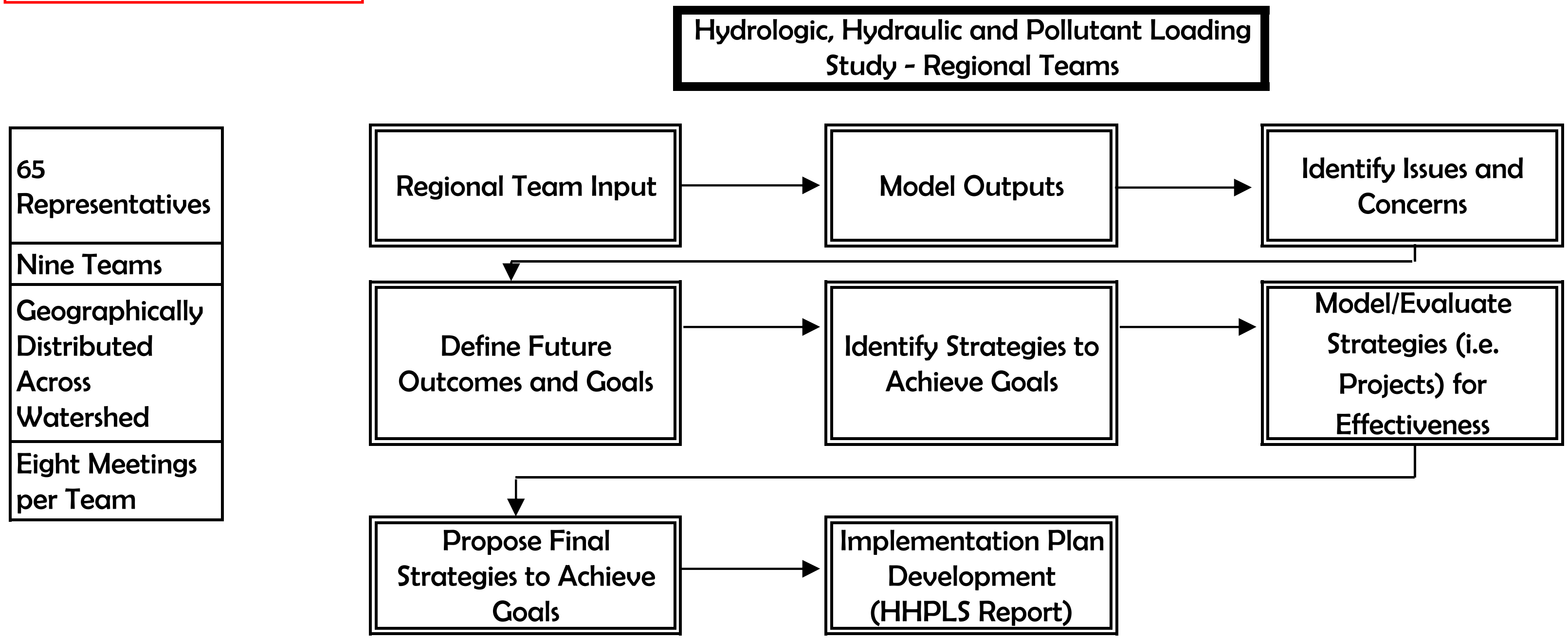
- 2016 – Formal Plan Review Process
  - Release draft plan to various advisory groups for 60-day comment period
  - Written responses to comments
  - Public hearing(s)
  - Prepare revised plan for final 90-day review
  - BWSR final approval

- 2017 – Plan Adoption – June 27, 2017

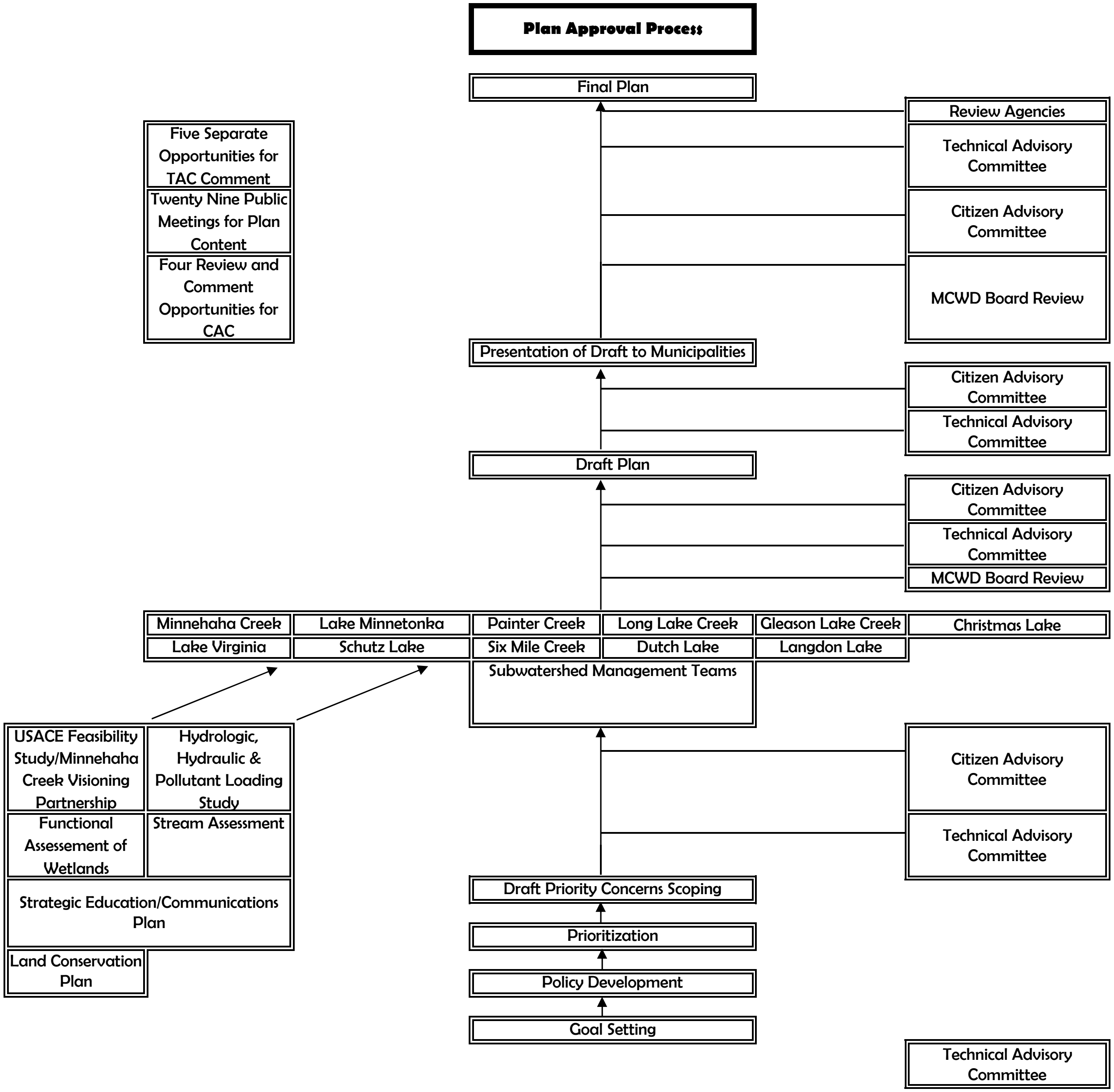
2007 Process Diagram 1

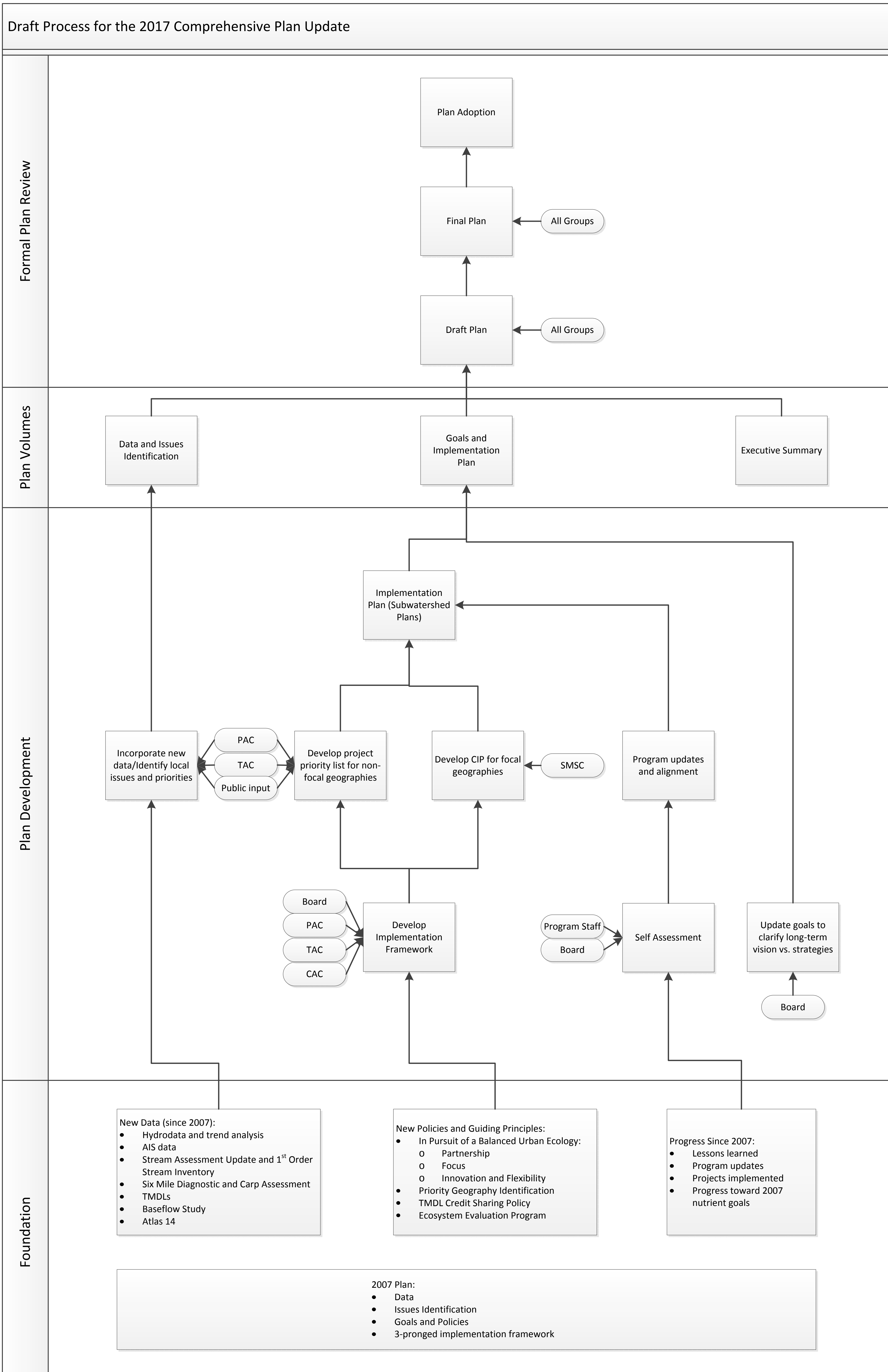


2007 Process Diagram 2



2007 Process Diagram 3




Draft Process for the 2017 Comprehensive Plan Update
Formal Plan Review
Plan Adoption
Final Plan
All Groups
Draft Plan
All Groups
Plan Volumes
Data and Issues Identification
Goals and Implementation Plan
Executive Summary
Plan Development
Implementation Plan (Subwatershed Plans)
Incorporate new data/Identify local issues and priorities
PAC
TAC
Public input
Develop project priority list for non-focal geographies
Develop CIP for focal geographies
SMSC
Program updates and alignment
Board
PAC
TAC
CAC
Develop Implementation Framework
Program Staff
Board
Self Assessment
Update goals to clarify long-term vision vs. strategies
Board
Foundation
New Data (since 2007):
• Hydrodata and trend analysis
• AIS data
• Stream Assessment Update and 1st Order Stream Inventory
• Six Mile Diagnostic and Carp Assessment
• TMDLs
• Baseflow Study
• Atlas 14
New Policies and Guiding Principles:
• In Pursuit of a Balanced Urban Ecology:
o Partnership
o Focus
o Innovation and Flexibility
• Priority Geography Identification
• TMDL Credit Sharing Policy
• Ecosystem Evaluation Program
Progress Since 2007:
• Lessons learned
• Program updates
• Projects implemented
• Progress toward 2007 nutrient goals
2007 Plan:
• Data
• Issues Identification
• Goals and Policies
• 3-pronged implementation framework

Water Resources Management Plan (2017) Timeline

		2014						2015												2016												2017					
		July	Aug	Sept	Oct	Nov	Dec	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec	Jan	Feb	March	April	May	June
Preliminary Planning	Develop framework/process	■	■																																		
	Develop scopes and execute contracts		■	■																																	
	Board policy discussions			■	■	■	■	■	■																												
	Refine outreach plan/messaging			■	■	■																															
	Establish advisory groups, schedules, agendas				■	■	■																														
	Self assessment				■	■	■	■																													
Outreach and Engagement	Public Opinion Survey							■	■																												
	Policymaker meetings							■			■			■					■				■				■										
	TAC meetings							■	■	■	■	■	■						■				■				■										
	CAC meetings							■			■			■					■				■				■										
	Six Mile Creek Advisory Group meetings														■	■	■	■																			
	Local subwatershed meetings														■	■	■	■																			
Plan Development	Update goals to clarify long-term vision vs. strategies				■	■																															
	Incorporate new data/studies					■	■	■																													
	Develop implementation framework								■	■	■	■	■																								
	Program updates, reorganization, and procedural updates													■	■	■	■																				
	Develop CIP for Six Mile Creek/focal geographies																		■	■	■	■															
	Develop project priority list for non-focal geographies																		■	■	■	■															
	Draft executive summary																						■	■													
Plan Review	60-day review																								■	■											
	Revisions, response to comments, and public hearing																										■										
	90-day review																											■	■	■							
	Revisions and response to comments																														■						
	BWSR approval and plan adoption																															■	■				X

Minnehaha Creek Watershed District ***REQUEST FOR BOARD ACTION***

MEETING DATE: July 31, 2014

TITLE: Adoption of a Framework for the 2017 Comprehensive Plan Update

RESOLUTION NUMBER: 14-059

PREPARED BY: Becky Houdek

E-MAIL: bhoudek@minnehahacreek.org **TELEPHONE:** 952-641-4512

REVIEWED BY: ☐Administrator ☐ Counsel ☒ Program Mgr. (Name):_James Wisker_____
☐ Board Committee ☐ Engineer ☐ Other

WORKSHOP ACTION:

☐ Advance to Board mtg. Consent Agenda. ☐ Advance to Board meeting for discussion prior to action.

☐ Refer to a future workshop (date):________ ☐ Refer to taskforce or committee (date):_______________

☐ Return to staff for additional work. ☐ No further action requested.

☒ Other (specify): Draft framework reviewed by PPC and forwarded to Board for final review prior to adoption

PURPOSE or ACTION REQUESTED:
Adoption of a framework for the 2017 Comprehensive Plan update

PROJECT/PROGRAM LOCATION:
N/A

PROJECT TIMELINE:
See attached schedule

PROJECT/PROGRAM COST:
N/A

PAST BOARD ACTIONS:
June 19, 2014 – Draft framework reviewed by Policy and Planning Committee and forwarded to the Board for final review prior to adoption

SUMMARY:
Over the past several months, there have been a number of discussions and presentations to the Board of Managers relating to the development of the next generation Comprehensive Water Resources Management Plan (Plan). The revised Plan is due ten years from the date that the Board of Water and Soil Resources approved the current plan, giving the District a deadline of June 27, 2017.

Staff has developed an overarching framework for development of the 2017 Plan that (1) connects and incorporates all past discussions; (2) defines a high level scope; (3) outlines a drafting structure; (4)

establishes a preliminary list of tasks and work products; (5) outlines an outreach plan; and (6) provides a preliminary process and schedule and describes roles for staff, Board, advisory committees, and broader public.

The draft framework was reviewed by the Policy and Planning Committee at its June 19, 2014 meeting. The presentation to the Committee focused primarily on the scope for the 2017 Plan revision. Staff's recommendation is that the 2017 Plan revision be an update, not a major rewriting, that focuses on developing policies and processes that improve implementation and service delivery. The Committee agreed with the proposed scope and directed that the framework be forwarded, with Committee discussion incorporated, to the full Board for final review prior to adoption.

Staff has refined the framework based on Committee feedback and developed a process, outreach plan, and schedule (Sections 5 and 6 of packet) commensurate with the agreed upon scope.

At the July 31, 2014 Board meeting, staff will provide an overview of the proposed framework. Once a framework is adopted, staff will begin developing work product, obtain proposals for contracted services, establish advisory committees, and initiate outreach.

Packet Materials:
The following materials are included in the packet and numbered as shown:

0. Cover Memo
1. Summary of past Board discussions
2. Purpose, Principles, and Scope
3. Structure
4. Tasks
5. Outreach Plan
6. Process, Roles, and Schedule

Appendix: Materials referenced in Section 1

RESOLUTION

RESOLUTION NUMBER: 14-059

TITLE: Adoption of a Framework for the 2017 Comprehensive Plan Update

WHEREAS, in April 2007, the Minnehaha Creek Watershed District (MCWD or District) Board of Managers adopted a watershed management plan (Plan) in accordance with Minnesota Statutes §103B.231;

WHEREAS, per Minnesota Statutes §103B.231, the District must update its Plan within ten years from the date the Plan was approved by the Board of Water and Soil Resources, giving the District a deadline of June 27, 2017;

WHEREAS, staff has developed an overarching framework for development of the 2017 Plan for Board adoption that (1) connects and incorporates all past discussions; (2) defines a high level scope; (3) outlines a drafting structure; (4) establishes a preliminary list of tasks and work products; (5) outlines an outreach plan; and (6) provides a preliminary process and schedule and describes roles for staff, Board, advisory committees, and broader public;

WHEREAS, the draft framework is predicated on the understanding that, based on past Board discussion, the 2017 Plan revision will be an update, not a major rewriting, that focuses on developing policies and processes that improve implementation and service delivery;

WHEREAS, the draft framework is strongly influenced by the Board adopted policy, *In Pursuit of a Balanced Urban Ecology,* which identifies partnerships, geographic focus, and flexibility as key principles to guide implementation;

WHEREAS, the draft framework was reviewed by the Planning and Policy Committee on June 19, 2014, and the Committee directed that the framework be forwarded, with Committee discussion incorporated, to the full Board for final review prior to adoption; and

WHEREAS, staff has refined the draft framework based on Committee discussion and developed an outreach plan, process, and schedule commensurate with the agreed upon scope;

NOW, THEREFORE, BE IT RESOLVED that the Minnehaha Creek Watershed District Board of Managers hereby adopts the preliminary framework for the 2017 Comprehensive Plan Update.

Resolution Number 14-059 was moved by Manager _____________, seconded by Manager ____________.
Motion to adopt the resolution ___ ayes, ___ nays, ___abstentions. Date: _______________.

____ Date:____________________________
Secretary

MINNEHAHA CREEK WATERSHED DISTRICT
QUALITY OF WATER QUALITY OF LIFE

MEMORANDUM

To: MCWD Board of Managers

From: Becky Christopher (Houdek), MCWD Planner

CC: James Wisker, Director of Planning and Projects

Date: November 6, 2014

Re: Comprehensive Plan

Purpose:
To provide a status report on the Comprehensive Plan, specifically Goals and Priorities and Subwatershed Reviews, as requested at the October 23, 2014 Board Meeting.

History/Recent Board Action/Discussion:

- At the March 20, 2014 Planning and Policy Committee meeting, Craig Dawson presented a recommendation for the reorganization of the District's goals to improve clarity and understanding.
- At the June 19, 2014 Planning and Policy Committee meeting, staff presented a comprehensive framework for the 2017 Plan update that (1) connected and incorporated previous discussions; (2) defined a high level scope; (3) outlined a drafting structure; (4) established a preliminary list of tasks and work products; and (5) mapped a process and schedule, including roles for advisory committees, the Board, and broader public. This framework was forwarded to and adopted by the Board at its July 31, 2014 meeting.

Current Status:
At the November 6, 2014 joint meeting of the Operations and Programs and Policy and Planning Committees, staff will be providing an update on the outreach process for the 2017 Plan update (see item 5.3). One of the items in the packet is a pending agenda list for future Plan-related Board/Committee discussions that includes the requested topics.

Next Steps:

Per draft pending agenda list:

- January-February PPC:
    - Self-assessment - Board input on current programs and new initiatives/emerging concerns
    - Update/refine list of goals - Follow up from Craig Dawson's March 2014 draft
- August-December PPC:
    - Subwatershed reviews

Attachments:

- March 20, 2014 Memo to Board – Alternatives for Organizing the 17 Goals in the 2007 Plan
- July 31, 2014 Draft 2017 Comprehensive Plan Framework (see Comp Plan folder in Dropbox)

If there are questions in advance of the meeting, please contact: Becky Christopher, Planner at bhoudek@minnehahacreek.org or 952-641-4512.

Alternatives for Organizing the 17 Goals in the
MCWD 2007 Comprehensive Water Resources Management Plan
March 20, 2014

Organizing the process for the update to the 2007 Comprehensive Water Resources Management Plan, which is due to be adopted by the end of 2017, is a work in progress. One of the first elements to be considered is the goals and guiding principles to be articulated in the Plan, as they provide focus to it. The following thoughts are for discussion purposes as the update process is beginning in earnest.

Contexts for organizing the key goals

MCWD Mission Statement (2003):

The Minnehaha Creek Watershed District is committed to a leadership role in protecting, improving, and managing the surface waters and affiliated groundwater resources within the District, including their relationships to the ecosystems of which they are an integral part, through regulation, capital projects, education, cooperative endeavors, and other programs based on sound science, innovative thinking, an informed and engaged constituency, and cost-effective use of public funds.

Key mission: Protect, improve, and manage surface waters, affiliated groundwater resources, and their ecosystems. These are goals.

Support for the mission: Regulation, capital projects, education, cooperative endeavors, other programs. These are tactics for achievement.

Guiding principles in support of mission: Activities based on sound science, innovative thinking, informed/engaged public, cost-effective use of public funds. These are also tactical, as they shape or frame tactics.

* * * * *

BWSR Rule Requirements: According to rules established by the Board of Water and Soil Resources (BWSR), comprehensive water resource management plans must address the five topics listed below.

- Water Quality
- Water Quantity
- Wetlands
- Groundwater
- Public ditches (drainage)

These topics need to be addressed, but they need not be individual goals (e.g., public ditches/drainage). Additionally, the new BWSR rules make watershed districts focus on making priorities in their plans.

* * * * *

New, Overarching Goal for 2017 Plan:

The Board's Resolution No. 14-009 adopts a framework, "In pursuit of a balanced urban ecology in the Minnehaha Creek Watershed," to guide the development of the District's update to its Comprehensive Water Resources Management Plan. *As stated in the Resolution, this framework is to guide the development the 2017 Plan and the goals in it.*

New Emphasis on Ecologically-Based Foundation for Plan:

Discussions began a few years ago on the approaches used for planning and assessing water quality in the Humber River watershed (Toronto, Ontario). These principles have been adapted and placed in the District's new water quality initiative, the Ecological Evaluation Program (EEP). The information developed through the EEP will provide the ecological underpinning in identifying priorities and opportunities in the District's Plan and activities.

* * * * *

An Alternative for Updating the Goals for the Comprehensive Plan

17 Goals in 2007 Comp Plan: Comments and observations have been made that the 17 goals are too many for people to understand what the main focus of the District really is. Listing them all as goals implies that they have equal priority, and managing them well is difficult. Some goals appear to be more tactical in nature, in that they are supportive of other goals. Many of the goals overlap, and/or have multiple benefits. Organizations perform better when there are just a few core goals; it is easier to focus efforts internally, and easier for the general public to understand its purpose and the relevance of its plans. (The 17 goal statements appear on the last two pages of this document.)

Here's a possible reorganization along the lines of the structure of the mission statement and BWSR's rule requirements, at least to start discussions.

Water Quality: Preserve, maintain, and improve aesthetic, physical, chemical, and biological composition of surface waters and groundwater within the District. (Goal 3)

Achieved/pursued through:

- Abstraction/Filtration (Goal 1)
- Public Health (Goal 4)
- Best Management Practices [BMPs] (Goal 8)
- Recreation (Goal 14)
- Erosion Control (Goal 15)
- Regulation (Goal 16)

Note that BMPs and Erosion Control are techniques, more administrative or directive in nature. The other goals are resources or outcomes that need to be addressed.

Water Quantity (Hydrology): Maintain or reduce existing flows from drainage within the watershed to decrease the negative effects of stormwater runoff and bounce from existing and proposed development as well as provide low flow augmentation to surface waters. (Goal 5)

Achieved/pursued through:

- Abstraction/Filtration (Goal 1)
- Navigation (Goal 7)
- Public ditches (Goal 10)
- Floodplains (Goal 13)
- Regulation (Goal 16)

Ecological Integrity: Promote activities which maintain, support, and enhance floral, faunal quantity and ecological integrity of upland and aquatic resources throughout the watershed. (Goal 2)

Achieved/pursued through:

- Shorelines and streambanks (Goal 6)
- Wetlands (Goal 11)
- Regulation (Goal 16)

- The Aquatic Invasive Species (AIS) management program has since been added to the Comprehensive Plan, which could be added under this goal of Ecological Integrity.

Groundwater: Protect and maintain existing groundwater flow, promote groundwater recharge, and improve groundwater quality and aquifer protection. (Goal 12)

Achieved/pursued through:

- Abstraction/Filtration (Goal 1)

<u>Community Engagement</u>: (This seems to be the theme among the remaining goals in the 2007 Comp Plan)

<u>Achieved/pursued through</u>:

- Education and communications (Goal 9)
- Recreation (Goal 14)
- Public input (Goal 17)

* * * * *

As the Plan will be updated, there 17 goals can be retained. The goal of reorganizing the goals is to create more focus and ease of understanding of the Plan. If there is general agreement about the suggested combination of the 17 goals to be incorporated into 5 goal topics, then we can begin to make them more consistent in language and logical order.

1. Abstraction/Filtration. Promote abstraction and filtration of surface water where feasible for the purposes of improving water quality and increasing groundwater recharge throughout the watershed.

2. Ecological Integrity. Promote activities which maintain, support, and enhance floral, faunal quantity and ecological integrity of upland and aquatic resources throughout the watershed.

3. Water Quality. Preserve, maintain, and improve aesthetic, physical, chemical, and biological composition of surface waters and groundwater within the District.

4. Public Health. Minimize the risks and threats to public health through the development of programs, plans, and policies that improve the quality of surface and groundwater resources.

5. Water Quantity. Maintain or reduce existing flows from drainage within the watershed to decrease the negative effects of stormwater runoff and bounce from existing and proposed development as well as provide low flow augmentation to surface waters.

6. Shorelines and Streambanks. Conserve the natural appearance of shoreline areas and minimize degradation of surface water quality which can result from dredging operations.

7. Navigation. Maintain the hydraulic capacity of and minimize obstruction to navigation without compromising wildlife habitat in water courses and preserve water quality and navigation appearance in shoreland areas.

8. Best Management Practices. Improve water quality by promoting best management practices (BMPs) requiring their adoption in local plans and their implementation on development sites.

9. Education and Communications. Enhance public participation and knowledge regarding District activities and provide informational and educational material to municipalities, community groups, businesses, schools, developers, contractors, and individuals.

10. Public Ditches. Maintain public ditch systems within the District as required under Statutory jurisdiction.

11. Wetlands. Conserve, create, and restore wetland resources and maximize the benefits and functionality of wetlands to the watershed.

12. Groundwater. Protect and maintain existing groundwater flow, promote groundwater recharge, and improve groundwater quality and aquifer protection.

13. Floodplains. Reduce the severity and frequency of flooding and high water by preserving and increasing the existing water storage capacity below 100-year flood elevations on all waterbodies within MCWD.

14. Recreation. Promote the recreational use, where appropriate, of surface waters within MCWD by providing recreation opportunities for citizens by promoting the use and enjoyment of water resources with the intent of increasing the livability and quality of life within the watershed.

15. Erosion Control. Control temporary sources of sediment from land disturbance and identify, minimize, and correct the effects of sedimentation from erosion-prone and sediment source areas.

16. Regulation. Promote effective planning to minimize the impact of development and land use change on water resources as well as achieve District goals.

17. Public Input. Solicit input from the general public with the intent that policies, projects, and programs will address local community values and goals as well as protect historic and cultural values regarding water resources; strive to manage expectations; base decisions on an educated public; foster an educated and informed public within the watershed.

MINNEHAHA CREEK WATERSHED DISTRICT
QUALITY OF WATER QUALITY OF LIFE

MEMORANDUM

To: MCWD Board of Managers

From: Darren Lochner, Education Manager

CC: Telly Mamayek, Communications Director

Date: November 6, 2014

Re: Minnehaha Creek Corridor and District Signage Standards

Purpose:

- To provide a status report on the Minnehaha Creek Corridor and District Signage Standards and related signage projects as requested, as requested at the October 23, 2014 Board Meeting.

Background and Project History:

- In 2012, the Citizens for the Minnehaha Creek Corridor (CMCC) completed an evaluation of the landings along Minnehaha Creek, from Gray's Bay to the Minnehaha Falls. The information gathered was used to identify opportunities for improvement to the landings as a way to enhance recreational use of the creek. From this, a clear need to advance consistent signage along the creek corridor surfaced. The MCWD Board of Managers subsequently directed staff to work with the CMCC and pursue a proposal for assessing the signage and landing needs along the creek to enhance the creek experience.

- An initial concept plan was presented to the Operations and Programs Committee in November, 2013. The Committee recommended the signs along the Creek be unique to the creek, point to access amenities and encouraged ADA accessible landing improvements where feasible.

- Based on Board of Managers' review and feedback, a proposal from Barr Engineering to develop a full implementation plan for all creek signage and landing upgrades was presented to the Board at the January, 9 2014 workshop. It was moved by Manager Casale, seconded by Manager Miller to advance the proposed resolution to the January 23, 2014 board meeting with a Board addition to the scope of work laying out Barr Engineering's cost to provide for repair and replacement for existing signage as needed on all District property, develop consistent visual standards, and to develop a policy and standard for District construction signage. The motion passed unanimously.

- At the January 23, 2014 board meeting, staff explained that the updated scope from Barr Engineering included design of distinctive signage templates for all kinds of District signs, as well as development of a repair and replacement plan. Manager Calkins emphasized the design template should look the same throughout the District and Managers should have the opportunity to comment on the draft concepts before approval. Manager Casale moved, seconded by Manager Calkins, to authorize the administrator to execute an agreement with Barr Engineering on the condition that the inventory of District signs be removed from the scope of work and District staff consult on the work products with Himle Rapp.

- In May, Barr Engineering staff Karen Kaul and Fred Rozumalski, alongside District staff, presented a canoe landing improvement concept for Gray's Bay and the drafts of the Minnehaha Creek Corridor signs and four categories of District signage templates for discussion and comment by the Board. Overall, the Board received the draft templates positively, suggesting minor edits to color and composition. The project team also presented to the CAC in May, obtaining additional feedback on the draft signage templates.

- Additional work has progressed since May, including internal program staff review and refinement of drafts.

Current Status:

- Staff is currently working to update the MCWD brand manual while finalizing edits to the Minnehaha Creek Corridor and District Signage templates.

Next Steps:

- Final signage templates will be brought before the Board for adoption at the December 11, 2014 workshop.

- Staff will be meeting with the appropriate government agencies along the Minnehaha Creek corridor during the next few months to get their input on the creek signage and canoe landing improvement recommendations and will report findings to the Board of Managers in the spring of 2015.

Attachments:

- May 2, 2013 update to MCWD Board
- Templates for: Interpretive, Informational, Construction, Access/Usage, Creek Signs, Parking.

If there are questions in advance of the meeting, please contact: Darren Lochner, Education Manager, dlochner@minnehahacreek.org, 952-641-4524.

MINNEHAHA CREEK WATERSHED DISTRICT
QUALITY OF WATER QUALITY OF LIFE

Memo

To: Board of Managers

From: Telly Mamayek, Communications Director and Mollie Thompson, Education Assistant

CC: David Mandt, Acting Administrator

Date: May 2, 2014

Re: Districtwide and Minnehaha Creek Signage and Landing Update

Attachment: Draft Access Improvement Plan – Gray's Bay Landing

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In 2012, the Citizens for the Minnehaha Creek Corridor (CMCC) completed an evaluation of the landings along Minnehaha Creek, from Gray's Bay to the Minnehaha Falls. The information gathered was used to identify opportunities for improvement to the landings, including consistent signage, enhanced accessibility, and amenities as a way to enhance recreational use of the creek. The MCWD Board of Managers then directed staff to work with the CMCC and pursue a proposal for assessing the signage and landing needs along the creek to enhance the creek experience.

An initial concept plan was presented to the Operations and Programs Committee in November, 2013. The Committee recommended the signs along the Creek be unique to the creek, point to access amenities and encouraged ADA accessible landing improvements where feasible. The Committee also agreed the District would pay for signage and access improvements as long as cities provide the space and site. Based Board of Managers' review and feedback, a proposal from Barr Engineering to develop a full implementation plan for all creek signage and landing upgrades was presented to the full Board in January, 2014 and was approved by a unanimous vote.

At the Board's request, attached is a preliminary concept plan developed by Barr Engineering for access improvements at the Gray's Bay Landing for review and refinement. Similar concept plans and recommendations are underway for each access point, but this is representative. Education staff and the CMCC will work with local municipalities this summer (Cities of Minnetonka, Hopkins, St. Louis Park, Edina, and Minneapolis, and the Minneapolis Park and Recreation Board, among other stakeholders) to implement the proposed plan. This will be detailed and recommended in both the Education and Operations and Maintenance 2015 Work Plans.

Enclosed: Draft Access Improvement Plan – Gray's Bay Landing

During the meeting, the Board will also have an opportunity to view and provide comment on the Districtwide signage templates, including wayfinding signage for Minnehaha Creek.

Interpretive Signage
TEMPLATE INSTRUCTIONS

BASIC INFORMATION:
This document template is set up as a layered file.
See Layers panel to manage layers.

Page 2 is the working template file. Save document as new name and delete unwanted pages.

Pages 3-5 are example pages, showing how the different elements of the template could be used in the creation of a sign file.

PRINTING/PRODUCTION INFORMATION:
- Document is 36”x24”
- 1/8” bleed included
- Colors in CMYK

MCWD Color Palette
The approved MCWD color palette is used in this template.

PRIMARY

CMYK Values
37/38/15/100

CMYK Values
100/0/0/0

SECONDARY

CMYK Values
40/0/100/0

CMYK Values
20/0/40/6

CMYK Values
100/80/30/5

CMYK Values
0/7/50/0

TERTIARY

CMYK Values
0/100/66/13

CMYK Values
81/70/0/0

CMYK Values
0/10/100/0

TITLE

Project Description text style

Caption style

Insert project photos in circles as applicable

Sub-heading

Body text

Sub-heading

Body text

MINNEHAHA CREEK
WATERSHED DISTRICT

Room Here for Contact Info or Funding Partner Logos

(952) 471-0590 or visit www.minnehahacreek.org

SHORELINE RESTORATION AREA

The Minnehaha Creek Watershed District has stabilized this shoreline using a lake-friendly approach. In this demonstration project, we see the utility of simple, natural methods in reducing lake pollution.

Clean lakes are more fun!

How was it done?

Sod was removed. Boulders were placed to strengthen banks. Compost logs further stabilized the shore until native vegetation was established. This formed a living mat that absorbs water and anchors soil.

A path was built with porous concrete, allowing rain to percolate into the ground rather than wash down slopes.

Next, a variety of native flora was planted on the upland. These plants grow easily here, so maintenance is minimal.

Why does it matter?

Three reasons: beauty, wildlife, and water...rocks at the waterline break waves as they roll ashore; thick vegetation slows stormwater runoff while deep root systems hold soil in place. Together, these landscape elements stop sediment erosion into the lake.

The result: **A cleaner Lake Minnetonka**

MINNEHAHA CREEK
WATERSHED DISTRICT

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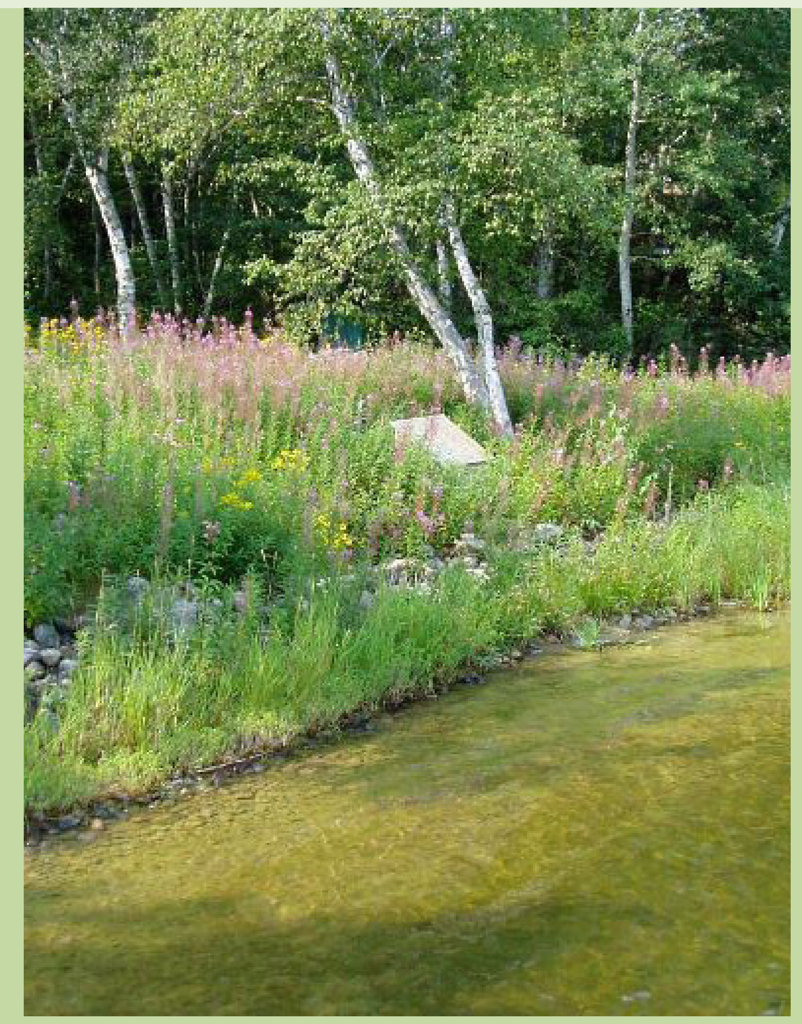

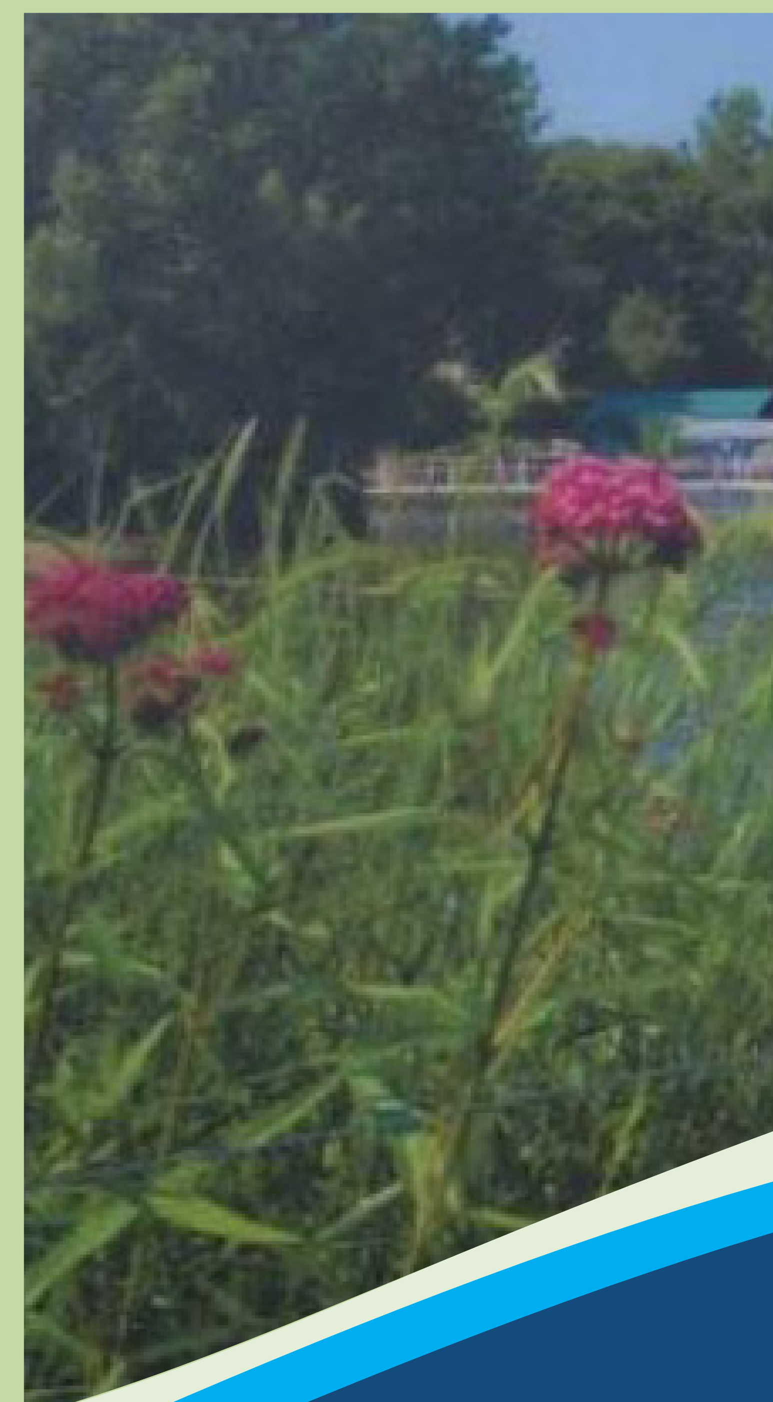

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Sub-heading

Room for additional text or infographic here.

MINNEHAHA CREEK
WATERSHED DISTRICT

Room Here for Contact Info or Funding Partner Logos

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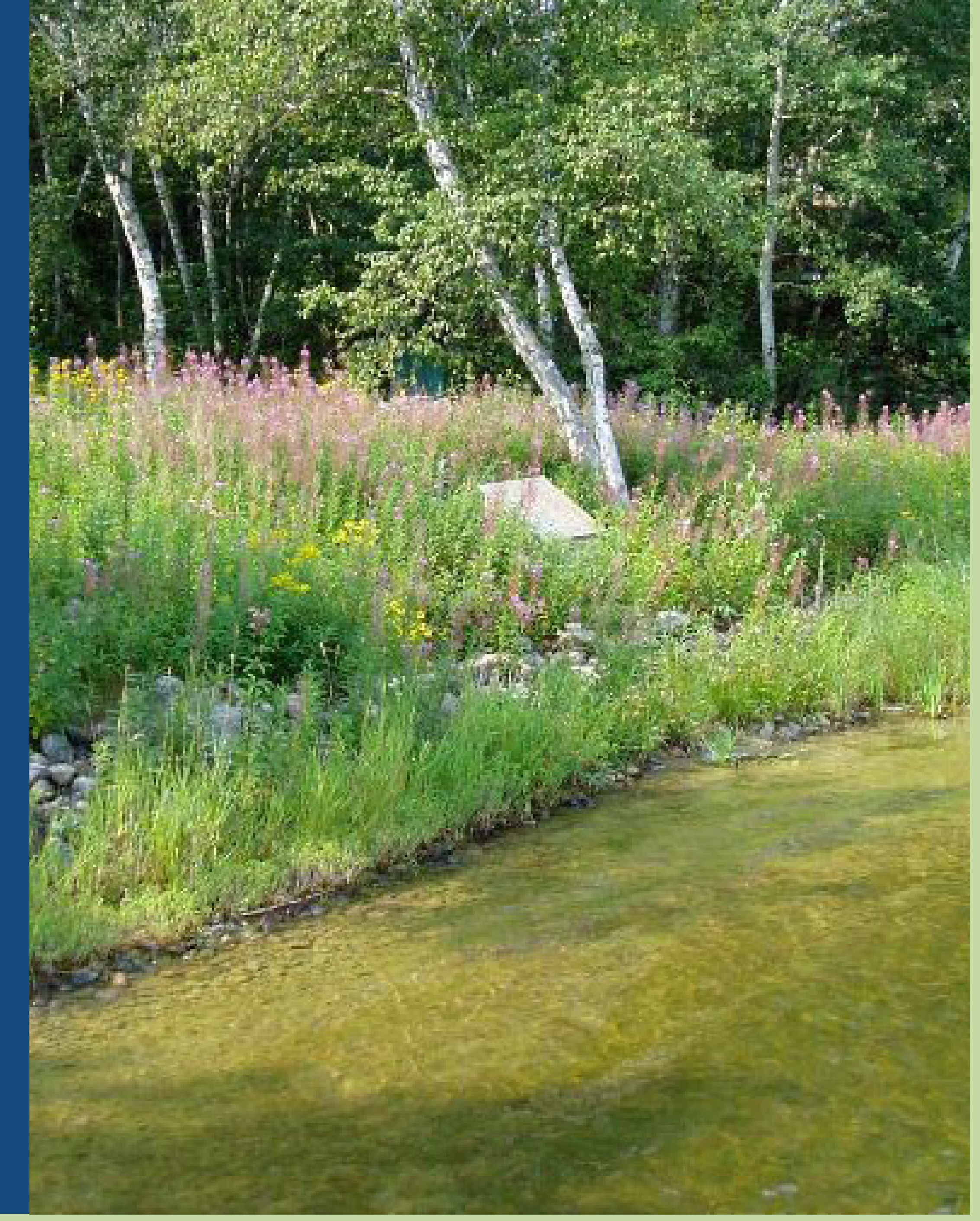

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The result: **A cleaner Lake Minnetonka**

How was it done?

Sod was removed. Boulders were placed to strengthen banks. Compost logs further stabilized the shore until native vegetation was established. This formed a living mat that absorbs water and anchors soil.

A path was built with porous concrete, allowing rain to percolate into the ground rather than wash down slopes.

Next, a variety of native flora was planted on the upland. These plants grow easily here, so maintenance is minimal.

Sub-heading

Room for additional text or infographic here.

MINNEHAHA CREEK
WATERSHED DISTRICT

Room Here for Contact Info or Funding Partner Logos

(952) 471-0590 or visit www.minnehahacreek.org

Informational Signage
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SECONDARY

CMYK Values
40/0/100/0

CMYK Values
20/0/40/6

CMYK Values
100/80/30/5

CMYK Values
0/7/50/0

TERTIARY

CMYK Values
0/100/66/13

CMYK Values
81/70/0/0

CMYK Values
0/10/100/0

TITLE

SUB-HEADING

Tertiary Information

MINNEHAHA CREEK
WATERSHED DISTRICT

Questions or Concerns?

**Call the Minnehaha Creek Watershed District
(952) 471-0590 or visit
www.minnehahacreek.org**

MUD LAKE CONSERVATION AREA

Owned and Managed to Protect Water Resources

With Grateful Appreciation to the Hegerle Family for their Generosity and Commitment to Conservation

MINNEHAHA CREEK
WATERSHED DISTRICT

Questions or Concerns?

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CMYK Values
100/0/0/0

SECONDARY

CMYK Values
40/0/100/0

CMYK Values
20/0/40/6

CMYK Values
100/80/30/5

CMYK Values
0/7/50/0

TERTIARY

CMYK Values
0/100/66/13

CMYK Values
81/70/0/0

CMYK Values
0/10/100/0

TITLE

SUB-HEADING

Project Explanation

ENGINEER **LANDSCAPE DESIGN** **CONTRACTOR**

MINNEHAHA CREEK
WATERSHED DISTRICT
www.minnehahacreek.org

City/Project Partner
Logo and Information
goes here

PAMELA PARK
WATER QUALITY IMPROVEMENT PROJECT

This project is a cooperative effort between the Minnehaha Creek Watershed District and the City of Edina to restore and protect Pamela Lake and provide water quality benefits to Minnehaha Creek.

ENGINEER
WENCK ASSOCIATES, INC.

LANDSCAPE DESIGN
BARR ENGINEERING CO.

CONTRACTOR
RICHARD KNUTSON, INC.

MINNEHAHA CREEK
WATERSHED DISTRICT
www.minnehahacreek.org

www.edina.mn.us

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LANDSCAPE DESIGN
BARR ENGINEERING CO.

CONTRACTOR
RICHARD KNUTSON, INC.

MINNEHAHA CREEK
WATERSHED DISTRICT
www.minnehahacreek.org

CITY OF EDINA, MINNESOTA
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PAMELA PARK
WATER QUALITY IMPROVEMENT PROJECT

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ENGINEER
WENCK ASSOCIATES, INC.

LANDSCAPE DESIGN
BARR ENGINEERING CO.

CONTRACTOR
RICHARD KNUTSON, INC.

MINNEHAHA CREEK
WATERSHED DISTRICT
www.minnehahacreek.org

www.edina.mn.us

NO TRESPASSING

PROTECTED NATURAL AREA

Native Prairie Planting in Progress

MINNEHAHA CREEK
WATERSHED DISTRICT

Questions or Concerns?

Call the Minnehaha Creek Watershed District
(952) 471-0590 or visit
www.minnehahacreek.org

NO TRESPASSING

PROTECTED NATURAL AREA

Native Prairie Planting in Progress

MINNEHAHA CREEK
WATERSHED DISTRICT

Questions or Concerns?

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NO TRESPASSING

PROTECTED NATURAL AREA

Native Prairie Planting in Progress

MINNEHAHA CREEK
WATERSHED DISTRICT

Questions or Concerns?

Call the Minnehaha Creek Watershed District (952) 471-0590 or visit www.minnehahacreek.org


MINNEHAHA CREEK
CANOE LANDING
MINNEHAHA CREEK
WATERSHED DISTRICT
BIG WILLOW PARK
MILE 13.4
P
MINNEHAHA CREEK
WATERSHED DISTRICT
PORTAGE AHEAD
50 FEET
MINNEHAHA CREEK
WATERSHED DISTRICT
73
HOPKINS
CROSSROADS
MINNEHAHA CREEK
WATERSHED DISTRICT

PARKING

CANOE LANDING

MINNEHAHA CREEK
WATERSHED DISTRICT

PARKING

CANOE LANDING

MINNEHAHA CREEK
WATERSHED DISTRICT

MEMORANDUM

To: MCWD Board of Managers

From: James Wisker

Date: November 6, 2014

Re: Minneapolis Infiltration Project and MPRB Discussions

Purpose:
To provide a status report on the Minneapolis infiltration projects and discussions with the Minneapolis Park and Recreation Board (MPRB) as requested by Manager Olson at the October 23, 2014 Board Meeting.

History:
The 2007 Minnehaha Creek Comprehensive Water Resource Management Plan (WRMP) identified capital projects needed to meet water resource goals. Within the Minnehaha Creek subwatershed, a series of capital projects were specified within the City of Minneapolis targeting regional volume and pollutant load reduction. These projects were primarily intended to coincide with city efforts to reduce flooding within the city grid system, offsetting potential downstream negative effects associated with the necessary upsizing of historically undersized municipal storm sewer systems and the disconnection of combined sewer overflows. Beyond addressing combined sanitary-storm systems and localized flooding, implementation in this geography also targeted the Lake Hiawatha impairment for nutrients.

The 2007 WRMP identified 15 capital improvement projects within this area, totaling $18,881,800. Initially, planning and implementation of these potential projects were proposed to be conducted through a large-scale and comprehensive feasibility study within priority flood areas, in partnership with the City of Minneapolis. However, for various reasons, several attempts to initiate such a large undertaking were abandoned.

Meanwhile, analysis of longitudinal water quality data within the Minnehaha Creek system revealed that the geography located between West 34th Street and Excelsior Boulevard in the cities of St. Louis Park and Hopkins, in absolute terms and on a unit area basis, exported the largest pollutant loads along Minnehaha Creek.

Given this knowledge, and with the support of the City of Minneapolis and the Minneapolis Park and Recreation Board, in June 2013 the MCWD Board of Managers adopted an amendment to the section of its Comprehensive Plan pertaining to volume control within the Minnehaha Creek subwatershed.

This plan amendment acknowledged that capital project implementation within the Minnehaha Creek subwatershed would be an ongoing process informed by refined technical knowledge of pollutant sources and geomorphological phenomena, available land and willing public or private partners. Moreover, the plan amendment, recognizing the influence of the subwatershed units between West 34th Street and Excelsior Blvd, reinforced that MCWD priorities would be set "foremost by diagnosing the spatial distribution of pollutant loadings to Minnehaha Creek."

While the "urban corridor" was established in this plan amendment as a foremost priority, the plan amendment also recognized the significance of the City of Minneapolis and the Minneapolis Park and Recreation Board as potential project partners. Specifically, the plan called for committing to MCWD investment where it would "best serve the combined needs of the involved entities."

This language was predicated on ongoing relationships with both the City of Minneapolis and the MPRB regarding opportunities to manage regional stormwater runoff on MPRB land between Lake Harriet and Hiawatha, and the study of flood area 21-22, MC-170 the direct drainage area to Lake Hiawatha.

In November 2012, the MPRB passed a unanimous resolution of support for the District's continued exploration of opportunities at Logan-James South Bank; East of Humboldt South Bank; West of Nicollet South Bank; West of Hiawatha and the Deer Pen below Minnehaha Falls. These five projects are projected to remove 229 lbs of total phosphorus annually for a projected capital cost of $1,387,000. Factoring in lifecycle costs, these projects were found to be cost beneficial, at $595/lb of TP removed.

Following the establishment of the urban corridor as a priority geography for capital implementation, during the acceptance of the 2014 Planning workplan, the Board expressed a desire to understand how the aforementioned projects fit into a comprehensive flood reduction strategy proposed by the City prior to committing substantial funds to lead and coordinate the efforts. District staff proposed to first advance a policy level partnership between the MCWD, City of Minneapolis and the MPRB, before bringing back a proposal to enter into design contracts for specific capital projects.

Since then, the City of Minneapolis and the MPRB have met several times to discuss opportunities to establish a policy framework that aligns vision, interest, and resources around mutually beneficial projects.

During the course of those conversations the MPRB established both a master planning effort for the land area between Lake Nokomis and Lake Hiawatha, and an ecological systems plan for all MPRB land. District staff is involved in these planning processes as part of the technical advisory committees and citizen advisory committees. Recent updates on these efforts were distributed to the Board electronically, on August 8, 2014.

Also during this time, the City of Minneapolis committed to funding a feasibility study with Houston Engineering to evaluate MC 170, flood study areas 21-22. On August 12, 2014, MCWD staff and the District Engineer met with the City of Minneapolis and MPRB representatives to discuss the findings of this study and the potential intersection of effort based on all past discussions to date.

The City's preliminary draft feasibility work clearly revealed that traditional watershed management efforts within the grid system (rain gardens, underground storage, etc) would be substantially insufficient to address flooding concerns within flood study area 21-22. The recommendations to address flooding within this area included substantial public investment in infrastructure and the need for long-term phasing plans.

One opportunity revealed during the meeting included the potential to alleviate pressure head within a pipe draining this subwatershed, located in the northwest quadrant of the Hiawatha Golf Course. Given the flooding experienced in spring 2014 and the subsequent emergence of Hiawatha Golf Course as a priority for MPRB investment, the project partners agreed that addressing hydraulic issues in the City's pipe through the golf course may be the most viable first phase solution. Subsequently, the project partners engaged in meetings with the MPRB golf operation staff to discuss the decision making process for the Hiawatha Golf Course, and the opportunity to develop a multi-objective, multijurisdictional partnership.

Following Board action directing the exploration of a partnership regarding Meadowbrook, and the assignment of a Board liaison, those preliminary meetings recently culminated in a meeting with MPRB leadership to discuss the planning and decision making process regarding the Hiawatha and Meadowbrook golf courses. On November 5, 2014 the MPRB will consider a public engagement plan to meaningfully engage constituents and potential project partners in the decision making process for both courses. Water resource planning related to these courses is anticipated to slow during the next several months as the MPRB operates its public engagement process, in advance of a potential February 2015 decision regarding the Hiawatha and Meadowbrook courses.

While the District has been engaged directly with both the City of Minneapolis and the MPRB in the coordination of a possible partnership around regional infrastructure investment, the District has also been coordinating with the Fulton/Lynnhurst/Armitage Neighborhood Associations along Minnehaha Creek.

These neighborhood associations, in coordination with the MPRB, recently completed a survey regarding Minnehaha Creek corridor usage for the area of park land between Minnehaha Parkway (at 50th St. W) and the Edina city limits.

617 people responded to the survey, of which 50% represented visiting Minnehaha Creek at least once a week, with 33% of respondents using the Creek corridor for walking along informal trails. Prioritized responses included (1) develop walking access; (2) make environmental improvements; and (3) keep the area natural. 80% of respondents were in favor of removing concrete spillways, controlling runoff and vegetative restoration of the corridor.

In addition to engaging the City of Minneapolis on spillway removal and stormwater improvements, Association leadership presented to the MCWD CAC in April 2014. In response, the CAC passed a resolution advising the MCWD Board to work with the MPRB to address the concerns raised.

While no formal Board action has been taken on this matter, District staff has incorporated this information into efforts to establish a meaningful and comprehensive partnership to address water resource issues while meeting partner objectives, consistent with the guidance of the 2013 Plan amendment.

In October, District Planning and Education staff met with Association leadership to maintain contact, coordinate and identify potential intersections of effort across the many public and private initiatives throughout the Minnehaha Creek corridor in Minneapolis.

Current Status:
Staff continues to coordinate with the City and MPRB to track efforts that may present opportunities for partnership, including neighborhood association planning, Minneapolis's Hiawatha Flood Area Study, the MPRB Ecological System Plan, the Nokomis-Hiawatha Regional Park Master Plan, and the proposed public engagement process for Hiawatha and Meadowbrook Golf Courses.

Attachments:
- 6-6-13 Minneapolis letter of support
- 6-7-13 MPRB letter of support
- Lynnhurst and Fulton Creek Corridor Survey Final Report
- September 4, 2014 Technical Memo - MCWD and MPRB Infiltration Concepts

If there are questions in advance of the meeting, please contact James Wisker at 952-641-4509 or Jwisker@minnehahacreek.org

Minneapolis
City of Lakes

Department of Public Works
Steven A. Kotke, P.E.
City Engineer
Director

350 South 5th Street - Room 203
Minneapolis MN 55415

Office 612 673-2352
Fax 612 673-3565
TTY 612 673-2157

June 6, 2013

Minnehaha Creek Watershed District
Attn.: James Wisker, Director of Planning, Projects & Land Conservation
18202 Minnetonka Boulevard
Deephaven MN 55391

Subject: Draft Minor Plan Amendment (Capital Improvement Section)

Dear Mr. Wisker:

Thank you for providing the opportunity to comment on the recently proposed amendment to the District's Plan. While remaining focused on the primary goals of the Minnehaha Creek Subwatershed, the plan amendment as proposed will allow MCWD to take advantage of critical project opportunities as they arise, minimizing administrative burden, and saving time and money. As such, the City of Minneapolis supports the approach being proposed by this amendment.

The Minneapolis stormwater management program endeavors to protect people, property and the environment, to meet or surpass regulatory requirements, to maintain and enhance infrastructure, to provide cost-effective services, to educate and engage the public and stakeholders, and to enhance livability and safety. The City and the Minneapolis Park and Recreation Board also operate under an MS4 Permit under the Clean Water Act, for which the primary goal is to restore and maintain the chemical, physical, and biological integrity of waters of the state through management and treatment of urban stormwater runoff.

As we have discussed over the last year, there are numerous opportunities for partnership between the City of Minneapolis and the Minnehaha Creek Watershed District regarding stormwater infrastructure improvements as the City carries out projects related to localized flood control, eliminating cross-connections related to combined sewer overflows, and water quality improvements (including achieving Total Maximum Daily Load waste load allocations for Minnehaha Creek and the lakes). We look forward to continued collaboration with the District to address our shared water resource goals.

Sincerely,

Lois E. Eberhart

Lois Eberhart
Water Resources Administrator
Public Works Surface Water & Sewers Division, 309 S Second Avenue, Minneapolis MN 55401
Phone 612-673-3260 *Email* lois.eberhart@minneapolismn.gov

Minneapolis Park & Recreation Board

Administrative Offices
2117 West River Road
Minneapolis, MN 55411-2227

Operations Center
3800 Bryant Avenue South
Minneapolis, MN 55409-1000

Phone
612-230-6400
Fax:
612-230-6500

www.minneapolisparks.org

June 7, 2013

James Wisker
Director of Planning, Projects & Land Conservation
Minnehaha Creek Watershed District
18202 Minnetonka Blvd
Deephaven, MN 55391

Dear Mr. Wisker;

I am writing this letter in response to the comment period notice for the Minnehaha Creek Watershed District's (MCWD) most recently proposed plan amendment. As you know, the MCWD and Minneapolis Park and Recreation Board (MPRB) have completed many projects in partnership and look forward to continuing that history together.

Most immediately, there are a series of potential improvements we have been discussing that would improve stormwater, the riparian corridor of Minnehaha Creek and water quality in Lake Hiawatha. It is MPRB's understanding that, while keeping the level of due diligence and public process we are accustomed to, the proposed language will allow MCWD to work nimbly with its project partners to locate and schedule projects where they accomplish the maximum water resource benefit while reducing the administrative burden encountered on some projects.

The MPRB supports MCWD's efforts to partner on restoring the Minnehaha Creek corridor and addressing the Hiawatha TMDL. Please accept this letter of support in your efforts and the proposed plan amendment.

Sincerely,

Bruce Chamberlain (cps)

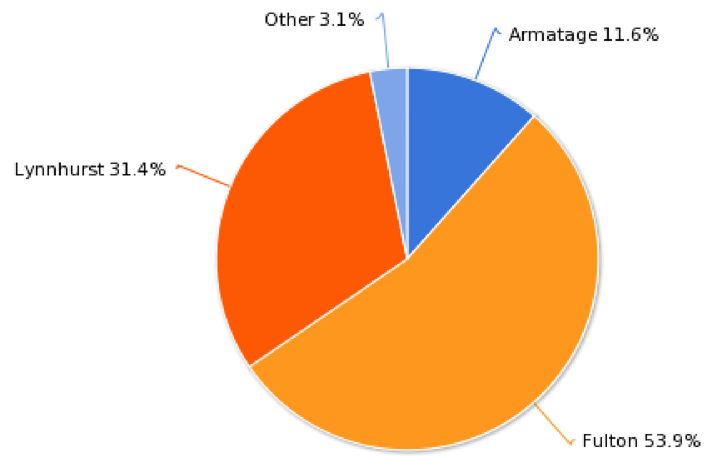
Bruce Chamberlain
Assistant Superintendent for Planning

Creek Corridor Survey Final Report

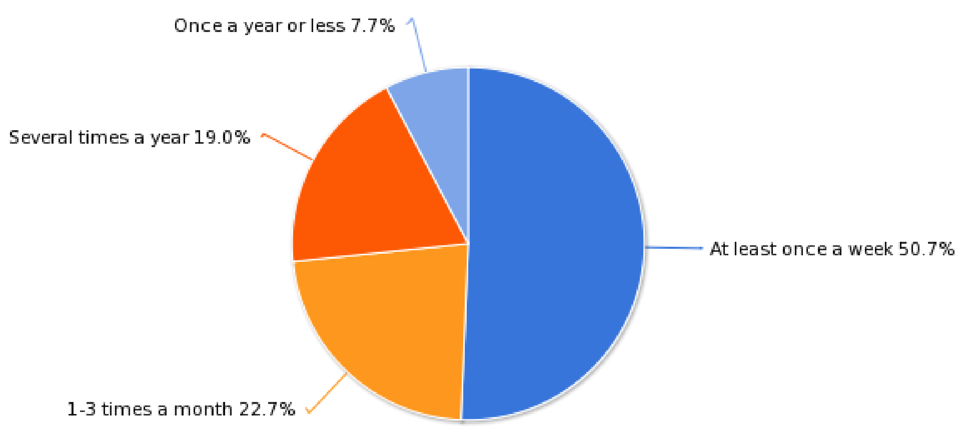
3-27-2014, by Jim Tincher

The Minnehaha Creek Corridor survey was mailed to all Lynnhurst and Fulton homes in late February and early March, and was communicated through the Armatage, Fulton and Lynnhurst websites, as well as through Nextdoor, Facebook and other vehicles. There were 640 respondents.

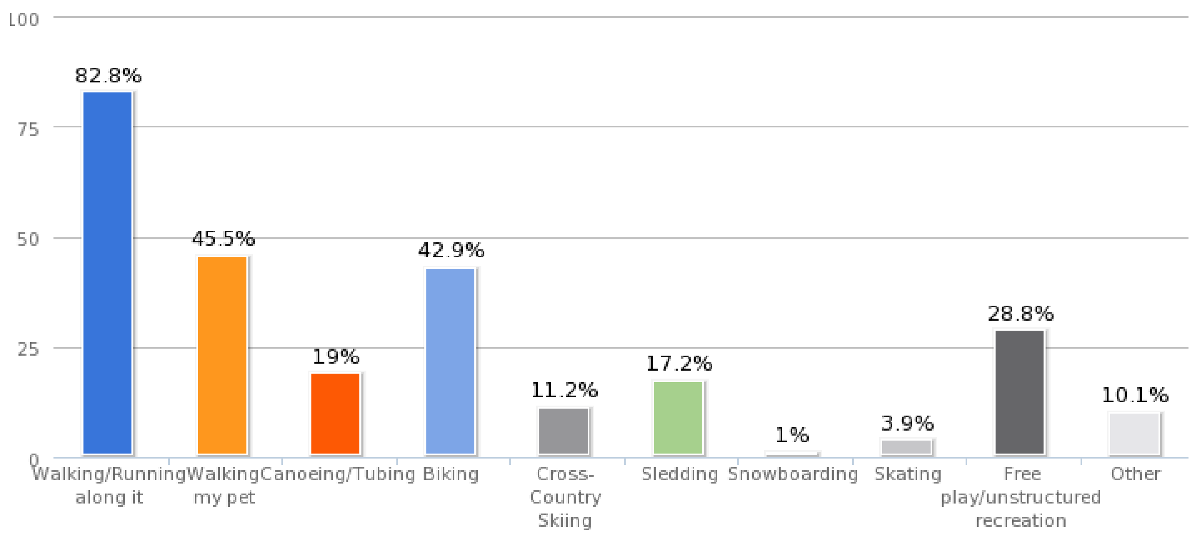
1. In which neighborhood do you reside? (select one)



2. How often do you visit this section of the creek? If it varies during the year, think of when you use it the most.



3. How do you typically use the creek? (Select all that apply)

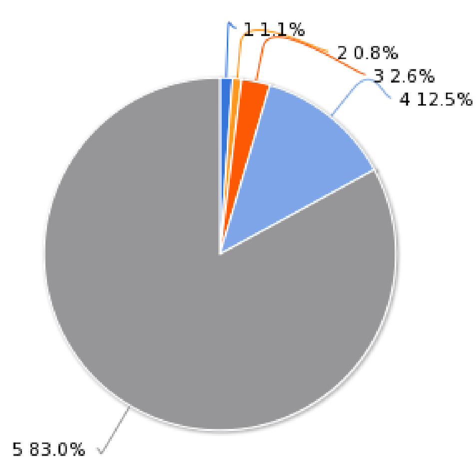


4. In your own words, tell us more about how you use the creek today

Category	#
Walking	191
Nature	154
Pet	65
Biking	63
Family Time	61
Day Out	24
Use the Water	16
Other	15
Don't Use	12

(Respondents could choose two answers. Full verbatims are available upon request.)

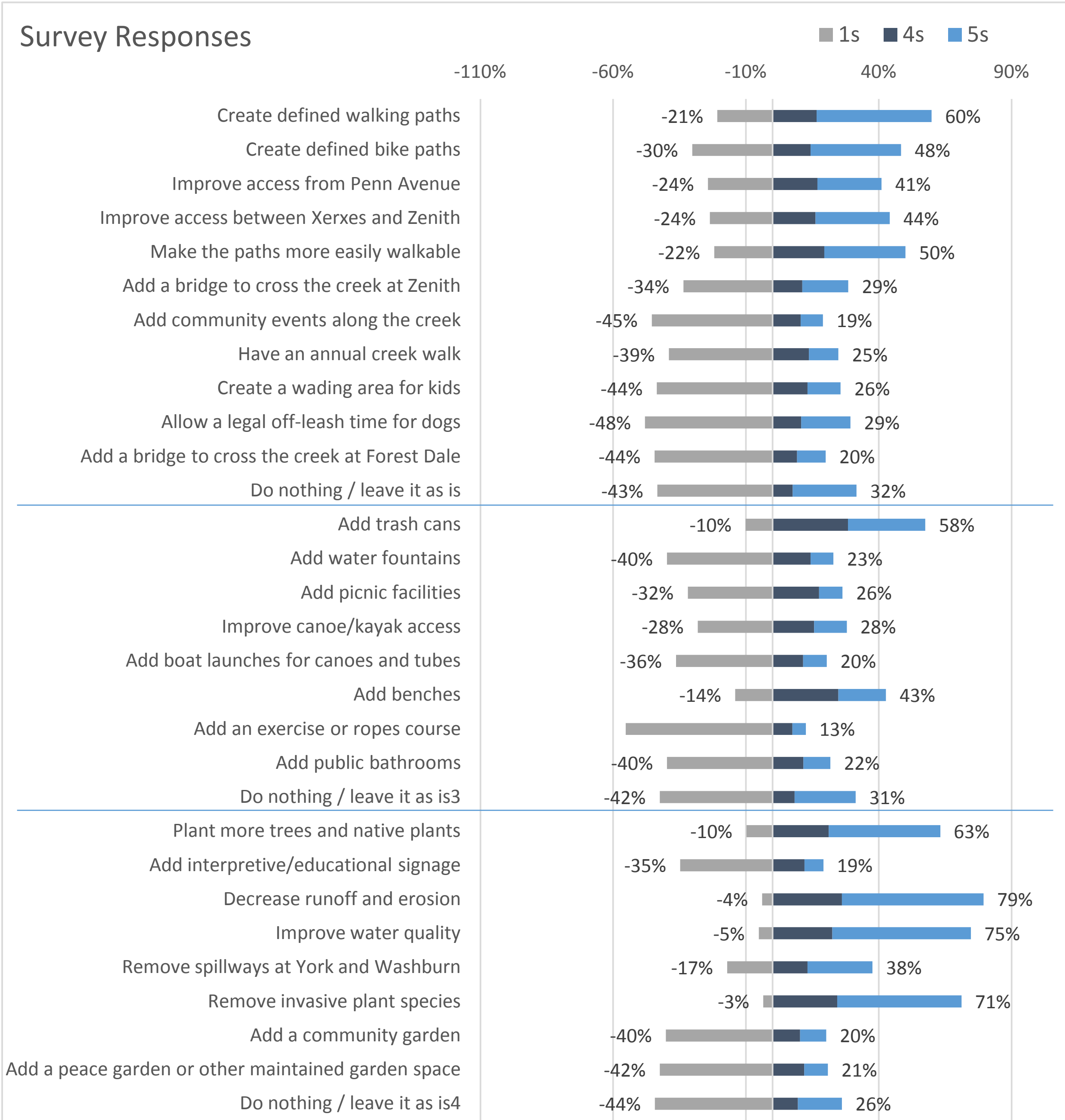
5. On a scale of 1-5, with 1 being not important and 5 being very important, how important is the creek corridor as a neighborhood asset? (1-5)



6. If you were to give advice on what could be done to improve the creek, what would you recommend?

Category	Responses
Walking Access	180
Environmental Improvements	168
Make it Natural	82
Add park/picnic spaces	59
Do Nothing	57
Biking Access	53
Other	19
Water Access	13
No Leashes	12
Pets on Leashes	8
Community Events	5
Airplane Noise	2
Signage	2
Require leashes	1

7-9. On a scale of 1-5, with 1 being not important and 5 being very important, please rate each of the following potential access and use improvements, potential amenities, and environmental improvements.


Survey Responses
1s
4s
5s
-110%
-60%
-10%
40%
90%
Create defined walking paths -21% 60%
Create defined bike paths -30% 48%
Improve access from Penn Avenue -24% 41%
Improve access between Xerxes and Zenith -24% 44%
Make the paths more easily walkable -22% 50%
Add a bridge to cross the creek at Zenith -34% 29%
Add community events along the creek -45% 19%
Have an annual creek walk -39% 25%
Create a wading area for kids -44% 26%
Allow a legal off-leash time for dogs -48% 29%
Add a bridge to cross the creek at Forest Dale -44% 20%
Do nothing / leave it as is -43% 32%
Add trash cans -10% 58%
Add water fountains -40% 23%
Add picnic facilities -32% 26%
Improve canoe/kayak access -28% 28%
Add boat launches for canoes and tubes -36% 20%
Add benches -14% 43%
Add an exercise or ropes course 13%
Add public bathrooms -40% 22%
Do nothing / leave it as is3 -42% 31%
Plant more trees and native plants -10% 63%
Add interpretive/educational signage -35% 19%
Decrease runoff and erosion -4% 79%
Improve water quality -5% 75%
Remove spillways at York and Washburn -17% 38%
Remove invasive plant species -3% 71%
Add a community garden -40% 20%
Add a peace garden or other maintained garden space -42% 21%
Do nothing / leave it as is4 -44% 26%

10. Do you have any comments for your neighborhood association about the Minnehaha Creek Improvement Project?

Category	Responses
Keep it Natural	125
General Approval	61
Walking Access	41
Environmental Improvement	32
Other	28
Involve the Community	21
Do Nothing	14
Maintenance	14
Biking Access	13
Amenities	12
Leashes	10
No Leashes	8
Water Access	3

Mike Panzer, PE, PG
Vice President
Wenck Associates, Inc.
1800 Pioneer Creek Ctr.
P.O. Box 249
Maple Plain, MN 55359-0249

(763) 479-4207
Fax (763) 479-4242
E-mail: mike.panzer@wenck.com

TECHNICAL MEMORANDUM

TO: Becky Houdek, Planning Technician
James Wisker, Planning Department Manager
Minnehaha Creek Watershed District

FROM: Mike Panzer, MCWD District Engineer

DATE: September 4, 2013

SUBJECT: MCWD and MPRB Cooperative Infiltration BMP Concepts

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1. Background

Wenck has previously identified and prepared an inventory of locations where active storm sewer outfalls discharge into Minnehaha Creek This was done as part of the Minnehaha Creek Stream Assessment in 2002. In 2012, MCWD staff conducted a review of historical aerial photographs showing natural alignment of the Minnehaha Creek channel in urban and suburban areas in the Cities of Minneapolis, Edina, St. Louis Park, Hopkins and Minnetonka. A combined overlay of the historical and storm sewer data has identified locations where there is potential to relocate the creek channel, closer to its' natural/historical alignment, and to also provide space for potential treatment of storm water before it is discharged to the creek. Treatment could be accomplished by diversion of discharges to infiltration areas.

MCWD staff directed the initial focus of locating sites be placed on potential opportunities in the City of Minneapolis because:

- The density of storm sewer outfalls in Minneapolis is high.
- The Minneapolis Park and Recreation Board (MPRB) staff had reacted favorably to the notion of creating low-maintenance BMPs at storm sewer outfalls located in the MPRB property, and
- Virtually all the land on both banks of Minnehaha Creek in Minneapolis was owned by MPRB.

Nine locations were initially selected that showed potential. These were later reduced to five locations as an initial project. The nine locations and five selected locations are shown below:

General Locations of Sites within the MPRB System

Later presentations were made to MPRB staff and MPRB Superintendent Miller as well as the Minneapolis Park and Recreation Board Commissioners. These presentations were well received and the Commissioners passed a resolution in support of the concept.

2. Generalized Concept for Further Development During Design of Each Site

The general concept for treatment of storm water discharged directly to the creek is as follows:

- Intercept and remove storm sewer outfalls that discharge directly to Minnehaha Creek
- Divert or redirect storm water flows to an infiltration site nearby and adjacent to the creek
- Design infiltration areas so that runoff from storms dissipates in 2-5 days
- Allow slow subsurface flow from infiltration areas back to the creek to enhance base flow in the creek and reduce the flashy nature of creek hydrographs
- Infiltration areas to be design to treat storm water for Total Suspended Solids and Total Phosphorus

- Incorporate modest planting plans that will minimize maintenance, including mowing
- Incorporate no new above ground structures except for possible new trail alignments, signage and or minor monitoring equipment
- Remove old pipes from the creek bed and restore vegetated banks where possible.

3. <u>Logan-James Avenues Area, South Bank of Creek</u>

This area is part of a 66 acre sub watershed draining to Minnehaha Creek. Approximately 11 acres of residential land along the south bank drains via 30-inch storm sewer <u>under</u> the creek to a lift station on the north side of the creek and West of James Avenue. The 30-inch storm sewer would be intercepted near the South bank and the runoff from the 0.5-inch precipitation event diverted to an infiltration area close to the creek designed for that purpose. Infiltrating water would be allowed to slowly drain subsurface back to the creek. The location of a potential infiltration area is shown below. The view is westerly with James Avenue to the back of the viewer and Minnehaha Creek flowing toward the viewer on the right side of the photo below.

4. <u>East of Humboldt Avenue and South of the Creek</u>

Another 6o acres discharges to Minnehaha Creek by means of 12-inch, 24-inch and 30-inch diameter storm sewers east of Humboldt Avenue and South of the Creek. These sewers would be intercepted in the park area and the runoff from the 0.5-inch precipitation event diverted to an infiltration area close to the creek designed for that purpose. Infiltrating water would be allowed to slowly drain subsurface back to the creek. The location of a potential infiltration site in the Humboldt Avenue area is shown below. The view is westerly with Humboldt Avenue in the background obscured by trees. Minnehaha Creek is flowing toward the viewer on the right side of the photo below.

5. Area West of Nicollet Avenue and South of the Creek

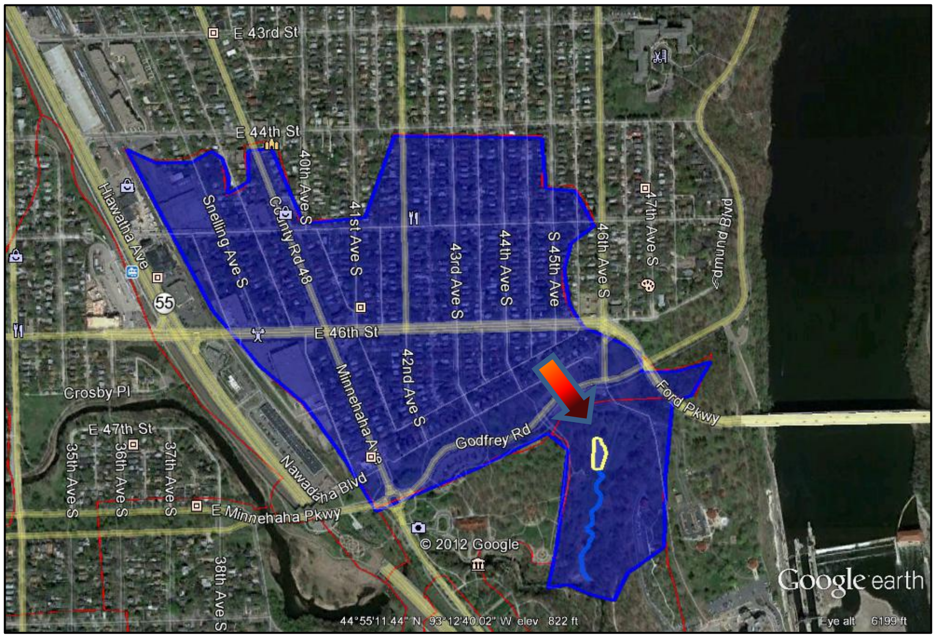
175 acres discharge to Minnehaha Creek by means of 36-inch and 48-inch diameter storm sewers near the intersection of Pleasant Avenue and Blaisdell Avenue with Minnehaha Creek. These sewers would be intercepted in the park area and the runoff from the 0.5-inch precipitation event diverted to a linear infiltration area close to the creek designed for that purpose. Infiltrating water would be allowed to slowly drain subsurface back to the creek. The location of a potential infiltration area is shown below, which is also the route of an informal footpath on the South creek bank. A new trail could be incorporated into the project. The view is westerly with Pleasant Avenue in the background obscured by trees. Minnehaha Creek is flowing toward the viewer on the right side of the photo below.

6. West of Lake Hiawatha

37 acres discharge to Minnehaha Creek in the Hiawatha Golf Course by means of 42-inch diameter storm sewer and channel on the East side of Longfellow Avenue and North of MPRB maintenance facility. This drainage would be intercepted in the park area and the runoff from the 0.5-inch precipitation event diverted to an infiltration area close to the creek designed for that purpose. Infiltrating water would be allowed to slowly

drain subsurface back to the creek. The location of a potential infiltration area is not expected to affect the golf course but that determination would need to be in conjunction with MPRB staff.

7. Deer Pen Area Below Minnehaha Falls



Approximately 130 acres of residential and park land drain directly to Minnehaha Creek through the Deer Park area via a 54-inch diameter storm sewer. The sewer discharges to the creek in the vicinity of the Wading Pool constructed by the US Army Corps of Engineers.

Wading Pool Area

The concept would be to remove the storm sewer and construct a dry channel and infiltration area in its place to reduce storm water volume and pollutant discharges from the drainage area to the wading area in the creek.

8. Estimated Burdened Construction Costs and Effectiveness

The estimated costs and cost-effectiveness for the 5 initial infiltration sites are shown in the table below:

		Burdened Capital Cost	10-year Reconstruction	Routine Annual O&M	20-year Annualized Cost	Annual TP Reduction (lbs)	Annual TSS Reduction (tons)	$/lb TP Removed	$/lb TSS Removed
Logan-James		$115,000	$92,730	$1,000	$11,387	11	1.7	$1,035	$3.35
East Humboldt		$167,000	$134,660	$2,000	$17,083	37	5.6	$462	$1.53
West Nicollet		$425,000	$342,699	$3,000	$41,385	92	13.7	$450	$1.51
West Lake Hiawatha		$130,000	$104,825	$1,000	$12,741	19	2.8	$671	$2.28
Deer Pen		$550,000	$443,492	$4,000	$53,675	70	10.3	$767	$2.61
	Totals:	$1,387,000	$1,118,407	$11,000	$136,270	229	34.1	$595	$2.00

Notes:
1. Burdened costs include design costs
2. Reconstruction is anticipated about every 10 years
3. TP reductions are based on the MCWD PLOAD model. The model is often found to significantly underestimate nutrient loading
4. TSS reductions are based on the MCWD PLOAD model

MINNEHAHA CREEK WATERSHED DISTRICT
QUALITY OF WATER QUALITY OF LIFE

MEMORANDUM

To: MCWD Board of Managers

From: Brandon Wisner

CC: James Wisker

Date: November 6, 2014

Re: Lakeview Golf Course, Orono

Purpose:
To provide a status report of the proposed residential development located at Lakeview Golf Course in the City of Orono; owned by Source Land Capital as requested at the October 23, 2014 Board Meeting.

Background:
Staff has been coordinating with Source Land Capital, the City of Orono and residents with a goal of proactively identifying permitting issues, and to investigate any potential for partnership.

Recent Board Action/Discussion:

- The proposed development has not been heard or discussed by the Board of Managers

Current Status:

- Permit application was received on Friday, October 16, 2014.
- Permit application is under review by District Staff and Engineering

Next Steps/Board Meetings:

- The application will require a 14 public notice to all properties within 600' of the property because the District's Stormwater Management rule is triggered.
- If written request of an interested party addressed to District staff and received by staff within 14 days after the public notice date, a permit application otherwise suitable for staff determination will be brought before the Board. In advance of Board consideration, staff will make reasonable attempts to determine and address the concerns of the requesting party.

If there are questions in advance of the meeting, please contact Brandon Wisner at 952-471-4505 or Bwisner@minnehahacreek.org

MINNEHAHA CREEK WATERSHED DISTRICT
QUALITY OF WATER QUALITY OF LIFE

MEMORANDUM

To: MCWD Board of Managers

From: James Wisker

Date: November 6, 2014

Re: Wayzata Lake Effect

Purpose:
To provide a status report on the City of Wayzata's Lake Effect initiaitve, as requested at the October 23, 2014 Board Meeting.

History/Recent Board Action/Discussion:
Bryan Gaddow, City of Wayzaya Planner, Tim Griffin and Josh Kinney of the St. Paul Riverfront Corporation appeared before the Board of Managers on December 19, 2013 to review the stakeholder-input and design-development efforts they have under way for redevelopment of the Lake Minneotnka Shoreline in Wayzata.

It was relayed that scenarios for lakeshore redevelopment have been developed and the City is working to establish public-private partnerships to facilitate implementation. Manager Blixt requested specific information regarding the shoreline design, explaining that the Board needed to consider potential for creating precedent for other communities wishing to similarly develop their shorelines.

The City of Wayzata explained that the city was simply seeking preliminary comments on overall concepts at this time, and specifics would evolve later as partnerships formed around specific elements of the plan. The Board of Managers reinforced the need for District staff to remain engaged with the City of Wayzata on future development plans.

Current Status:
Consistent with this direction, and in response to recent development potential, the City is coordinating a meeting with MCWD staff on November 6 to discuss opportunities as they relate to the Lake Effect Plan and the potential for water resource improvement.

If there are questions in advance of the meeting, please contact: James Wisker at 952-641-0590 or Jwisker@minnehahacreek.org

MINNEHAHA CREEK WATERSHED DISTRICT
QUALITY OF WATER QUALITY OF LIFE

MEMORANDUM

To: MCWD Board of Managers

From: Yvette Christianson and Kelly Dooley

CC: Craig Dawson

Date: November 6, 2014

Re: Ecosystem Evaluation Program

Purpose:

To provide a status report on the progress of the Ecosystem Evaluation Program (EEP) as requested at the October 23, 2014 Board Meeting.

Background:

The EEP was developed to be used as an ecosystem management evaluation tool to assess watershed conditions on a graded scale, identify stressors and target areas that need improvement or protection, and develop management strategies to protect and improve water resources. This was also to be used in coordination with the development of the 2017 Comprehensive Plan.

Project History:

- Language added to the existing 2007 Comprehensive Plan
- December 2011 Ecosystem Based Approach for Watershed Management-Wenck Associates
- 2011-2012 Hydrodata Committee Gap Analysis
- October 2012 Humber River visit, Gary Wilkins, Toronto and Region Conservation
- November 7, 2013 Planning and Policy Committee: Review of the Hydrodata Department's Gap Analysis completed in 2012 and introduction of MCWD Subwatershed Health Assessment Report (SHARe)
- January 16, 2014 Planning and Policy Committee: EEP (aka: SHARe) budget and timeline was presented and discussed.
- February 6, 2014 Operations and Programs Committee: EEP recommendations presented.
- May 19, 2014 Wenck Associates signed the agreement to work with MCWD's EEP for 2014

Recent Board Action/Discussion:

- February 27, 2014 Board Meeting: Resolution 14-xxx, Authorization to Continue Developing the Ecosystem Evaluation Program for 2014. Develop the Workplan for 2015, and Hire a Full Time Temporary Staff for One Year
- March 27, 2014 Board Meeting: Resolution 14-017, Authorization to Continue Developing the Ecosystem Evaluation Program for 2014. Develop the Workplan for 2015, and Hire a Full Time Temporary Staff for One Year-**Amendment Approval**
- April 24, 2014 Board Workshop: Resolution 14-028, Authorization to contract with Wenck Associates Inc. for consulting services for the Ecosystem Evaluation Program for 2014

Current Status:

- August 26, 2014 Ecosystem Evaluation Program Brown Bag Presentation
- September 25, 2014 1st Technical Advisory Committee Meeting
- October 9, 2014 Board Workshop Informational Item: Ecosystem Evaluation Program Update
- October 28, 2014 2nd Technical Advisory Committee Meeting

Next Steps/Board Meetings:

November 6, 2014 Joint Committee Meeting: Authorization to contract with Wenck Associates, Inc. for second year consulting services for the Ecosystem Evaluation Program

Attachments:

- Timeline and program status
- Technical Memorandum from Wenck Associates outlining the overall approach for development of the program
- Watershed Wide Ecosystems Services flow chart
- Ecosystem Evaluation Program's 1st Technical Advisory Committee meeting notes

If there are questions in advance of the meeting, please contact: Yvette Christianson and Kelly Dooley

MINNEHAHA CREEK WATERSHED DISTRICT
QUALITY OF WATER QUALITY OF LIFE

Monitoring Department – Ecosystem Evaluation Program Update

Introduction

This report will provide an update on the Monitoring Department's Ecosystem Evaluation Program activities through the end of September 2014. The next update will occur in December 2014. If there are questions regarding any elements of this report, please contact Yvette Christianson at 952-641-4514 / ychristianson@minnehahacreek.org or Kelly Dooley at 952-641-4515 / kdooley@minnehahacreek.org.

Timeline and Program Status

Task	Subtask	Timeframe	Status
Introductory Meeting with Partners (e.g., CAC and Technical Advisory Committee (TAC))	• Deep & Shallow Lakes • Streams & Wetlands	July 2014 (Pushed back to September to accommodate TAC member's field schedules)	**Completed:** Met with CAC on September 24, 2014; Met with TAC on September 25, 2014
Identify key features of health and ecosystem services		July – October 2014	**In Progress:** Ecosystem Services and functions have been identified; redefining the list with TAC's input
Identify appropriate metrics and indices (data collection/analysis)		October – December 2014	**In Progress:** Identified potential metrics/ indices; meet one on one with agencies on the TAC and internal staff to get more information

Task	Subtask	Timeframe	Status
Update datasets and fill data gaps	• Deep & Shallow Lakes • Streams & Wetlands	Spring - Summer 2015	**TBD:** Wenck is reviewing the data and determining the data gaps for collection in Summer 2015
Follow up meeting: Partners & Consultant (e.g., CAC, TAC, and Board of Managers)		Winter 2014 – 2015	**In Progress:** Setting up the next TAC for a date in October/November 2014; Provide 2nd update to the Board in December 2014
Literature research & stressor response		July – October 2014	**In Progress:** The research and stressor response information is being incorporated into generating the list of ecosystem services, functions and potential metrics/indices

Enclosed Documents

- Technical Memorandum on the Approach for the Ecosystem Evaluation Program with attachment
    - Provided to the TAC members for the September 25, 2014 meeting
    - Table 1 was the focus of the TAC meeting discussion

- September 25, 2014 TAC meeting minutes

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TECHNICAL MEMORANDUM

TO: Kelly Dooley, Minnehaha Creek Watershed District
Yvette Christianson, Minnehaha Creek Watershed District

FROM: Joe Bischoff, Wenck Associates, Inc.
Diane Spector, Wenck Associates, Inc.

DATE: September 18, 2014

SUBJECT: Approach for the Ecosystem Evaluation Program

The purpose of this technical memorandum is to outline the overall approach for developing the Ecosystem Evaluation Program for the Minnehaha Creek Watershed District (MCWD).

Purpose

The purpose of the Minnehaha Creek Ecosystem Evaluation Program (EEP) is to develop and implement a watershed wide ecosystem evaluation/grading tool to assess watershed condition, inform monitoring and other data collection, identify target areas that need improvement or that may be impacted by potential stressors, and ensure that the District's management strategies effectively protect and improve water resources. EEP will be designed to more effectively communicate the watershed's condition to the public and stakeholders. The Program will assess and report watershed health through the use of environmental indicators or metrics that will serve as the basis for project and program targeting and as the measures of environmental change.

The goals of the program are:

1. Provide a tool to deliver a wide variety of highly technical information in an understandable form for local citizens, municipalities, and other agencies.
2. Provide a tool for targeting programs to address watershed deficiencies and measuring environmental change.

Approach

The guiding principle of the District's 2007 Comprehensive Water Resources Management Plan was Integrated Resource Management. Integrated Resource Management is an interdisciplinary approach to water resources management that focuses on specific water resource, subwatershed, or watershed *outcomes* rather than on *processes* such as wetland regulation, runoff rate control, or BMP selection. This approach recognizes that water resources are complex, dynamic systems that require integrated decisions about water quality, water quantity, ecologic integrity, and land use and regulation to achieve complex and multi-dimensional end goals. The Plan established a number of goals in each of the 11 subwatersheds and defined associated metrics to evaluate progress. Among these indicators were:

- In-lake nutrient concentrations
- Watershed nutrient loading goals
- Acres of land conserved in Key Conservation Area
- Acres of restored/created wetlands
- Surficial groundwater levels
- Stream Visual Assessment Protocol scores
- Macroinvertebrate Index of Biotic Integrity

The Ecosystem Evaluation tool builds off that approach and expands it by defining the health of the watershed and its features in the context of key ecosystem services. To accomplish this, we must first determine the key ecosystem services provided in the watershed and what features or components of the watershed are critical in providing these ecosystem services. Once the key ecosystem services and critical watershed components are defined, the current health or condition of the watershed will be determined through the use of indicators or metrics. Following that, potential stressors that could negatively impact those services or value will be identified. Management and implementation activities can then be developed to address those stressors with protection or improvement actions.

The process will follow the 6 steps below:

1. Identify the key components that describe the health of the watershed feature (lake, stream, wetland, upland).
    a. Identify the key ecosystem services to be protected
2. Identify the metrics or indices required to evaluate health of each of the identified components
    a. Collect and analyze data associated with each of these metrics
3. Develop scales for each of the metrics or indices using statistical analyses, reference sites, and literature values
    a. Statistical analysis of the data
    b. Literature review of index values at different scales (metro, ecoregion, state, region)
4. Develop grades for each of the resource features and watershed as a whole
    a. Develop scales combining metrics
5. Develop lists of poor scoring metrics or data gaps
6. Develop programmatic approaches to addressing scored resources
    a. Developing monitoring approach to fill data gaps (Hydrodata)
    b. Develop management actions focused on improving resources and areas with low scoring metrics (Planning)
    c. Develop outreach programs to communicate grades (Communications)
    d. Develop protection strategies for resources and areas with high scoring metrics (Planning)

Following is description of the current status in developing key ecosystem services, critical watershed components, and appropriate metrics to evaluate watershed conditions.

Technical Memo
Approach for the Ecosystem Evaluation Program
Minnehaha Creek Watershed District
September 16, 2014

Ecosystem Services

Ecosystem services are simply defined as the benefits people get from ecosystems. These benefits include provisioning services such as food and water; regulating services such as flood and disease control; cultural services such as spiritual, recreational, and cultural benefits; and supporting services such as nutrient cycling that maintain the conditions for life on Earth. The Millennium Ecosystem Assessment group (MA) defines the different types of Ecosystem Services as:

Provisioning services: The products obtained from ecosystems, including, for example, genetic resources, food and fiber, and fresh water.

Regulating services: The benefits obtained from the regulation of ecosystem processes, including, for example, the regulation of climate, water, and some human diseases.

Cultural services: The non-material benefits people obtain from ecosystems through spiritual enrichment, cognitive development, reflection, recreation, and aesthetic experience, including, e.g., knowledge systems, social relations, and aesthetic values.

Supporting services: Ecosystem services that are necessary for the production of all other ecosystem services. Some examples include biomass production, production of atmospheric oxygen, soil formation and retention, nutrient cycling, water cycling, and provisioning of habitat.

The MA is an international work program designed to meet the needs of decision makers and the public for scientific information concerning the consequences of ecosystem change for human well-being and options for responding to those changes.

Using this framework, there are number of ecosystem services that can be identified for watersheds as well as the key watershed components supporting the ecosystem services (attached figure). Determining a watersheds ability to provide all of these services at this level of detail is quite challenging and very labor intensive. In an attempt to simplify the approach and improve understandability, the ecosystem services were reduced to six primary categories for this assessment including:

1. Flood Control
2. Nutrient Cycling
3. Biodiversity
4. Habitat Diversity
5. Recreation
6. Drinking Water Supply

Key Watershed Features

To develop an understanding of the health of the watershed, the watershed was broken into its key components that support or deliver identified ecosystem services. These key components were selected based on scientific understanding of these areas to deliver ecosystem services as well as focus areas for the Minnehaha Creek Watershed District. These are not intended to be all inclusive, rather to focus on the primary management areas for the district and to encompass the majority of critical ecosystem services that are provided by the Minnehaha Creek watershed.

The following key watershed components will be included in the study:

- Deep Lakes
- Shallow Lakes
- Streams
- Wetlands
- Terrestrial Habitat
- Groundwater
- Precipitation/Hydrology

Shallow and deep lakes were separated due to their functional differences as well as differences in ecosystem services provided. For example, deep lakes sustain a different suite of recreational services than shallow lakes. Precipitation and hydrology are a unique watershed “feature” in that it is dependent on other components such as wetlands, uplands, and streams. However, the hydrologic functioning of a watershed is critical for supporting almost all of the identified ecosystem services, so it was broken out into its own category for evaluation.

Indicators

Watershed health indicators or metrics will be used for each watershed component to measure the health of that component and its ability to provide key watershed ecosystem services. The goal for this project is to use metrics and indices already developed by other agencies and to build off of those wherever possible. Table 1 lists a number of potential metrics and indices that have been applied in Minnesota. Several of these indices provide an assessment across a number of ecosystem functions. For example, the Floristic Quality Index can be used as an index for the health of the plant community and also its habitat conditions for supporting waterfowl.

Table 1. Watershed features, functions and potential metrics for the MCWD Ecosystem Evaluation Program.

Watershed Feature	Ecosystem Service	Functions	Potential Indicators/Metrics
Deep Lakes	Flood Control	Watershed storage	TBD - Hydrology
	Nutrient Cycling	Nutrient sink, source, transformer	Water quality parameters
	Biodiversity	Resilient biological community Recreational use (hunting and fishing)	Fish IBI Floristic Quality Index Invasive Species (presence/absence; abundance) Land use change? Imperviousness?
	Habitat Diversity	Fish, macroinvertebrate, and wildlife habitat	Floristic Quality Index Shoreline Development Index Connectivity (# of culverts, dams, etc.) Fragmentation
	Recreation	Access	Public access
		Aesthetics	Water quality parameters
	Drinking Water Supply	Groundwater recharge	TBD – Groundwater Lake level trends Monitoring well elevations
Shallow Lakes	Flood Control	Watershed storage	TBD - Hydrology
	Nutrient Cycling	Nutrient sink, source, transformer	Water quality parameters
	Biodiversity	Resilient biological community Recreational use (hunting and fishing)	Fish IBI Floristic Quality Index Invasive Species (presence/absence; abundance) Wildlife surveys (waterfowl, birds, etc.) Land use change? Imperviousness?
	Habitat Diversity	Fish, macroinvertebrate, and wildlife habitat	Floristic Quality Index Shoreline Development Index Connectivity (# of culverts, dams, etc.) Fragmentation
	Recreation	Access	Public access
		Aesthetics	Water quality parameters
	Drinking Water Supply	Groundwater recharge	TBD – Groundwater Lake level trends Monitoring well elevations

Watershed Feature	Ecosystem Service	Functions	Potential Indicators/Metrics
Streams	Flood Control	Conveyance	TBD - Hydrology
	Nutrient Cycling	Nutrient sink, source, transformer	Water quality parameters
	Biodiversity	Resilient biological community Recreational use (hunting and fishing)	Macroinvertebrate IBI Fish IBI
	Habitat Diversity	Fish, macroinvertebrate, and wildlife habitat	Stream Visual Assessment Rapid Bioassessment Protocol MPCA protocol Fluvial geomorphology assessments
	Recreation	Access	Public Access Fish IBI
		Aesthetics	Stream Visual Assessment Rapid Bioassessment Protocol
	Drinking Water Supply	Groundwater recharge	TBD - Groundwater
Wetlands	Flood Control	Watershed storage	TBD - Hydrology
	Nutrient Cycling	Nutrient sink, source, transformer	Water quality parameters
	Drinking Water Supply	Groundwater recharge	TBD - Groundwater
	Biodiversity	Habitat diversity	Invasive Species (presence/absence; abundance) Wetland Health Evaluation Program protocol Land use change? Imperviousness? Functions and values assessments
	Habitat diversity	Vegetative diversity	MPCA Wetland IBI Functions and values assessments
Terrestrial Habitat	TBD	TBD	TBD
Groundwater	TBD	TBD	TBD
Precipitation/Hydrology	TBD	TBD	TBD

Following is a brief description of some of the key indicators that will be explored for this project. Note that at this stage in the project, the indicator list is not exhaustive and new indicators may be added or subtracted as the project progresses. Rather, this list is a preliminary list of indicators already developed or utilized in Minnesota. Further literature review is needed prior to finalizing the list of indicators and metrics.

*MPCA's Index of Biotic Integrity for Streams. T*he MPCA recently developed a macroinvertebrate and fish community-based Index of Biological Integrity (M-IBI) for Minnesota's streams and rivers. The primary intended use for this tool is the assessment of aquatic life use support.

Development of the M-IBI utilized a standardized protocol developed by researchers from the United States Environmental Protection Agency and elsewhere (Whittier et al. 2007). Minnesota's streams and rivers were first partitioned into five distinct classes, and a unique IBI was developed for each. Within each stream class, biological metrics were sequentially ranked and eliminated by a series of tests, and selected for inclusion in each IBI. Among the most important tests was an evaluation of each metric's ability to distinguish most-disturbed sites from least-disturbed sites. More information can be found at http://www.pca.state.mn.us/index.php/water/water-monitoring-and-reporting/biological-monitoring/index-of-biological-integrity.html.

MNDNR Index of Biotic Integrity for Fish in Lakes. Excerpt from http://www.legacy.leg.mn/projects/lake-index-biological-integrity-assessments-0.

The Minnesota Pollution Control Agency currently uses IBIs for fish and macroinvertebrates (stream-dwelling insects and other critters) to help determine whether streams and rivers are impacted by water pollution. DNR is developing similar tools, using fish and aquatic plants, to identify lakes that may be impacted to support Legacy Amendment assessment efforts. The development of an IBI involves sampling a wide range of lakes, from high-quality systems to those with significant water quality impacts, plus detailed statistical analysis. The DNR's current effort is focused on collecting information about the entire fish community including non-game fish that have not been traditionally sampled by fishery managers and are often more sensitive to watershed and shoreline disturbance. In addition, DNR is beginning work on development of a plant IBI, especially important for assessing shallower wildlife lakes.

In FY14, DNR biologists will complete approximately 135 fish IBI surveys, which include near-shore fish communities and game and nongame fish surveys in the shallow and deep water zones. IBI survey information will be used as part of MPCA's watershed assessments. Using the data collected to date, DNR Biologists will work with MPCA to finalize a fish IBI tool for most lake types and develop a Biological Condition Gradient (BCG) Model for Minnesota lakes. We expect to finalize the IBI and BCG models by early 2015. Biologists will also begin work on developing IBI tools for aquatic plants in FY14.

Floristic Quality Index. The Floristic Quality Assessment (FQA) is a vegetation-based ecological assessment approach that can be used for shallow lake vegetation quality monitoring and assessment. FQA is based on the Coefficient of Conservatism (*C*), which is a numerical rating (0 –10) of an individual plant species' fidelity to specific habitats and tolerance of disturbance. Plant species that have narrow habitat requirements and/or little tolerance to disturbance have high *C*-values and vice versa. FQA metrics derived from on-site vegetation data and the *C*-values have been found to be effective indicators of wetland quality–similar to Indices of Biological Integrity (IBIs).

MPCA Wetland Floristic Quality Assessment. Excerpt from http://www.pca.state.mn.us/index.php/water/water-types-and-programs/surface-water/wetlands/floristic-quality-assessment-for-minnesota-wetlands.html.

The MPCA has fully developed the FQA (see Floristic Quality Index description above) for use in Minnesota's wetlands. This includes: assigning *C*-values to Minnesota's wetland plant species; developing data-driven benchmarks to translate FQA results into assessments; and developing a 'Rapid FQA' geared towards broader usage. The MPCA is currently utilizing the FQA approach to monitor all wetland types in Minnesota through our wetland quality status and trends monitoring.

Wetlands Functions and Values Assessment. In 2001-2003 the District undertook a *Functional Assessment of Wetlands* (FAW) on all wetlands greater than one-quarter acre in size. This assessment used a variant of the Minnesota Routine Assessment Method. Wetlands that were evaluated as Exceptional or High on certain ecological or hydrologic values were assigned to the Preserve category. The balance of evaluated wetlands were assigned to a category based on this assessment of current functions and values, with Manage 1 wetlands exhibiting higher values and Manage 2 and 3 moderate or lower values.

Invasive Species Indicators. The presence or absence of invasive species can be used to assess the health of a plant community beyond the use of Floristic Quality Assessments, especially in lakes. Lakes can be scored separately based on the presence or absence of key invasive species and assigned grading based on their abundance and overall impact on the system. An index for the presence and impacts for invasive species has not been identified yet, but may be developed during the project.

Shoreline Development Index. The amount of development along a lake's shoreline can impact ecosystem functions and lake health. To date, no indexes for the impacts of shoreline development on the lake have been identified. However, research is being compiled to determine appropriate metrics. For the purpose of regulating shoreline stabilization projects, the District has developed an erosion susceptibility classification system.

Connectivity and Fragmentation. Connectivity of habitat features and habitat fragmentation are critical areas that need to be assessed. Indices to assess upland patch cohesion, connectance, and traversability have been developed, but there are few indices have been identified to date, but a literature review is underway to identify appropriate metrics. Metrics may include number of dams, culverts and water control structures, habitat fragmentation measures, and other easily obtained information.

Water Quality Parameters. There are numerous water quality standards that will be applied to measure health of the watershed from a nutrient cycling perspective.

Recreational Access. Recreational access can be assessed simply by identify those waterbodies with or without public access.

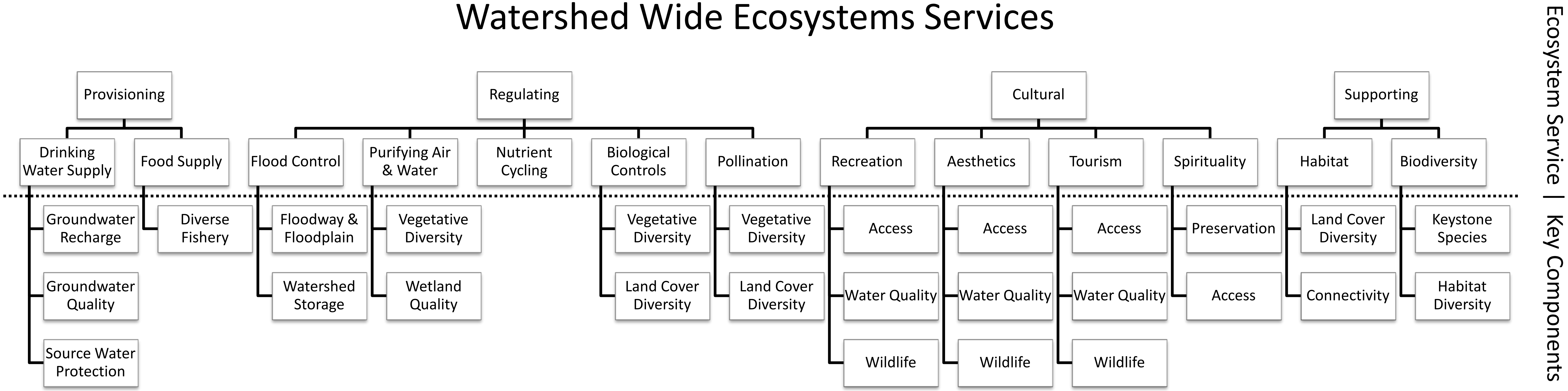
Stream Assessments. In 2003 the District assessed the physical and biological condition of Minnehaha Creek and five principle upper watershed streams. The Minnehaha Creek stream assessment included a fluvial geomorphic investigation to evaluate the stability of the creek as well as evaluation of creek conditions using the standard assessment tools Stream Visual Assessment Protocol and Pfankuch Channel Stability. Additional indices to evaluate streams might include Rosgen's Bank Erosion Hazard Index (BEHI) or the Rapid Bioassessment Protocol.

Next Steps

Using the above described framework, the next step is to further explore the identified indicators and metrics and their application in scoring system. The MCWD team will be reaching out to Agency leads on many of these metrics to explore their application in the Ecosystem Evaluation Program and how MCWD may be able to partner with Agency.

MCWD also identified three test subwatersheds to apply the scoring systems to evaluate their efficacy. The MCWD team are currently compiling data for these subwatersheds to assess application scale, data quality and data gaps.

Watershed Wide Ecosystems Services



Ecosystem Evaluation Program's Technical Advisory Committee
September 25, 2014

TAC Members:

Joe Bischoff (Wenck), Diane Spector (Wenck), Peter Sorenson (U of MN), Justine Koch (U of MN), Emily Deering (U of MN), Kim Laing (MPCA), Chris Zadak (MPCA), Will Bouchard (MPCA), Richard Kiesling (USGS), Brian Vlach (TRPD), Rich Brasch (TRPD), Kate Drewry (MnDNR), Nick Proulx (MnDNR), Tony Brough (Hennepin Co), Adam Arvidson (MPRB), Jen Kostrzewski (MCES), Brian Johnson (MCES), Cassie Champion (MCES), Yvette Christianson (MCWD), Craig Dawson (MCWD), Kelly Dooley (MCWD) and *Conference Called in:* Jacquelyn Bacigalupi (MnDNR) and Taylor Polomis (MnDNR)

TAC Minutes:

After Introductions, Joe Bischoff started off by stating this TAC should function more like a work group with interaction and collaboration among all members. He then presented the powerpoint on the Ecosystem Evaluation Program to the TAC members. The objectives for the meeting were to discuss if the list of the Ecosystem Services and functions on the table on page 6 of the Technical Memo were appropriate and to discuss the next steps for the second TAC meeting.

The following questions/comments were addressed:

- We should consider grouping Biodiversity and Habitat Diversity as one ecosystem service instead of separating them out.
- Plankton, especially the zooplankton, are important. They are missing from the list of metrics. Plankton drive the fish community.
    - Minneapolis Chain of Lakes has a plankton data set

- DNR does not manage shallow lakes for fish but for waterfowl, another metric to consider.
    - DNR makes a good point, how do we break out the uses for deep/shallow lakes and wetlands?
    - It's really important that we define the different uses between shallow lakes and wetlands not only for management action but also to set expectations for the public.
    - Fishless shallow lakes have importance for amphibians, but their presence is more tied to hydrology – could be another metric.
    - DNR suggests using the Fisheries Lake Class System to define lakes vs wetlands.
    - Fish are not a good indicator/metric for shallow lakes due to winterkills. Plants may be a better indicator.
        - However, the presence/absence of carp could be used as an indicator in shallow lakes
    - Lakes that winterkill still provide valuable information, so fish should still be used as an indicator for shallow lakes
        - Shallow lakes have winter kills
        - Wetlands do not have winter kills
    - Consider adding oxygen dynamics to shallow lakes indicators, can help detect flip
- How do recreational uses fit into the program?
- The cultural/recreation/aesthetics piece is important, but will be difficult to devise metrics/scales all can agree upon
- The recreation metric would seem to undermine the ecological metrics and lower the overall E-grade. Recreation is very important, especially in an urban watershed.

    - The plan was not to average the grades of the metrics similar to the Humber River Report Card
    - Recreation could be a recommendation rather than a metric (ex: list the types of recreation supported for each waterbody)
- A topic for future discussions is resolving conflicting metrics (e.g., providing public access may negatively impact fish community)
- The focus/goal should be more towards sustainability because everything has been altered
- Considering grading or assessing based on current ability to meet its 'best attainable condition' for its function rather than a reference condition
- Essentially a functional assessment on all waterbodies should be done
    - Is the grading scale the main objective? Functional assessment would be ideal.
    - The District wants the grades as public communication tool
    - Expanded grading system that encompasses more ecosystem parameters, rather than just water quality which is the current MCES grading system that the District uses
- The Shallow Lakes Example flow chart in the presentation – Stressors – then Opportunities – then Management Actions. What opportunities are present in the subwatershed to develop/carry out management actions?
    - Opportunities such as all the lakeshore in Minneapolis being owned by the MPRB. Lakeshore owned by homeowners around Lake Minnetonka limits the opportunities for action.
- For the management action part – need more data otherwise we should not be making any decisions/plans for action on how to manage the stressor without data
    - If there is a lack of data, then that metric will be incomplete until data is available
- What scale idea does Wenck/MCWD have in mind?
    - Basin (lakes)/ Reach (streams) scale that works with the Index of Biological Integrity (IBIs).

Next Steps:

- Email ideas on ecosystem services via Dropbox
- Smaller meetings with individual agencies to get more detailed information on metrics and the available data
- Next TAC meeting (October/November) 3 short presentations from the following experts:
    - Tired Aquatic Life Uses (TALU), Wetland IBIs and Stream IBIs – Will Bouchard (MPCA)
    - Lake Fish and Plant IBIs – Jacquelyn Bacigalupi and colleague (MnDNR)
    - Current Lake Grading system and Trophic Status Index – Brian Johnson (MCES)

MINNEHAHA CREEK WATERSHED DISTRICT
QUALITY OF WATER QUALITY OF LIFE

MEMORANDUM

To: MCWD Board of Managers

From: Eric Fieldseth

CC: Craig Dawson

Date: November 6, 2014

Re: Status update on Six-Mile Creek Carp Assessment

Purpose:

- To provide a status report on carp study report as requested at the October 23, 2014, MCWD Board Meeting.

Background:

- U of M researchers began work in the Six-Mile Creek Subwatershed on June 9, 2014. A public information meeting was held on June 18, 2014 at the Victoria City Hall, for which Board members received announcement. Per the agreement for services, the researchers are to provide staff with monthly progress reports. Progress is also occasionally reported in *Splash!* updates. Most recently, an update/progress memo was in the October 23, 2014, Board meeting packet as an informational item on the agenda. Staff will continue to provide quarterly updates to the Board on the progress of the study. The agreement for services also obligates the U of M to present an annual report on work performed, to be made during the first quarter of the following year.

Attachments:
October 23, 2014, Update to MCWD Board

If there are questions in advance of the meeting, please contact: Eric Fieldseth, 952-471-7873 or efieldseth@minnehahacreek.org.

MEMORANDUM

TO: MCWD Board of Managers
FROM: Eric Fieldseth, AIS Specialist
DATE: October 23, 2014 Board Meeting
SUBJECT: Six-Mile Creek Carp Assessment Update

The Six-Mile Creek Carp Assessment got underway on June 9th, 2014. The purpose of the study is to determine the abundance, seasonal movements, and recruitment patterns of common carp in the Six Mile Creek Sub-Watershed to enable development of carp control strategies for restoration of the sub-watershed. This will involve several survey tools including: electrofishing to estimate adult carp abundance, trap-net surveys to sample juvenile carp and identify carp nurseries, radio-tracking of tagged carp to track movement in the system, and aging studies to examine historical trends in recruitment.

Adult Carp Abundance

During the months of June and July, the U of MN completed several electrofishing surveys on assessment lakes, which will give an estimate for adult common carp abundance. Overall, adult carp abundance varies across the sub-watershed but in general is high. Preliminary estimates are indicating most lakes likely have a summer time carp density well in excess of the 100 kg/ha threshold previously identified as damaging in shallow lakes (Bajer et al. 2009). Halsted's Bay seems to be significantly high. Another round of electrofishing was completed in September as the researchers were radio-tagging carp, and those numbers are similar to the summertime numbers.

Identification of sources of juvenile carp

Trap-net surveys were done from August to mid-September to sample juvenile carp in the system as well as native fish such as sunfish. This info will help identify possible carp nurseries in the sub-watershed. Juvenile carp have only been found in a handful of locations so far, with Big SOB Lake, which is on the Tom Redmond property near Parley Lake, having the highest number as well as a pond near Crown College; both feed into Parley Lake. Researchers also found one juvenile in Mud Lake, and some in a pond in between Sunny and Auburn Lakes. Surprisingly, no juvenile carp were found in Marsh Lake, which is between Piersons and Wassermann Lakes, but they did find a substantial number of sunfish, which act as predators on carp eggs. It's possible that Marsh Lake only winterkills occasionally, and when it does those could be the times where carp are successful in spawning and those fish eventually could re-populate Piersons and other lakes. MCWD staff will start monitoring dissolved oxygen levels in Marsh Lake this winter, as well as some other lakes in the subwatershed, to determine possible winterkill conditions in lakes of interest.

MCWD staff along with U of MN researchers met with the property owner and managers of Big SOB Lake to discuss the findings as they are very concerned of carp in their lake and want to manage for a healthy fishery. Several things were discussed, including aeration and permanent barriers between their lake and Parley Lake. The property owner seemed very eager to implement anything that needed to be done. Improvements made in this lake will help address what appears to be a carp nursery in the sub-watershed.

Seasonal distribution and movement patterns of adult carp

By mid-September, researchers started to implant radio tags in carp throughout the system. Due to the complexity of the system, especially around the Mud and Parley Lake area, as well as the significantly high adult carp population in Halsteds Bay, they wanted to implant more tags in these lakes. The larger number of tags in this area will help us better understand the movement patterns of carp between these lakes and the surrounding wetlands, as well as where the carp in Halsteds Bay go (they may utilize the Six-Mile Creek lakes or some may go into other bays of Lake Minnetonka). Due to the increase number of tags in this area, the MCWD agreed to purchase an additional 20 tags for a cost of $3,460 to allow a more representative number of carp in all major lakes in the sub-watershed to be radio-tagged. Tracking these radio-tagged carp will be ongoing throughout the fall and winter, and will provide valuable movement data of carp in the system and may lead to new areas that need to be examined, as well as provide possible key areas where removal can be focused in future years.

Historical patterns of carp recruitment via ageing analysis

The approved scope of work allows two ageing studies to be done in two of the proposed carp management units. In 2014, that study will be completed on carp from Parley, Mud and Halsteds. This work will be done over the winter months. In 2015, the ageing study will likely be completed on carp from Piersons, Wassermann and Marsh Lake.

Progress & Concerns

Overall, things are on track and there have been no major issues. There are still some small ponds that the researchers would like to access, but access has been difficult due to low water levels or no accessible areas for a boat. Higher water in the spring may allow for access to some of these waterbodies, so further attempts will be made in the spring of 2015.

MEMORANDUM

To: MCWD Board of Managers

From: Tiffany Schaufler

CC: James Wisker

Date: November 6, 2014

Re: Minnehaha Creek base flow and Gray Bay Dam operations

Purpose:

- To provide a status report on base flow in Minnehaha Creek and a comprehensive review of the operation of the Grays Bay Dam as requested at the October 23, 2014 Board Meeting.

Background:

October 22, 2009 Board Meeting: Mike Panzer presented a review of the history and operation of the Gray's Bay dam. No direction from the Board was given to staff to pursue amending the Gray's Bay operating plan.

- May 20, 2010, Staff drafted a memorandum to the Board of Managers titled Operation of the Grays Bay Dam for discussion related to opportunities to extend baseflow by discharging below elevations 928.6', current dam closure elevation.

- During the course of these and other discussions, the District Engineer has rendered the opinion that revisions to the operation procedures are projected to provide minimal additional benefit when measured against the extremely lengthy and expensive public process required.

Recent Board Action/Discussion:

- January 9 2014 Board Workshop: Dr. John Nieber from the University of Minnesota presented the Baseflow Restoration Study in Minnehaha Creek.
    - Discussion included how local surficial groundwater recharge in gaining reaches, such as those within the urban corridor, may complement potential changes in the operating procedure for Grays Bay Dam,

Current Status:

- The Board has not given any specific direction to staff or requested to discuss dam operations at a committee meeting. The District Engineer

Attachments:

- June 5, 2013 email from Jack Gleason at the DNR on dam operations. Forwarded to Managers Olson, White and Calkins on June 5, 2013.
- Baseflow Final Report

If there are questions in advance of the meeting, please contact Tiffany Schaufler at 952-471-4513 or Tschaufler@minnehahacreek.org

From: Gleason, John (DNR) [mailto:john.gleason@state.mn.us]
Sent: Wednesday, June 05, 2013 9:12 AM
To: Eric Evenson
Cc: Tiffany Forner; Jennie Skancke (DNR)
Subject: RE: Dam Operations

Eric,

As you are aware, the dam is operated under a plan developed by the District and authorized by the DNR; any change to the operating plan proposed by the District would have to be approved by the DNR. We appreciate the effort the District takes to operate the dam so diligently and professionally. From our perspective, we would consider the existing plan to be complex but appropriately so given the competing and conflicting goals of various stakeholders. We feel the current operating plan adequately balances well these competing goals. The risk in changing the operating plan to favor the goals of a limited set of stakeholders would require that other valid goals be abandoned or compromised.

In the 5+ years that I have been in this position, I receive annually requests from citizens to alter the flow of water out of Lake Minnetonka. These requests are made to a meet a single, private, individual goal without consideration to the other goals of the operating plan. For example, I get calls every summer from residents along Minnehaha Creek and kayakers who would like more flow in the creek i.e. a lower operating level for Gray's Bay Dam. The same day I'll get a call from a resident on Lake Minnetonka who wants the dam raised so lake levels stay higher. I advise these citizens of the other goals of the operating plan and often that is enough information for them to understand why their request cannot be accommodated. For the more persistent citizens, I site Minnesota Rules 6115.0220 regarding Water Level Control structures. Subpart 1C (Goals) states the artificial manipulation of water levels should be limited and is only allowed when "the balance of affected public interests clearly warrants the establishment of appropriate controls and <u>it is not proposed solely to satisfy private interests</u>" (emphasis mine).

The operating plan for Gray's Bay Dam clearly balances the affected public interest on Lake Minnetonka as well as Minnehaha Creek for such purposes such as flood control, limiting shoreline erosion, and supporting aquatic life and public recreation. Any potential change to the operating plan would have to demonstrate how all the competing public interests are enhanced over the current operating plan. The DNR would oppose – and not approve – any change to the operating plan that was being proposed to satisfy private interests.

The DNR's mandatory option for lake residents like REDACTED is to extend the dock out further, as long as a extending it will not be a public safety hazard. That is the lowest impact solution and the easiest and least expensive to implement when compared to dredging.

Thanks again to you, Tiffany, and the other staff at MCWD for your great work in operating the dam and your constant efforts and many programs to protect, preserve, and restore our natural resources.

Please let me know if you have any questions,

Jack

John (Jack) Gleason | Area Hydrologist - West Metro | MnDNR | 1200 Warner Road | St. Paul, MN 55106 | T: 651-259-5754 |
John.Gleason@state.mn.us

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MINNEHAHA CREEK WATERSHED DISTRICT
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Minnehaha Creek Baseflow and Stormwater Infiltration: Interim Report II

MWMO Watershed Bulletin: 2008-1

Prepared for the MWMO by:
University of Minnesota

Minnehaha Creek Baseflow and Stormwater Infiltration: Interim Report II

Prepared for the MWMO by:

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Acknowledgements

Yvette Christianson, Tiffany Forner, James Wisker and Michael Hayman
Minnehaha Creek Watershed District (MCWD)

Udai Singh, Mississippi Watershed Management Organization (MWMO)

Laina Breidenbach, Tom Detrich, Michael Kramer, Ugonna Ojiaki, Jess DeGennero & Lauren Sampedro (University of Minnesota students)

Perry Jones (USGS)

■ ■ ■

Front Cover:

(Left Photo) Upstream view from below Minnehaha Falls within Minnehaha Falls Park. Minneapolis, MN. *Photograph by T. Moore of the University of Minnesota.*

(Right Photo) University of Minnesota undergraduate student Laina Breidenbach collecting a piezometer measurement at the Blake Cold Storage Site. Hopkins, MN. *Photograph by T. Moore of the University of Minnesota.*

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University of Minnesota. 2013. *Minnehaha Creek Baseflow and Stormwater Infiltration: Interim Report II*. MWMO Watershed Bulletin 2008-1. 51p

Minnehaha Creek Baseflow and Stormwater Infiltration: Interim Report II

MWMO Watershed Bulletin: 2008-1

Prepared for the MWMO by:
University of Minnesota

Abstract

Minnehaha Creek ranks among the Twin Cities' most valued natural resources. However, frequent drought periods – which have left the creek and its falls dry in 9 of the last 14 years – impair both the ecological and cultural value of the creek. Rapid fluctuations in stream flow due to stormwater runoff exacerbate flow-related impairments in Minnehaha Creek. Given interest in both improving flow conditions in the creek and managing stormwater runoff, we have posed the following question: Can stormwater runoff be infiltrated and stored in the shallow aquifer to contribute to stream baseflow in Minnehaha Creek? To answer this question, we adopted a "weight of evidence" approach in which current groundwater contributions to Minnehaha Creek were quantified and gaining and losing reaches of the stream were identified. On an annual basis, baseflows provide about 1.5 inches, or 33%, to the total stream flow in Minnehaha Creek. Using isotopic separation techniques, we determined that only 5 to 15% of this baseflow is comprised of groundwater; lakes and other surface water sources make up the remainder. Groundwater-surface water interactions at specific points within the stream were quantified through corroboration of seepage meter, temperature profile, and piezometer measurements. In general, groundwater fluxes were upward upstream of Browndale Dam (0.1 to 1.9 cm/d), but downward downstream of Browndale Dam (0 to 0.4 cm/d). When extrapolated to the reach scale, we obtained an estimate of net groundwater discharge on the order of 0.3 in/yr, which is in close agreement with isotope-based approximations (0.2 in/yr). Underlying hydrologic conditions likely play a key role in controlling the quantity of groundwater available for discharge to Minnehaha Creek. Of the average annual 6.7 inches of recharge to the surficial aquifer, about 6.5 inches is "lost" via deep seepage to underlying bedrock aquifers. While these conditions limit baseflow benefits from infiltration practices distributed throughout the watershed, we have identified locations along the creek where underlying geology could support baseflow discharge through focused stormwater recharge to the creek's riparian aquifer. These areas are coincident with continuous extents of the Platteville formation, a limestone and

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shale complex believed to act as an aquitard to prevent vertical losses to underlying bedrock aquifers. Such conditions exist upstream of Browndale Dam. Opportunities for stormwater infiltration-baseflow augmentation could be created downstream as well, but would likely require more engineered approaches such as impermeable liners to prevent vertical seepage losses.

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Minnehaha Creek Baseflow and Stormwater Infiltration: Interim Report II

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Executive Summary

Flowing nearly 22 miles from its origin at Grays Bay to its confluence with the Mississippi River; Minnehaha Creek ranks among the Twin Cities' most valued natural resources. The storied Minnehaha Falls are perhaps the creek's most popular feature and attract over a half million visitors each year. Frequent drought periods – which have left the creek and its falls dry in 9 of the last 14 years – impair both the ecological and cultural value of the creek. Rapid fluctuations in streamflow due to stormwater runoff exacerbate flow-related impairments in Minnehaha Creek.

Given interest in both improving flow conditions in the creek and managing stormwater runoff, we have posed the following question: Can stormwater runoff be infiltrated and stored in the shallow aquifer to contribute to stream baseflow in Minnehaha Creek? To answer this question, we must first understand the following:

- What is the existing contribution of groundwater relative to other sources of flow in Minnehaha Creek across a spectrum of flow conditions?
- What is the existing status of groundwater-surface water interactions in Minnehaha Creek? How do groundwater contributions vary spatially along the creek? Can we identify specific locations suitable for artificial recharge (and subsequent stream discharge) through focused stormwater infiltration?
- What are the underlying factors that drive observed groundwater-surface water interactions in the Minnehaha Creek system (e.g., geology, altered hydrology and groundwater residence time, etc.)?

We have combined analyses of existing hydrologic and geologic datasets with new isotopic data (oxygen-18 and hydrogen-2 isotopes) collected from the Minnehaha Creek system to understand baseflow sources and their relative contribution to flow in Minnehaha Creek at the watershed-scale. General conclusions from this watershed-scale perspective include:

- Surface waters (e.g., lakes, wetlands) are the predominant source of flow in Minnehaha Creek, particularly during low flow periods. In late August 2012, less than 10% of flow in the creek (< 1 cfs) was attributed to groundwater based upon the isotopic composition of water in the creek.
- Watershed-wide groundwater fluxes are influenced by strong downward gradients. As reported by Tipping (2011), median travel time through the surficial aquifer to the underlying bedrock aquifer is on the order of one-half year. This means that water infiltrated far from the creek riparian zone is "lost" to deep bedrock recharge rather than discharging to the creek as baseflow.
- Streamflow recession analysis by the method of Brutsaert and Nieber (1977) about 5% of the watershed is underlain by stream-feeding aquifers. This result corroborates with geologic data indicating rapid vertical travel throughout the surficial aquifer, with the result that very little groundwater is available during drought periods (as demonstrated by isotopic data).

Despite the lack of wide-scale groundwater inputs to the creek, opportunities may exist to augment groundwater-fed stream discharge at locations where upward groundwater fluxes are supported by local hydrogeologic conditions. Such opportunities were investigated through site-specific measurements of groundwater fluxes within the creek (by seepage meters and streambed temperature profiles) and its riparian area (through monitoring of groundwater piezometric head relative to the stream) to identify locations along the creek conducive the groundwater discharge. Findings of site-specific investigations include:

- Groundwater fluxes were generally upward between the creek's headwater wetlands and Browndale Dam. Flux magnitudes ranged from 0.1 to 1.9 cm d^{-1} as determined with seepage meters and temperature profile measurements. Between Browndale Dam and Hiawatha Avenue, groundwater fluxes were generally in the downward direction, and ranged from 0 to 0.4 cm d^{-1}.
- Considering evidence from seepage measurements, groundwater fluxes inferred through streambed temperature profiles, piezometric head measurements, and characterization of subsurface conditions, groundwater discharge could be augmented through focused stormwater infiltration at sites such as:
  - The wetland complex between Minnetonka Blvd and Highway 169 in Minnetonka
  - The Cold Storage site in Hopkins
  - Utley Park in Edina

Based on these analyses, the overall weight of evidence suggests ***groundwater contributions to the creek are limited under existing conditions***, likely due to rapid transit through the shallow quaternary aquifer to underlying bedrock aquifers. ***However, there are locations along the creek at which infiltrated stormwater could be translated to stream baseflow***. These are locations at which local subsurface conditions support upward discharging groundwater. It is apparent that infiltration measures will need to be located at strategic sites where the shallow aquifer system is found to discharge to the creek.

Through the completion of Results 1 (geologic and hydrologic characterization) and 2 (field data collection and interpretation), we have identified several areas of future research need that will help to identify actions that can be taken to increase baseflow in Minnehaha Creek. These include development of a GIS-based decision support tool for evaluating the potential of a site to contribute to stream baseflows through stormwater infiltration, characterization of groundwater flow along subsurface pathways coincident with storm drains and municipal sewer lines, and monitoring of pilot projects designed to enhance groundwater contributions to Minnehaha Creek.

1. Introduction and Scope

This report is a follow-up to "Minnehaha Creek Baseflow & Stormwater Infiltration Interim Project Report 1," in which Result 1 (characterization of watershed hydrology and geology) and work completed to date toward Result 2 (field assessments of groundwater contributions to stream baseflow) were reported. Work completed since Report 1 is reported herein, including:

- Evaluation of baseflow sources through isotope collection and analysis
- Quantification of site-level groundwater discharge (or surface water loss) through temperature profile and seepage meter measurements
- Site-level soil/aquifer characterization and aquifer storage dynamics
- Synthesis of existing hydrogeologic data to support interpretation of field data

Our objective in collecting these data is to better understand the dominant hydrologic processes in the watershed with particular emphasis on interactions between Minnehaha Creek and its riparian aquifer. Through the synthesis of these data, we intend to inform stormwater management strategies for baseflow optimization in the Minnehaha Creek watershed.

This is among one of the first studies to frame surface-groundwater interactions in the context of stormwater management and utilization of stormwater infiltration as a means of improving baseflow conditions. A few modeling studies have been conducted to assess potential effects of stormwater infiltration through low impact development (LID) scenarios on groundwater recharge (Shuster et al., 2007) and stream baseflow (Zimmer et al., 2007). With respect to such modeling activities, Hamel and Fletcher (2013) demonstrated that prediction of baseflow during drought periods improved as with greater complexity in the model's representation of subsurface storage reservoirs. To the best collective knowledge of the authors, field examinations of the impact of LID and stormwater infiltration on stream baseflow have not been attempted. Hamel et al., (2012) suggest that the lack of studies dealing with linkages between stormwater infiltration and stream baseflow may stem from the complexity of groundwater-surface water interactions. This complexity arises from the heterogeneous nature of aquifer systems and development of preferential pathways along which groundwater flows. As reviewed by Vogt et al. (2010), within channel groundwater-surface water exchanges are known to vary in space (for example, due to heterogeneity of streambed materials and their associated hydraulic conductivity) and time (for example, with temporal increases and decreases in streamflow). Groundwater-surface water interactions also vary as a function of the hydrogeologic context of a particular subcatchment, necessitating a case-by-case assessment for ascertaining the potential to impact stream baseflow through stormwater infiltration. This work provides an important step toward a field evaluation of baseflow impacts affected through focused stormwater infiltration.

The organization of this report follows the line of questions investigated in determining the potential to augment baseflows in Minnehaha Creek through stormwater infiltration. These questions included:

- What is the existing contribution of groundwater relative to other sources of flow in Minnehaha Creek across a spectrum of flow conditions?
- What is the existing status of groundwater-surface water interactions in Minnehaha Creek?
- How do groundwater contributions vary spatially along the creek? Can we identify specific locations suitable for artificial recharge (and subsequent stream discharge) through focused stormwater infiltration?
- What are the underlying factors that drive observed groundwater-surface water interactions in the Minnehaha Creek system (e.g., geology, altered hydrology and groundwater residence time, etc.)?

We begin with observations at the watershed scale to lay a framework in which overall source contributions to Minnehaha Creek are identified and quantified. We then focus in on groundwater-surface water interactions at specific locations within the stream channel. We return to the watershed scale to examine hydrogeologic and other factors that may control observed groundwater-surface water dynamics in Minnehaha Creek. Finally, opportunities for baseflow augmentation through focused stormwater infiltration and recharge are discussed within the context of field observations and hydrogeologic controls.

2. Minnehaha Creek Hydrology: Characterizing Flow and Flow Sources

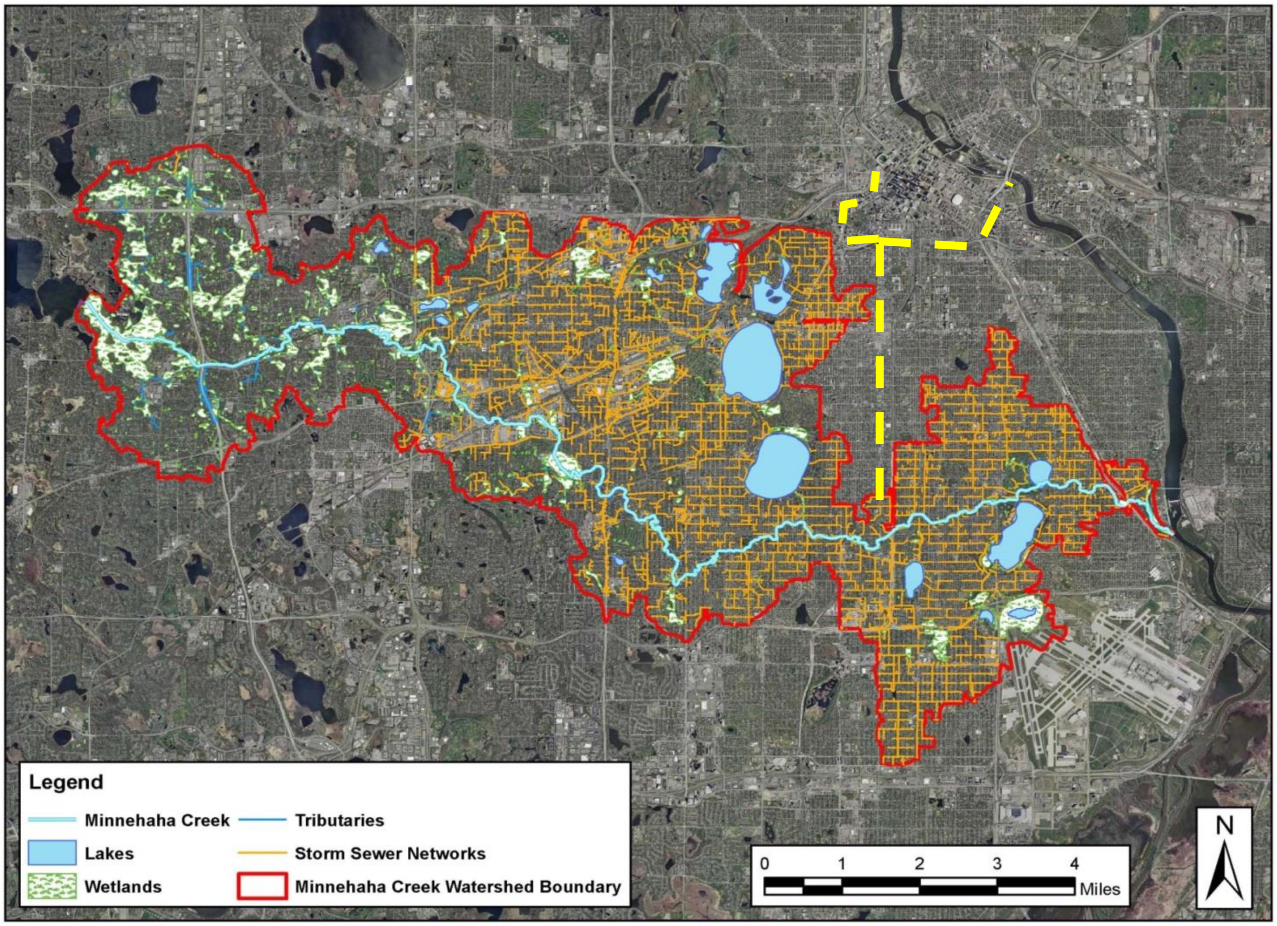


Figure 1. Potential sources and sinks of flow to Minnehaha Creek. Interstate 35W stormwater drainage system indicated by yellow dashed lines. Aerial photograph from MnGeo 2012 and all other data provided by MCWD. Map created by Ryan Birkemeier.

An understanding of the contributions of various flow sources, particularly groundwater, in Minnehaha Creek is foundational to assessing the potential to augment those flows through stormwater infiltration. The Minnehaha Creek Watershed can be conceptualized as a network of sources and sinks of stream flow in Minnehaha Creek (Figure 1). We have used a number of complimentary approaches to quantify the magnitude of these fluxes, including:

- a flow balance approach using available hydrologic data
- analysis of the isotopic composition of the creek and its sources
- field measurements of groundwater fluxes within the streambed

Consideration of each of these data sets, which represent different spatial and temporal scales, improves our interpretation of hydrologic dynamics of the Minnehaha Creek system. Each of these data sets is presented in the following sections, along with conclusions based on these multiple lines of evidence.

2.1 Flow Balance

The U.S. Geologic Survey has maintained a gauging station on Minnehaha Creek at Hiawatha Avenue, approximately one mile upstream of the creek's confluence with the Mississippi River, since 2006. These data were used to calculate the average annual flow in Minnehaha Creek. Contributions from Grays Bay were estimated over the same period of record (2006-2012).

Estimations for contributions from Grays Bay were based on a flow error analysis completed using stage differences and specific D_{calc} (i.e. height of dam opening) values provided by MCWD. Specific stage differences (i.e. hydraulic head differences) were based on the difference between the water level elevation within Grays Bay and the downstream wetland at the dam outlet. Gauges at both of these locations provided a water elevation value every 15 minutes, with the exception of the years 2006 and 2007. D_{calc} values provided by MCWD were based on use of a specific discharge equation for the dam. A discharge value (based on a required discharge level or that required to maintain 'natural' flow conditions within Minnehaha Creek) was entered into the equation, in addition to several specific dam characteristics and a stage difference value, to obtain a D_{calc} value. The stage difference value and values of specific dam characteristics were based on the conditions when altering the height of the dam opening (i.e. calculation of D_{actual} for dam opening changes using D_{calc} value). The dam opening height is generally altered several times throughout the spring, summer, and fall to maintain required and or 'natural' discharge values. Provided D_{calc} values and stage differences values were then re-entered into the dam discharge equation used by MCWD to calculate discharge values relative to discharge values provided by MCWD. In general, discharge values matched the discharge values provided by MCWD at the time of dam opening height changes. This finding makes sense because in both cases all values used in the discharge equation were the same. However, after dam opening height alterations and between successive dam opening height alterations, the actual discharge out of the dam varied considerably relative to the values provided by MCWD. This finding is not completely unexpected due to natural variances observed in flow from changing environmental conditions (temperature, precipitation, etc.). In addition, MCWD actively manages the dam opening to prevent large variances in flow level. However, this finding is critical for determination of contributing flow from Gray's Bay because small errors in flow level can have large effects on calculations of groundwater contributions to Minnehaha Creek. As a result of this, the flow error analysis was critical in determining the best possible estimates for groundwater contributions within the flow balance. Results for the flow error analysis and all provided MCWD dam discharge equation information is provided in Appendix I.

Runoff contributions from the lower watershed were estimated by applying a baseflow filter (Nathan and MacMahon, 1990) to the Hiawatha Avenue stream flow record (after subtracting flow from Grays Bay) to separate the stormflow component of the hydrograph. The resulting average annual contribution from each of these sources is presented in Table 1. The volume remaining after Grays Bay and runoff volumes are subtracted from the total flow measured at Hiawatha Avenue is assumed to represent baseflow. The resulting volume (1.7×10^8 ft^3, or 1,500 MG) is equivalent to approximately 1.5 inches of discharge over the lower watershed, and may be comprised of flow from wetlands, other lakes, and groundwater. Flow data is not available for these sources; however, the relative contribution of these sources may be estimated through the isotopic analysis described in the next section.

Table 1. Average annual flow contributions of Lake Minnetonka via Grays Bay, stormwater runoff, and other baseflows to average annual stream flow in Minnehaha Creek for the period 2006-2012

Flow Source	Annual Volume (ft^3)	Annual Contribution (%)	Runoff Depth (inches)
Grays Bay	8.8E+08	69%	3.09*
Storm flow	2.4E+08	18%	2.06
Baseflow	1.7E+08	13%	1.46
Total flow, Minnehaha Creek	**1.3E+09**	**100%**	**---**

*Grays Bay depth calculated over upper Minnehaha Creek watershed area (123 mi^2); storm and baseflow calculated over lower Minnehaha Creek watershed area (47 mi^2).

2.2 Separation of Baseflow into Source Components based on Isotopic Evidence

The use of isotopes to separate a mixture (in this case, Minnehaha Creek) into its source components (for example, water from Lake Minnetonka, the Chain of Lakes, wetlands, stormwater runoff, and groundwater) is based on the premise that each of these sources has a unique isotopic composition. In water, unique oxygen and hydrogen isotopic compositions may arise through fractionation processes. In natural waters, evaporation is the primary fractionation process through which heavier isotopes are concentrated in waters with higher rates of fractionation (such as surface water) relative to waters in which fractionation processes are not as dominant (such as groundwater). For this study, samples were collected from potential sources of flow to Minnehaha Creek – including Lake Minnetonka, Lake Harriet, stormwater runoff, summer rainfall, snowmelt, and riparian groundwater – and analyzed to determine the concentration of oxygen-18 (O^{18}) and hydrogen-2 (H^2) relative to the lighter, and more prevalent, oxygen-16 and hydrogen-1 isotopes. Sampling sites were also selected along the length of the creek to represent the mixture of these source waters (Figure 2). Samples were collected during high and low flow periods to capture variation in flow sources across a spectrum of flow conditions (Figure 3). Figure 4 presents isotopic signatures of samples collected from Minnehaha Creek and its potential flow sources during a runoff-dominated period (May 28 and June 6, 2012) and a low flow period (Aug. 22, 2012). Samples collected on May 28 followed a series of storms that produced a total of 4 inches of rainfall between May 23 and 28. Samples collected on June 6 represented the falling limb of the hydrograph following these storms during which there was no precipitation. Grays Bay dam was opened shortly after the May 28 sampling event and was discharging 12 cfs on June 6. The dam was closed for the season two days prior to the Aug. 22 sampling event. Additional samples were collected during the 2013 spring melt to characterize the isotopic composition of snowmelt inputs to shallow groundwater and the creek channel. Samples collected during the summer and fall of 2013 are awaiting analysis at the University of Minnesota Biometeorology Lab where equipment malfunction has delayed sample processing.

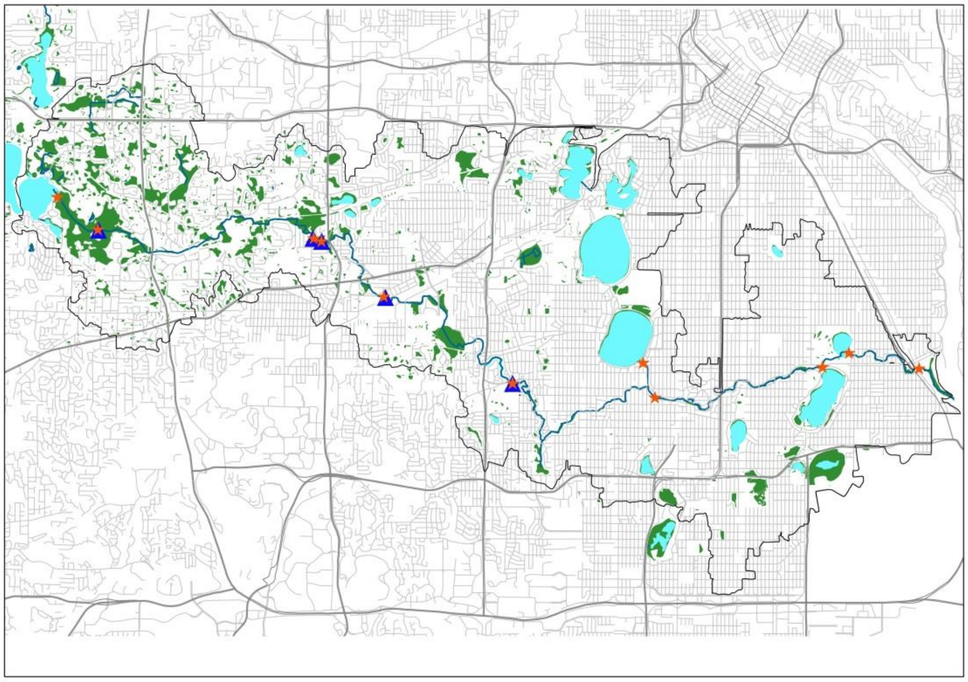


Figure 2. Sample locations for O18 and H2 isotope analysis. Surface water sample sites are marked with a star symbol; groundwater samples were collected from locations marked with triangles. Samples were collected across a range of seasonal flow conditions.

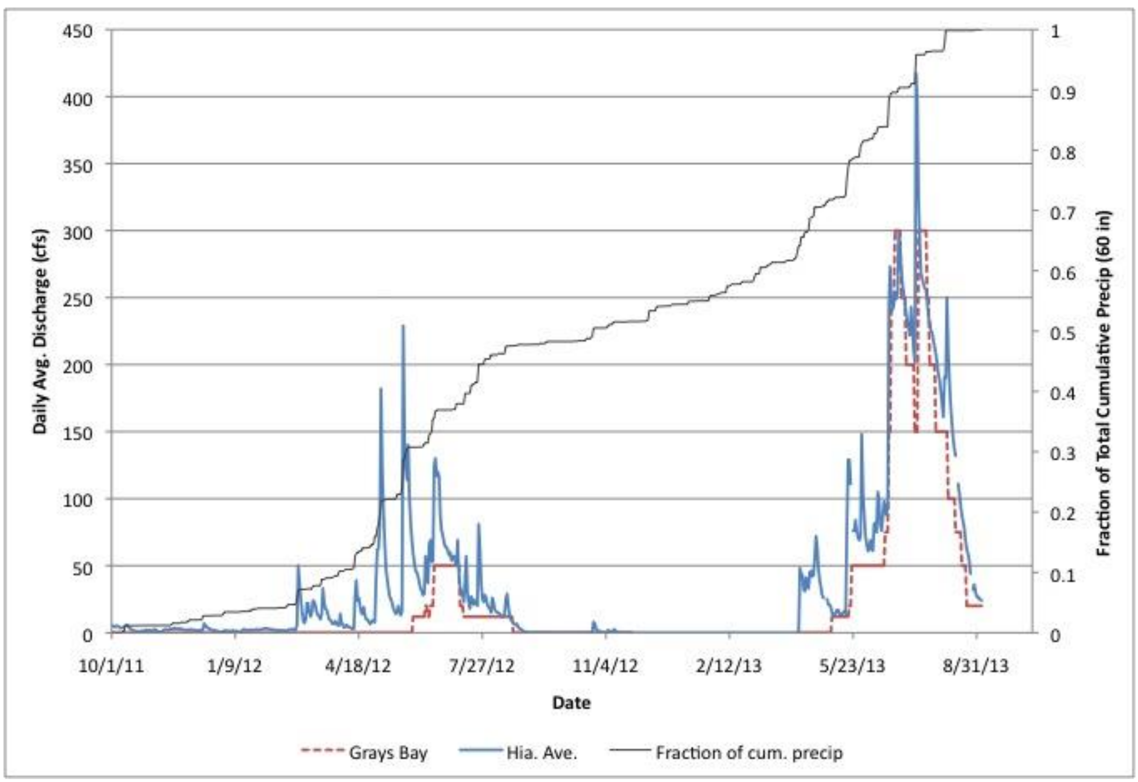


Figure 3. 2012-2013 flow hydrograph of Minnehaha Creek at Hiawatha Ave (solid blue line) with discharge from Lake Minnetonka via Grays Bay (dashed red line). Isotope collection times are highlighted. Samples were collected during high flows following rainfall (May 27 and 28, 2012), snowmelt (March 30, 2013), and interceding drought periods (August 22, 2013; Nov 5, 2013).

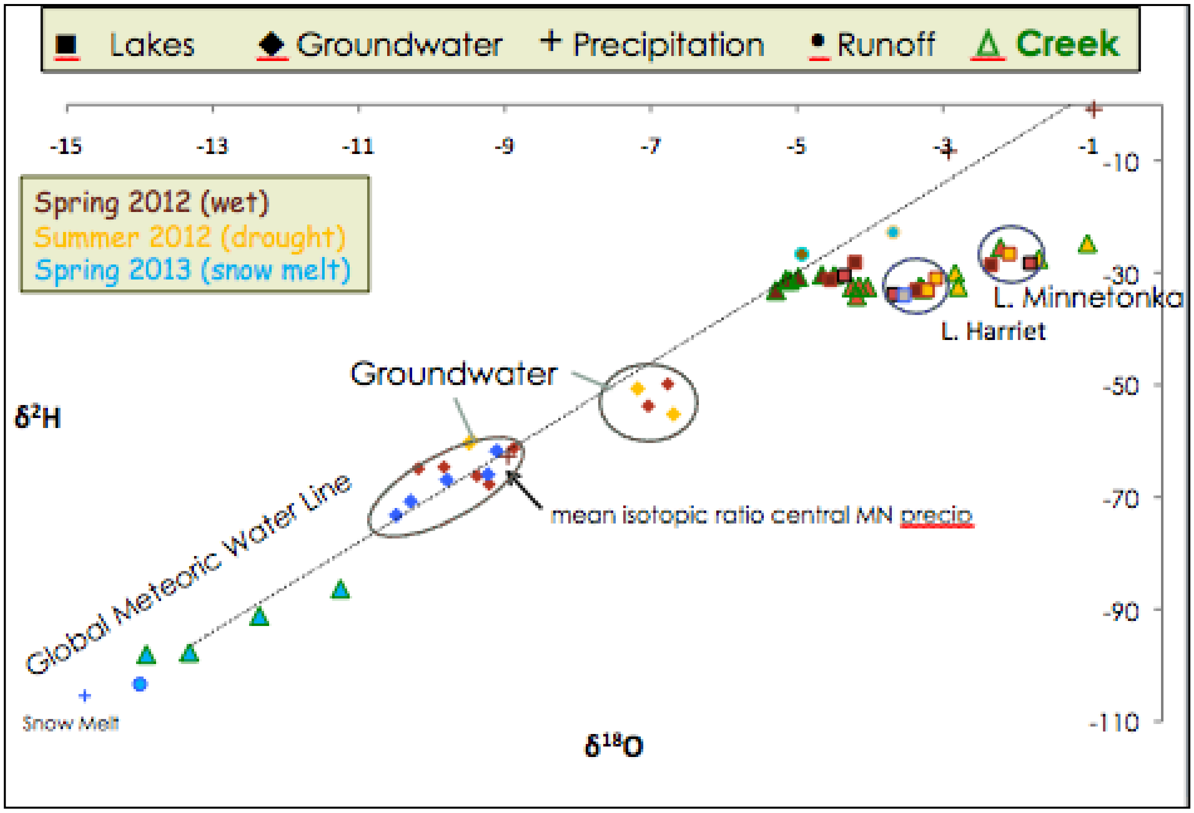


Figure 4. Plot of oxygen-18 ($\delta^{18}O$) and hydrogen-2 (δ^2H) isotope ratios relative to the established standard of mean ocean water. Increasing δ values indicated increasing concentration of heavier isotopes. Symbols designate sample type (rectangles = lake samples; circles = stormwater runoff; astrix = precipitation; diamonds = groundwater; triangles = creek) while color designates sample time (blue = high flow on May 28, 2012; green = June 6, 2012 recession; maroon = Aug 22, 2012 drought; light blue = March 2013 snowmelt). As indicated by the relative position of the points, the creek's isotopic signature aligns more closely to that of its surface water sources (e.g., Lakes Minnetonka and Harriet) than to its adjacent riparian groundwaters, particularly during the transition from high to low flow conditions.

Figure 4 illustrates the clear distinction between surface and groundwater samples on the basis of their ^2H and ^{18}O isotopic compositions. The extent to which water is enriched with ^2H and ^{18}O isotopes is reflected by the δ value, which increases (or becomes less negative) with enrichment of heavier isotopes. Precipitation inputs in the Minnehaha Creek watershed fall along the Global Meteoric Water Line (MWL), the solid line in Figure 2.4 that describes the ratio of ^2H to ^{18}O isotopes in waters that have not undergone excessive fractionation, such as precipitation. As described in other studies (e.g., Harvey and Welker, 2000; Brooks et al., 2012), the relative isotopic composition of precipitation in the Minnehaha Creek watershed is dependent upon temperature, with rainfall originating from the Gulf of Mexico (e.g., May 25, 2012 rainfall sample) typified by larger δ values and winter snow having smaller δ values. The degree to which the isotopic ratio of samples stray from the MWL indicates higher rates of fractionation. For example, Lakes Minnetonka and Harriet, from which lighter isotopes selectively evaporate to results in a relative enrichment of heavier ^2H and ^{18}O isotopes, plot to the right of the MWL. In contrast, groundwater samples collected from the shallow aquifer underlying the riparian area (see Section 3.3 for piezometer locations) cluster near to the MWL, reflecting the meteoric origin of groundwater through recharge of rainfall and snowmelt. The majority of groundwater samples cluster around the mean O^{18} and H^2 ratio of precipitation in SW Minnesota, as reported by Magner et al. (2004). The isotopic composition of a subset of well samples, all taken from piezometers located near the channel (within 25 meters) at the Jidana Park wetland, form a second cluster positioned between meteorically-derived groundwater and surface water samples, indicating water from Minnehaha Creek likely moves into the bank at this site. Monitoring of hydraulic heads in piezometers located at this site also suggest creek-to-groundwater flow occurs (Section 3.3.1).

The isotopic composition of samples collected from the creek is the product of the mixture of the various source waters. Samples collected from the creek on May 28 are strongly influenced by precipitation and stormwater runoff as evidenced by their relative similarity with samples collected from a stormwater retention pond and tendency to cluster along the MWL. The creek's isotopic signature shifts toward a greater abundance of heavier isotopes during the falling limb of the storm hydrograph on June 6 and, even more so, during low flow conditions on August 22. In effect, the creek's isotopic signature becomes more "lake-like" as discharge shifts from high to low flow conditions. The apparent influence of Lake Minnetonka waters are strongest at the Jidana wetland site, located about 1 mile downstream of Grays Bay dam and, during the Aug. 22 low flow period, at the Lahti-Gaynor wetland site, located an additional 4.5 miles downstream. A key observation from these isotopic data is the separation between the isotopic ratios observed in Minnehaha Creek and adjacent riparian groundwaters. This separation suggests that **groundwater contributes very minimally to flow in Minnehaha Creek, even during low flow conditions when the creek is no longer receiving inputs from Lake Minnetonka**.

Although we are still awaiting analysis of our complete 2013 isotope dataset, we can make some preliminary estimates of the relative contribution of lake, precipitation, and groundwater sources in Minnehaha Creek. Each of these sources, also known as end-members, can be quantified through simultaneous solution of two (for two contributing sources) or three (for three contributing sources) equations relating the ^{18}O and/or ^{2}H isotopic ratios with the fraction of flow contributed by each source. Details of the end-member analysis are provided in Appendix II. Results of the isotopic end-member analysis are summarized in Table 2. The percent contribution of groundwater to both total flow and baseflow is reported. The digital filter developed by Nathan and MacMahon (1990) was used to separate stream flow into storm- and baseflow components (Figure 5). As indicated in Figure 5 and Table 2, groundwater comprises a larger portion of stream baseflow (nearly 20%) during wet periods in Spring 2012. During drought of August 2012, the contribution of groundwater to baseflow dwindles to about 5% (Figure 6). Figure 6 contrasts the groundwater component of baseflow during these two periods. If the isotopic "snapshots" collected during wet and dry periods of this study were representative of the rest of the flow record, then of the approximately 1.5 inches per year of baseflow, about 0.2 to 0.25 inches is contributed by groundwater.

Table 2. Results of end-member analysis using ^{18}O and/or ^{2}H isotopic compositions of Minnehaha Creek and its source waters. The percent contribution of flow sources relative to total flow (as measured at Hiawatha Avenue) and to baseflow (as determined by applying the baseflow filter of Nathan and MacMahon (1990) to the total stream flow record) is presented

Sample event	% Total Flow in Minnehaha Creek			% Baseflow in Minnehaha Creek	
	Runoff	Lakes	Groundwater	Lakes	Groundwater
Spring 2012 (wet)	60	34	6	81	19
Spring 2012 (recession period)	--	90	10	84	16
Summer 2012 (drought)	--	>95	<5	95	5
Spring 2013 (snowmelt)	70	30	<1	**	**

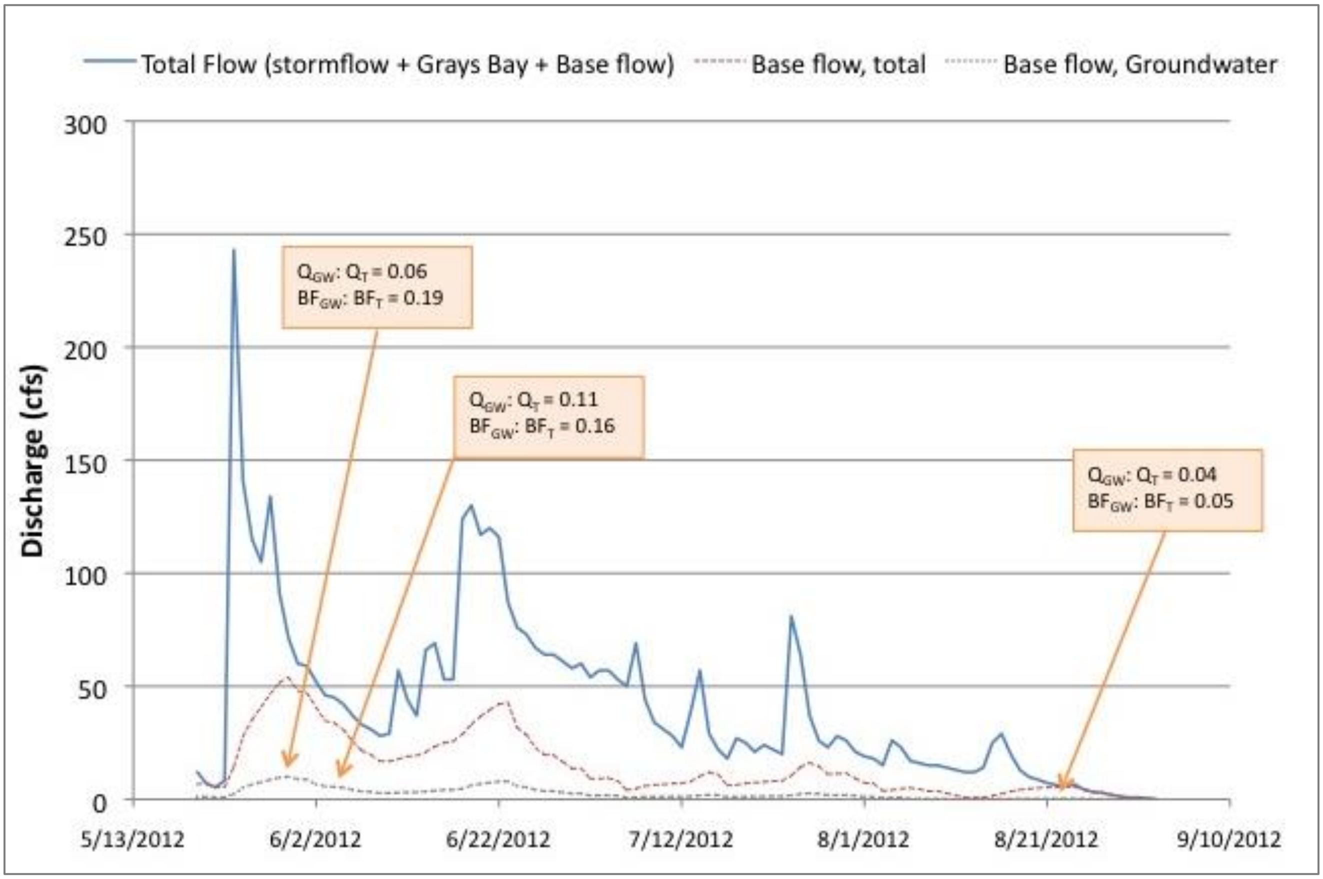


Figure 5. Separation of total flow (solid blue line) into baseflow (dashed red line) and storm flow (area between baseflow and total flow lines) using the baseflow filter of Nathan and MacMahon (1990). Isotopic-based estimates of the groundwater component of total flow (Q_T) and baseflow (BF_T) are highlighted for the May 28 (storm peak), June 6 (recession), and August 22 (drought flow) samples.

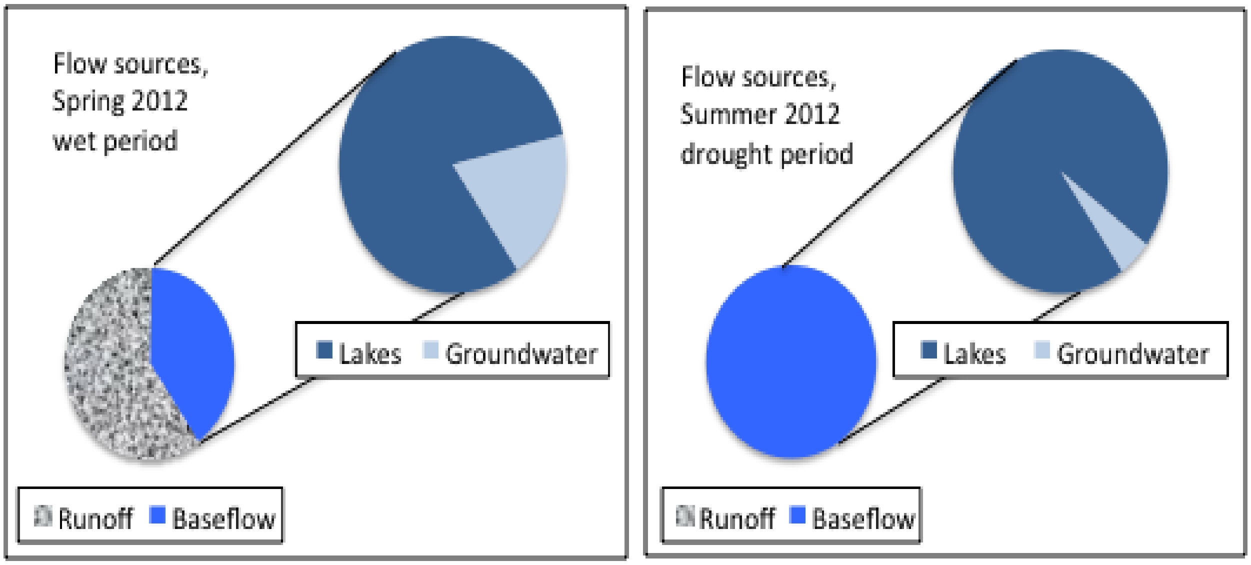


Figure 6. Relative fraction of stream baseflow originating from lakes/surface waters (dark blue sliver) versus groundwater (light blue sliver) during wet conditions (Spring 2012) and drought conditions (Summer 2012).

3. Groundwater-Surface Water Interactions within Minnehaha Creek

The water balance and isotopic analysis provide a high-level view of groundwater contributions to Minnehaha Creek. However, it does not provide a site-level understanding of groundwater-surface water dynamics, which is crucial to assessing the potential for baseflow augmentation via stormwater infiltration. The following sections present results and interpretation of field data collected to quantify interactions between Minnehaha Creek and the shallow aquifer at the site-level. As reviewed by Vogt (2009), groundwater-surface water exchanges are known to vary in both space and time due to variables such as heterogeneity of streambed materials and subsurface flow paths, deposition and subsequent erosion of clogging layers, and spatial and temporal variation in hydraulic gradients. These factors contribute to uncertainty in quantifying groundwater fluxes along the length of a stream. Additional uncertainty arises through the measurements themselves, none of which is without error. In light of these uncertainties, we adopted multiple methods by which to determine groundwater contributions to Minnehaha Creek. These methods include direct measurement of streambed fluxes with seepage meters, indirect estimates obtained through streambed temperature profile measurements, assessment of near-stream hydraulic gradients with shallow piezometers. Measurements were taken at locations along the length of the stream to examine how groundwater-surface water interactions may vary longitudinally (Figure 7). The results of these point measurements are then extrapolated to the reach scale to produce an estimate of total groundwater contributions with to compare to isotope analysis presented in Section 2.

3.1 Seepage Meter Measurements

Seepage meters allow direct measurement of fluxes into (groundwater discharge) or out of (surface water loss) the streambed (Rosenberry and LaBaugh, 2008). We constructed meters out of 1-gallon plastic buckets, 8-inches in diameter each, to which a plastic bag was attached through a series of garden hose fittings (Figure 8). The base of the bucket is inserted into the streambed and the plastic bag attached with a known volume of water.

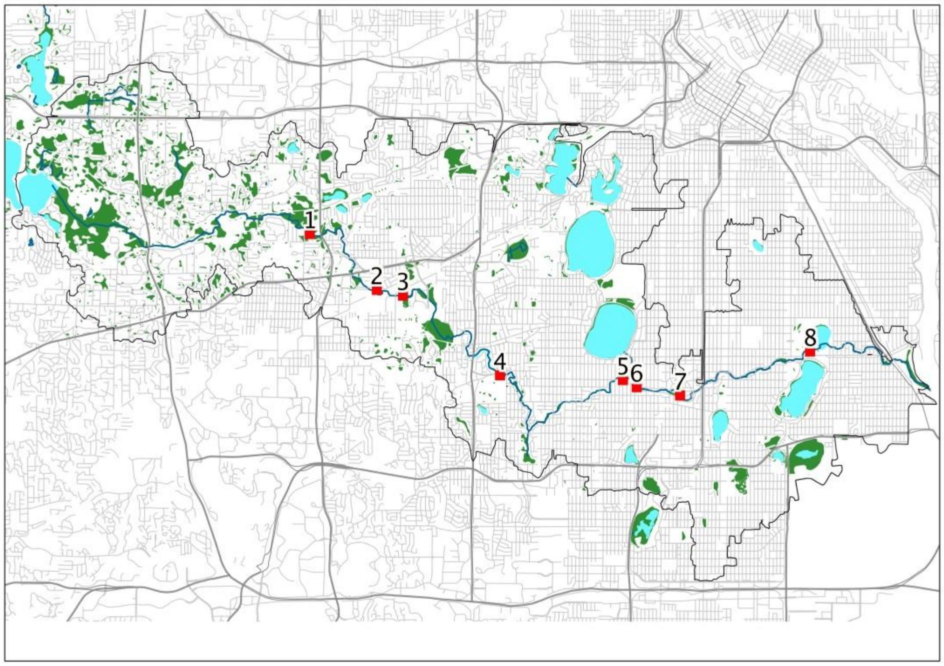
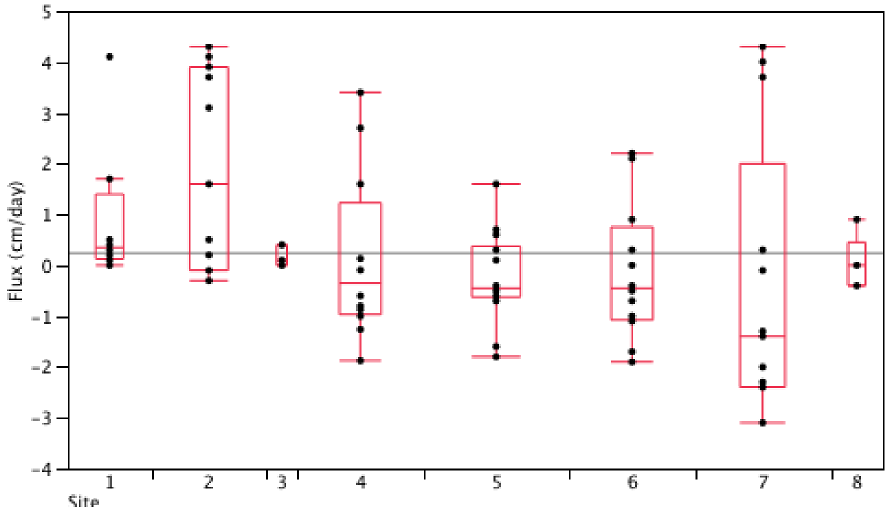


Figure 7. Locations of field measurements on Minnehaha Creek. Triangles mark reaches in which seepage meters measurements were taken, diamonds mark reaches in which streambed temperature profile measurements were made, and circles denote the locations of piezometer networks.

Figure 8. Seepage meters used to measure fluxes into or out of the streambed. (a) Close-up of hose-fittings used to attach the seepage meter to a plastic bag in which the change in volume of water over a set period of time is known. The valve is closed with the bag is removed or attached to avoid losing water. (b) Seepage meter deployed in streambed. (c) Measuring the volume of water in seepage meter bags 24 hours after deployment.



Location	Flux (cm/d)	Direction
1. Lahti Lane	0.5	upward
2. Blake	1.9	upward
3. Reach 20	0.2	upward
4. Utley Park	0.1	upward
5. James	0.3	downward
6. Humboldt	0.2	downward
7. Pleasant	0.1	downward
8. Hiawatha	0	neutral

Figure 9. Box plots of seepage meter measurements at 8 locations along Minnehaha Creek. Sites are presented in order from upstream to downstream; numbers correspond to site names in the right panel table and to numbering in Figure 3.1. The gray horizontal line denotes the average flux rate across all sites (0.2 cm/day upward); average flux rates by site are listed in the table in the right panel. Flux rates less than 0 signify seepage of surface water into the streambed.

Following a 24- to 48-hour period, the seepage meter bags are detached and their volume is measured. The change in bag volume over the known period of time represents the rate of seepage into or out of the area of streambed enclosed by the seepage meter. Seepage meter measurements taken at the Blake Cold Storage site during the fall of 2012 indicated upward groundwater discharge ranging from 0.1 to 6.2 cm d^{-1}, with an average of 2.8 cm d^{-1}. Seepage meter measurements were expanded to 7 other sites in 2013, with 4 to 5 meters deployed at each site (Figure 7).

Seepage meters were developed for lentic environments and high flow velocities can cause inaccuracies (Rosenberry and LaBaugh, 2008). For this reason, seepage meter measurements in Minnehaha Creek were taken when flow in the creek was less than 12 cfs. This requirement limited 2013 measurements to the late fall. Seepage fluxes measured at each site are presented in Figure 9. Negative values result when the volume of water in the seepage bag decreases over time and signify movement of water out of the channel. Positive values indicate rates of upward discharging groundwater. As seen by the spread of data in Figure 9, measured seepage fluxes ranged from positive (groundwater discharge) to negative (groundwater recharge) within single sites. Despite this variability, mean and median seepage rates tend to decrease from upstream to downstream sites. This pattern indicates that (1) the greatest potential for groundwater contributions to stream flow is in the upper half of Minnehaha Creek and (2) lower reaches, particularly below the Chain of Lakes, may actually lose surface water to underlying aquifers.

3.2 Temperature Measurements

Streambed temperature profiles compliment seepage meter measurements as an indirect means of estimating groundwater fluxes. As depicted in Figure 10, the degree of curvature of the temperature profile with increasing depth below the streambed can be used as an indicator of the rate of groundwater discharge or recharge, and thus the method is applicable in both gaining and losing streams (Rosenberry and LaBaugh, 2008; Vogt et al., 2010).

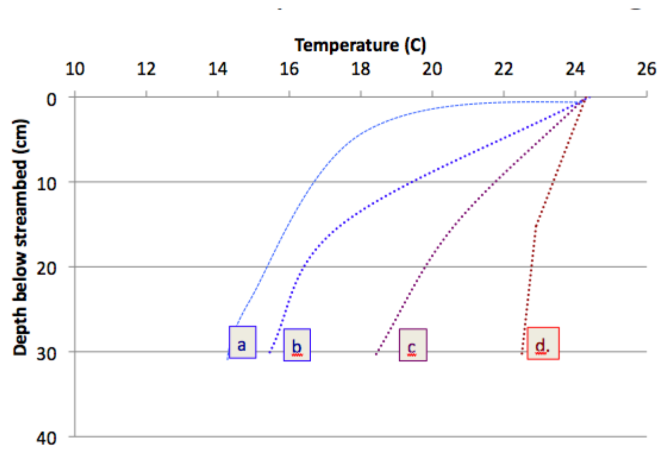


Figure 10. Schematic of temperature versus depth profiles for scenarios in which groundwater is discharged to the stream at a high (a) and medium (b) rates. The linear profile (c) represents a situation in which groundwater is neither discharged nor recharged. The case in which recharge occurs from the surface is represented by (d). *Observed temperature profiles are a result of heat conduction (from the surface) and convection (from groundwater) when flow is from groundwater to the surface.*

Temperature profiles were measured in Minnehaha Creek by two methods: (1) with a temperature probe (Hannah Instruments) manually inserted into the streambed at 15 cm (6 in) intervals at a discrete point in time and (2) as a continuous time series using temperature data loggers (Solinst Level Logger) placed at the surface and at a depth of 30 cm (1 ft) below the streambed. The majority of temperature profiles were measured with the temperature probe due to the ability to obtain measurements from a large number of locations, to better capture the spatial variability in groundwater discharge along the length and width of the stream. However, since groundwater flux models based on continuous data are expected to be more accurate, continuous data were also collected at a single site (site 2 in Figure 7) and paired with temperature probe measurements to compare results. The magnitude and direction of groundwater fluxes were estimated by solving the 1-dimensional heat flux model under the assumption of steady state conditions for point measurements with the temperature probe (Arriaga and Leap, 2006). For the continuous dataset, the equation was solved for transient conditions following the numerical methods presented by Gulliver (2010) and Lapham (1989). A description and sample calculation for both approaches is presented in Appendix III. Unlike seepage meter measurements, our temperature probe method was not limited by high flow conditions so that data could be collected throughout the flow season. Probe measurements were taken at 20 sites, with repeated measurements during the summer of 2012 and 2013. Within each site, 8 to 10 temperature profiles were measured across the width of the channel. The results of temperature profile measurements are summarized in Figure 11. The points in the box plot represent average seepage rates calculated for profiles measured at the right bank, thalweg, and left bank of the channel. A more detailed summary table including sampling dates is included in Appendix 2. Two observations to be made from temperature-based flux approximations are (1) the magnitude and direction of groundwater fluxes can vary substantially within the same site across the width of the channel and (2) despite within site variability, groundwater fluxes tend to decrease or become negative (indicating downward flow of surface water) from upstream to downstream. The majority of sites below Browndale Dam (site 9 through 20 in Figure 11) were characterized by downward groundwater fluxes.

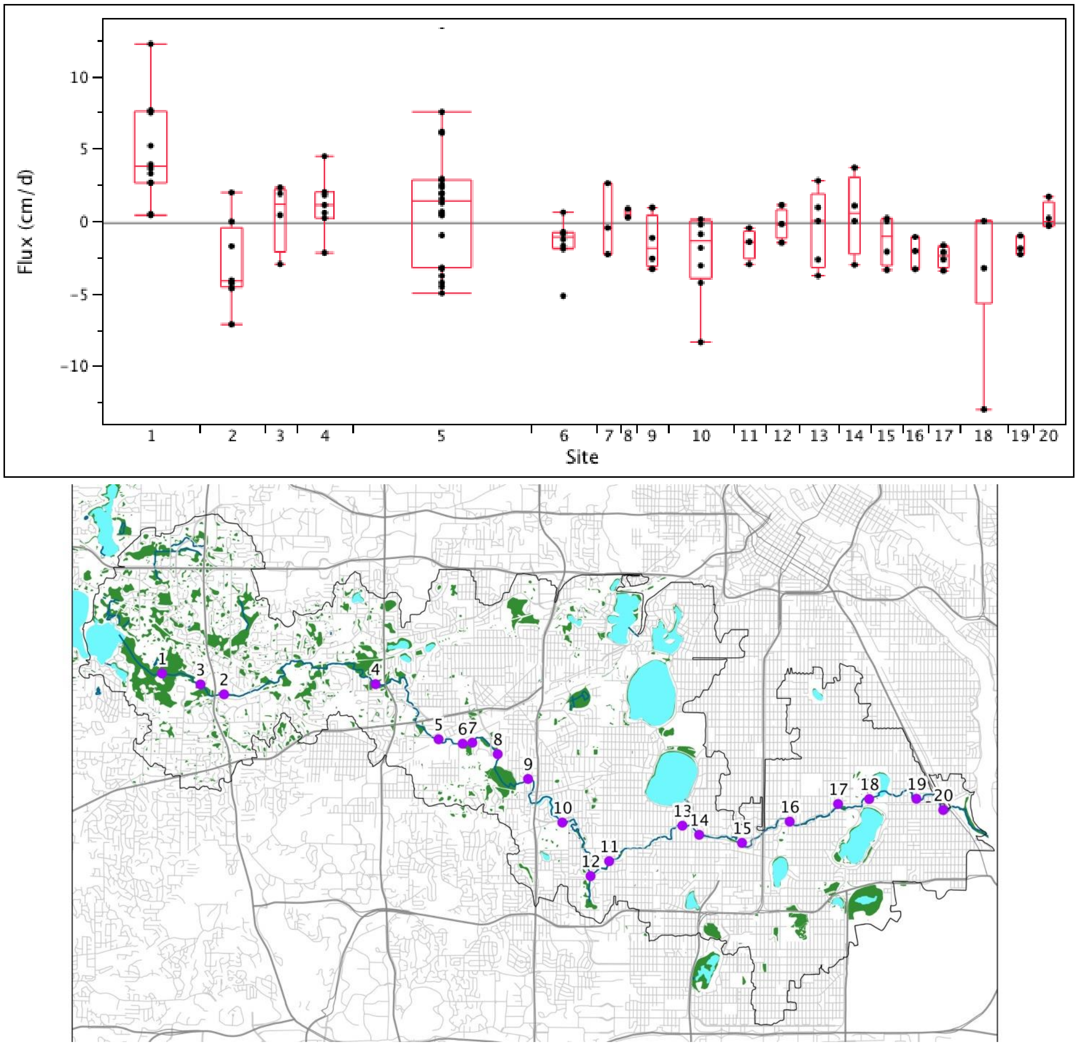


Figure 11. Box plot of groundwater flux as calculated from measured streambed temperature profiles at 20 sites along the length of Minnehaha Creek. Numbered labels in the box plot correspond to numbered locations of temperature probe sites in the map. Within each site, temperature profiles were measured at 8 to 10 locations across the width of the channel 2 or more times during the summer of 2012 and 2013. The gray horizontal line represents the mean of all measurements (-0.1 cm/day). Positive flux values represent upward groundwater movement; negative flux values denote downward groundwater flux.

3.3 Piezometer Measurements

Piezometers were installed to support interpretation of seepage meter and temperature data at four sites of interest, including within the wetland complex in the creek's headwaters (Jidana Park), a wetland five miles downstream (Lahti Lane), at the Cold Storage site in Hopkins, and at Utley Park immediately downstream of Browndale Dam (Figure 12). Details regarding piezometer installations are included in Appendix IV. Piezometric heads that are greater than the surface water elevation in the channel indicate horizontal flow through the aquifer to the stream. Sites at which the groundwater piezometric head is greater than surface water elevations in the creek could support groundwater discharge and, therefore, may be candidate sites for stormwater recharge efforts. Piezometric head measurements at each of the four locations are presented in the following sections. Corroboration with seepage meter and temperature profile data are highlighted, as is the application of these results to interactions between the creek and its riparian aquifer system.

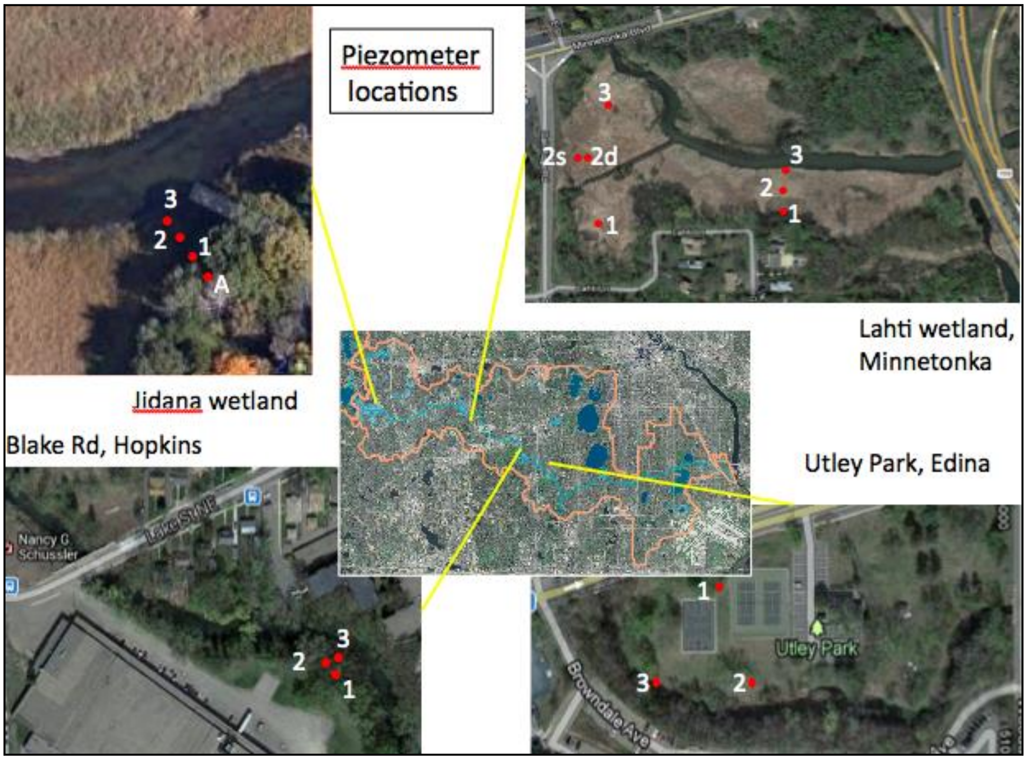


Figure 12. Location of piezometer installations along Minnehaha Creek. Filled circles denote approximate location of piezometers. Numbers correspond to numbering of piezometers in Figures 13 – 16.

3.3.1 Jidana Wetland Site, Minnetonka

The Jidana wetland park is located approximately one mile downstream of Grays Bay. The surficial aquifer at this site lies below approximately two feet of organic/peaty soils. Groundwater head elevations relative to that of surface water were measured on an approximately weekly basis at this site from July 2012 to November 2013 (Figure 13). During this period, both surface and groundwater elevations were highly correlated with Grays Bay discharge. Despite the differences in flow conditions from 2012 (57% below average annual flow) and 2013 (26% above average annual flow), groundwater elevations followed a similar pattern at this site. During periods when Grays Bay discharge was constant or increasing, groundwater elevations tended to be equal to or greater than surface water in the stream channel, indicating the potential for groundwater discharge to the stream. However, during periods when Grays Bay discharge was decreasing or equal to zero, groundwater elevations tended to fall below that of the stream, indicating the potential for recharge from the channel to the riparian aquifer. Streambed temperature profiles taken at this site during June and July of 2012 and 2013, periods during which Grays Bay discharge was *not* receding or equal to zero, indicated upward discharging groundwater in the range of 0.4 to 12 cm/day. Flux measurements taken after Grays Bay was closed in October 2013, however, ranged from 0 to -1 cm/day *downward*. Such movement of water from the creek into the shallow groundwater was also suggested by the isotopic composition of samples collected from the piezometers within 75 ft of the stream channel (Wells 3, 2, and 1 in Figure 13). Isotope mixing analysis indicated a mixture of 70% meteoric waters (i.e., recharge from rainfall and snowmelt) and 30% Lake Minnetonka water (see Appendix II for calculations). These results indicate this site may contribute to losses of water from the channel, at least during drought periods.

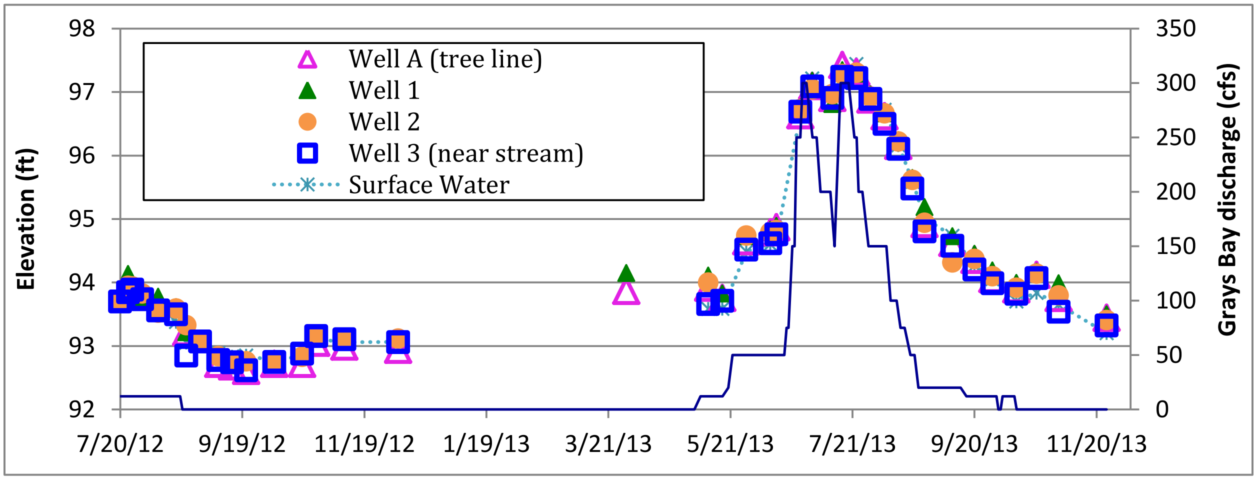


Figure 13. Piezometric head and surface water elevation measurements at the Jidana Park wetland complex located in the creek's headwaters. Groundwater head is highly correlated with Grays Bay discharge, shown on the left y-axis.

3.3.2 Lahti Wetland Site, Minnetonka

The Lahti wetland, named after Lahti Lame to which it is adjacent, lies about 5.5 miles downstream of Grays Bay. A 5-6 ft thick layer of organic/peaty soils overlays the surficial aquifer at this site. The surficial aquifer consists of sand and gravel with occasional cobbles. A confining clay layer was discovered at a depth of about 45 ft below the wetland. Two sets of well were installed at this site. On the downstream (east) side of this wetland, a series of three wells were hand-augered in August 2012. On the upstream (west) end of this site, a series of four wells were installed in June 2013. Two of these wells (Wells 2s and 2d in Figure 14) were installed by a drill rig to depths of 12 ft and 25 ft.

At both the upstream and downstream ends of this site, the piezometric head of the surficial aquifer was greater than the surface water elevation for the duration of the monitoring period. This included periods in which flows from Grays Bay were receding or equal to zero. This result is in accordance with both seepage meter (average value = 0.9 cm/day) and temperature-based (average value = 1.1 cm/day) flux measurements. It is likely that the confining clay layer encountered at 40 ft serves to perch the water table at this location. Based on seepage meter, temperature, and piezometer measurements, we believe this site (or others with a similar confining layer) hold potential for stormwater recharge and baseflow discharge.

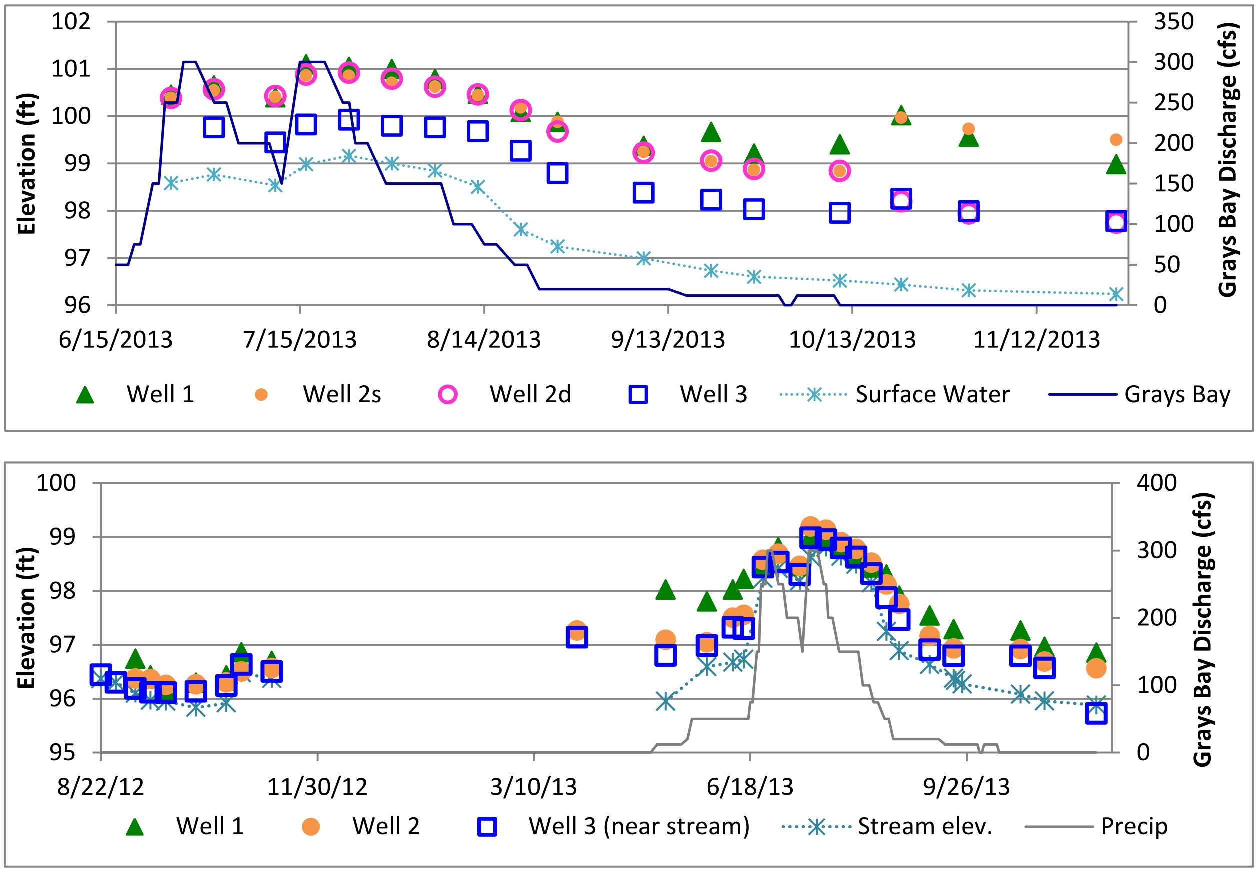


Figure 14. Piezometric head and surface water elevation measurements of the upstream (top panel) and downstream (bottom panel) ends of the Lahti wetland, located along Minnetonka Blvd between Oak Ridge Rd and Highway 169 in Minnetonka. Well 2s and 2d on the upstream end are 12- and 25-ft deep, while the depth of all other wells ranges from 8 to 5 ft.

3.3.3. Blake Cold Storage Site, Hopkins

Piezometers were installed at the Hopkins Cold Storage site, just downstream of the creek's crossing at Blake Road North. Located approximately 7.5 miles downstream of Grays Bay, this site may be utilized by the MCWD to manage stormwater from a relatively large pipeshed. Thus, it was important to install piezometers here to better characterize groundwater dynamics and subsurface materials. The surficial aquifer at this site is overlain by 0.5-2 ft of organic soil within the wooded riparian area. Soil cores were also taken at a higher elevation in the lawn area adjacent to the riparian buffer with a drill rig (Figure 3.9). The surficial aquifer in this area was overlain by 7-12 ft of sandy clay fill material. The aquifer itself was comprised of sandy glacial outwash material with silt interspersed with gravel. Sandy clay is typically found under perched ponds and lakes in Minnesota (Kersten et al. 2003), suggesting the potential for holding stormwater from being lost directly to the bedrock aquifer on the site.

During the 2012 drought period, piezometric head at this site remained greater than surface water elevations in the creek (Figure 3.9). This relationship persisted through the spring and early summer of 2013 but, as flows receded and eventually ceased from Grays Bay, a depression developed between the stream surface elevation and the head of the piezometer nearest the stream (Well 3 in Figure 3.8). This indicates a potential reversal in flow from the channel to the riparian groundwater system.

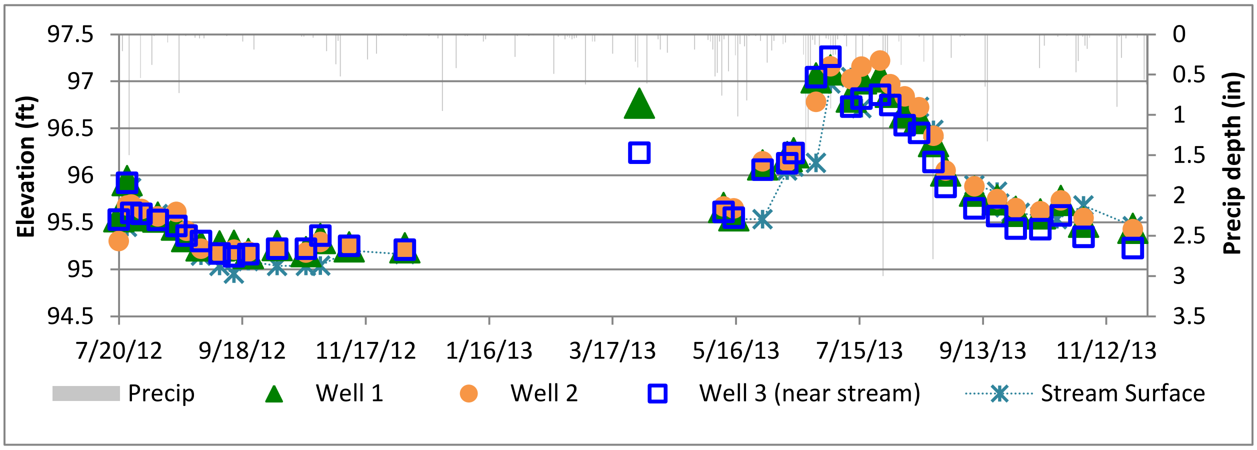


Figure 15. Piezometric head versus precipitation depth at the Blake Cold Storage Site.

Such a relationship is expected during recession periods. The isotopic composition of groundwater within these wells indicated origins through recharge of precipitation rather than surface waters such as Lake Minnetonka, which would suggest that such flow reversals have minimal impact on the overall composition of the groundwater system. Given strong indication of groundwater discharge at points within this reach, this site would likely support discharge of focused stormwater infiltration.

3.3.4 Utley Park Site, Edina

Utley Park is located immediately downstream of the Browndale Dam in Edina, approximately 11.5 stream miles from Lake Minnetonka's outlet at Grays Bay. Like the Blake Road site, Utely Park lies in a strategic location for potentially enhancing stream baseflow in concert with stormwater mangement as it is surrounded by runoff-generating impervious areas and is underlain by the Platteville limestone, a geologic formation which may perch water in the surficial aquifer and prevent vertical losses (see Section 4). As suspected based on observations during site reconnaissance and as revealed by bore holes drilled by Braun Intertech for this study, the surficial aquifer at this site is composed of highly transmissive sands and gravels. It is underlain by a confining layer of clay at a depth of about 50 ft, which could serve to perch the water table and prohibit vertical leakage to underlying aquifers.

Observed piezometric heads within the surficial aquifer remained greater than surface water elevations in the stream, indicating lateral groundwater movement toward the stream during the observation period (Figure 16). While upward discharging groundwater (on the order of 0.1 cm/day) was detected through seepage meter and temperature-based flux calculations at a few points within this reach, the majority of measurement points indicated downward discharging groundwater (on the order of 1 cm/day). Given the geologic conditions underlying this site, it may be possible to promote groundwater discharge to the stream by creating a groundwater mound through focused stormwater infiltration at this site. However, more investigation using fire hydrant source water would be warranted prior to commencing such efforts.

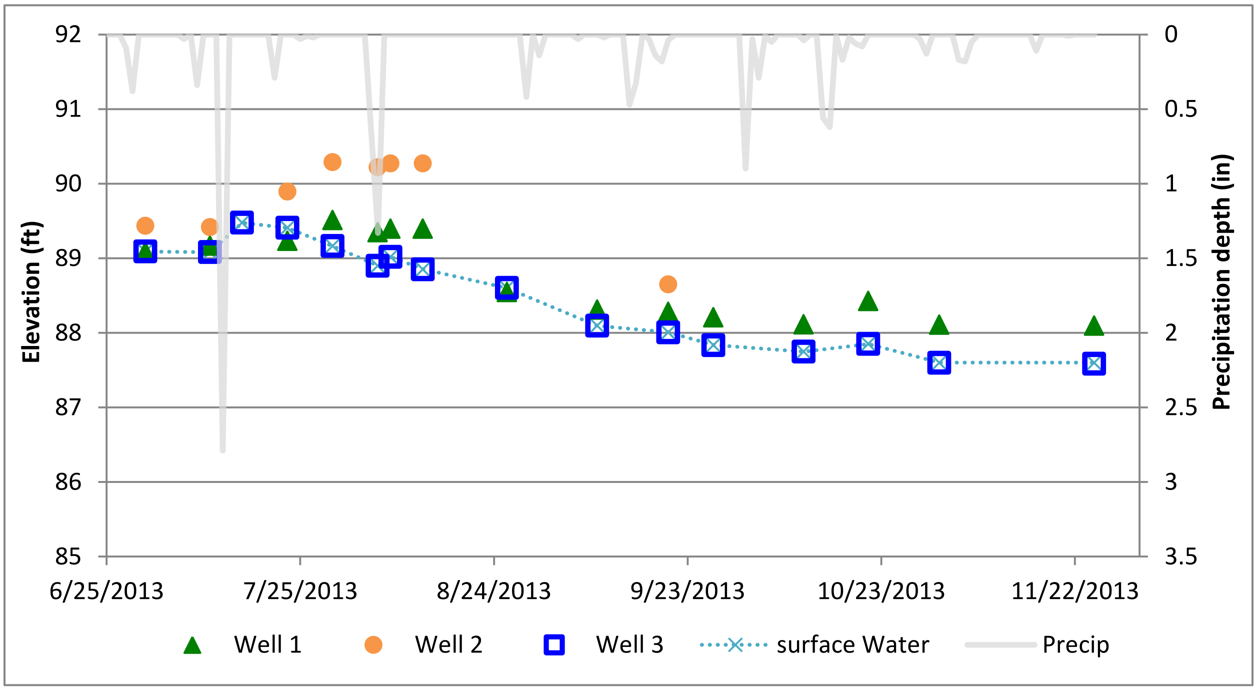


Figure 16. Groundwater piezometric head (Wells 1 and 2) and surface water elevation measurements (Well 3) at Utley Park, immediately downstream of Browndale Dam in Edina.

3.4 Extrapolation of Point Measurements to Reach Scale

The field measurements described in the preceding sections quantify groundwater fluxes at discrete points along the stream channel. While these measurements are useful for characterizing the spatial heterogeneity of groundwater-surface water interactions along the length of the stream, one cannot get a sense of overall groundwater contributions and/or losses without extrapolating from these point measurements to the reach scale. In the following sections, we describe how the point measurements were used to approximate reach wide groundwater fluxes on an annual basis. The results of this approach are then compared to the estimate of net groundwater discharge obtained through isotope analysis (0.2-0.26 inches/year).

3.4.1 Channel Width Analysis

A channel width analysis for length of Minnehaha Creek was initially completed to determine historic changes in channel width due to straightening and narrowing of the creek over the course of increasing urban development within the channel corridor. Representative reach channel areas and channel center lines were first created using 1892 and 1912 geo-referenced survey maps (C.M. Foote & Co., 1892; Wirth & Vitrud, 1912, respectively) and 2012 aerial photos and LiDAR (MnGeo, 2012; MnGeo, 2011, respectively) within ArcGIS. Channel width was then determined by dividing representative reach channel areas by channel center lines for each of the three years. Initial results for comparison of current aerial photo and LiDAR-derived channel width conditions to the 1892 and 1912 geo-referenced survey maps did not yield results suggesting significant changes in channel width for the majority of reaches. In addition, it was not possible to locate survey notes for either survey map and as a result it was not possible to determine whether the channel conditions were drawn anatomically correct. Based on this, changes in channel conditions were mainly used to infer potential old channel locations and sinuosity changes and the representative reach channel areas instead were used to calculate reach scale groundwater fluxes. All results from this analysis are presented in Appendix V.

3.4.2 Reach Groundwater Fluxes

For each reach identified in the width analysis, an average groundwater flux rate was assigned. This flux rate corresponded to the average rate measured via seepage meters and/or temperature profiles across points within that reach. If field measurements were not taken within a reach identified in the width analysis, then the rate from the reach nearest in proximity and channel characteristics (e.g., similar bed material, slope, channel geometry) was assigned. If the average rate observed across points in a given reach was downward in direction, then a negative flux value was assigned. The assigned flux was then multiplied by the length and width of the channel to obtain a volumetric, daily flux. This flux was then multiplied by 365 days per year to produce an annual volume of groundwater discharge or recharge. The net groundwater discharge obtained by this method was 0.31 inches per year. While this can only be considered as a rough approximation, it compares very favorably with isotope-based estimates of groundwater contributions to baseflow (0.2-0.26 inches per year). Results are presented in Table 3.

Table 3. Net groundwater discharge estimated on reach basis by applying average of point measurements (via seepage meter and/or temperature-based flux calculation) taken within a given reach to the total streambed area within that reach

Reach	2012-Length (ft)	2012-Area (ft²)	*Seepage measurement - Location(s)*	*Flux: cm/d (+ UP)*	*Volume loss (-) or gain (+) (ft³/yr)*	
1	4,456	156,891	estimate	0	0.00E+00	
2	765	26,089	estimate	0	0.00E+00	
3	3,638	291,940	Hiawatha Ave; S. 38th Ave	-0.9125	-3.19E+06	
4	3,651	143,349	L. Hiawatha	-0.805	-1.38E+06	
6	1,898	64,088	L. Hiawatha	-0.805	-6.18E+05	
7	3,002	100,751	L. Hiawatha, 49th-Cedar	-1.7275	-2.08E+06	
8	4,929	162,230	49th-Cedar	-2.65	-5.15E+06	
9	3,752	123,370	50th-Minnehha	-2.36	-3.49E+06	
10	4,185	131,831	Pleasant	-0.76	-1.20E+06	
11	4,892	176,668	Girard, James	-0.3825	-8.09E+05	
12	6,061	200,902	Girard, James	-0.3825	-9.20E+05	
13	4,655	147,602	James	-0.425	-7.51E+05	
14	4,069	141,071	Arden Park, Edina res	-0.835	-1.41E+06	
15	4,884	185,157	Arden Park, Edina res	-0.835	-1.85E+06	
16	1,169	37,557	Utley/mill	-0.49	-2.20E+05	
17	5,506	851,447	Yosimite	-2.62	-2.67E+07	
18	1,852	85,148	Yosimite	-2.62	-2.67E+06	
19	4,429	1,491,623	Excelsior	0.38	6.70E+06	
20	6,061	212,472	Schloff, Meadowbrook bridge, Reach 20, Excelsior, Methodist	0.80375	2.05E+06	
21	3,022	124,965	Blake	1.92	2.87E+06	
22	1,956	170,836	DQ wetland	1	2.05E+06	
23	3,493	350,682	Lahti	1	4.20E+06	
24	4,934	172,431	Hopkins Xroads	0.7	1.45E+06	
25	4,809	377,872	Big Willow, Civic Center	0.7	3.17E+06	
26	1,664	43,866	Big Willow	0.7	3.68E+05	
27	6,352	231,812	Big Willow	0.7	1.94E+06	
28	3,799	139,195	Big Willow	0.7	1.17E+06	
29	3,512	106,250	Burwell	-3.02	-3.84E+06	
30	9,998	1,412,332	Jidana, wetland opposite	3.8	6.43E+07	
Total	76,164	6,282,318	**Sum, *net* annual groundwater discharge:**		**3.39E+07**	ft³/yr
					0.31	in/yr

4. Factors Driving Observed Groundwater-Surface Water Interactions within Minnehaha Creek

The weight of evidence provided by seepage meter measurements, temperature profiles, and isotopic composition of the creek and its source waters indicates annual groundwater contributions on the order of 0.2 to 0.3 inches per year. This represents less than 7% of total annual flow in Minnehaha Creek, and only 3-4% of the 6.7 inches of annual recharge estimated for the watershed (Barr, 2008). A natural question follows: why the paucity of groundwater in Minnehaha Creek? This is not merely a question of curiosity; understanding the underlying factors driving observed groundwater-surface water interactions can provide important insights to potential to manage stormwater for baseflow augmentation. We posit that geologic factors exert important controls, though anthropogenic influences such as groundwater pumping and subsurface drainage may also contribute. In the following sections, we discuss these controls within the context of baseflow augmentation in Minnehaha Creek.

4.1 Geologic Controls: the Platteville Limestone and Buried Bedrock Valleys

The lower Minnehaha Creek watershed is underlain by a layer of unconsolidated sediments deposited by glaciers during the Quaternary period. The average thickness of the quaternary deposits across the lower watershed is 100 ft, ranging from complete absence of these deposits in the vicinity of Minnehaha Falls to over 300 ft beneath the Chain of Lakes. This particularly thick region of quaternary deposits coincides with an erosional bedrock valley created by glacial and pre-glacial fluvial processes that was then filled by glacial outwash. These deposits form the quaternary, or surficial, aquifer, the mean saturated thickness of which is 100 ft. Interactions between the creek and this surficial aquifer have been the primary interest of this study. As shown in Figure 17, the surficial aquifer surface is more or less coincident with the creek channel from Grays Bay outlet to the upstream end of the impoundment formed by Browndale Dam. Below Browndale Dam, the water table surface diverges from the streambed, indicating the potential for losses from the channel to the underlying aquifer.

Below the unconsolidated materials of the surficial aquifer lie a series of bedrock formations, the uppermost of which is the Platteville-Glenwood limestone formation. The Platteville is present throughout about 60% of the lower watershed (Figure 18). This formation has been described as a discrete aquitard with very low vertical conductivity (Runkel et al., 2011). The next bedrock unit in succession is the St. Peter Sandstone, which is the uppermost bedrock unit across 31% of the watershed. Although horizontal conductivities may be as high as 10 ft/day, the lower portion of the St. Peter is characterized by low permeability and acts as a hydraulic barrier between the St. Peter and the Prairie du Chien (Runkel, 2003). Below the Chain of Lakes, pre-glacial erosional processed removed both the Platteville and the St. Peter formations, creating the present-day “bedrock window” in which the surficial aquifer is in direct contact with the Prairie du Chien. This condition is restricted to about 9% of the lower watershed. Figures 17 and 18 illustrate the spatial relationship between the land surface (which coincides with the Minnehaha Creek streambed in 17), the surficial aquifer, the uppermost bedrock surface, and potentiometric head associated with the Prairie du Chien aquifer.

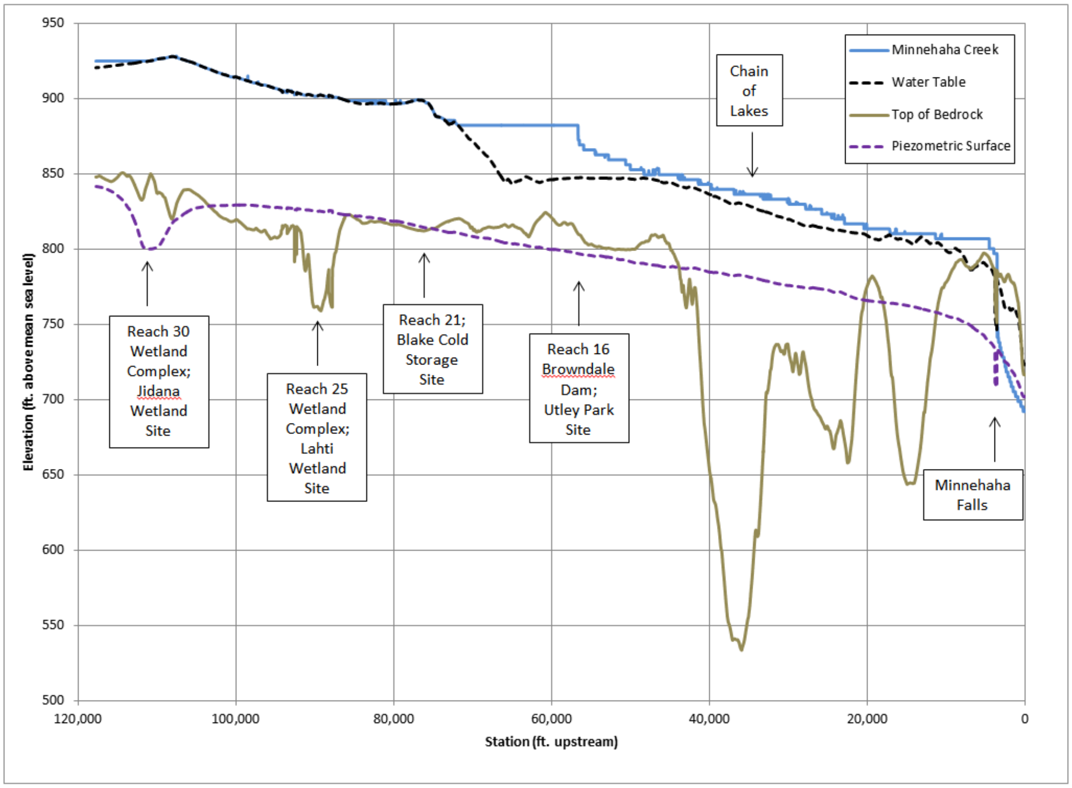


Figure 17. Long profile depicting surficial and bedrock aquifer systems along the length of Minnehaha Creek. Long profile created within ArcScene by Ryan Birkemeier using 1 M LiDAR surface (MnGeo 2011) and water table, top of bedrock, and piezometric surface data (Tipping, 2011).

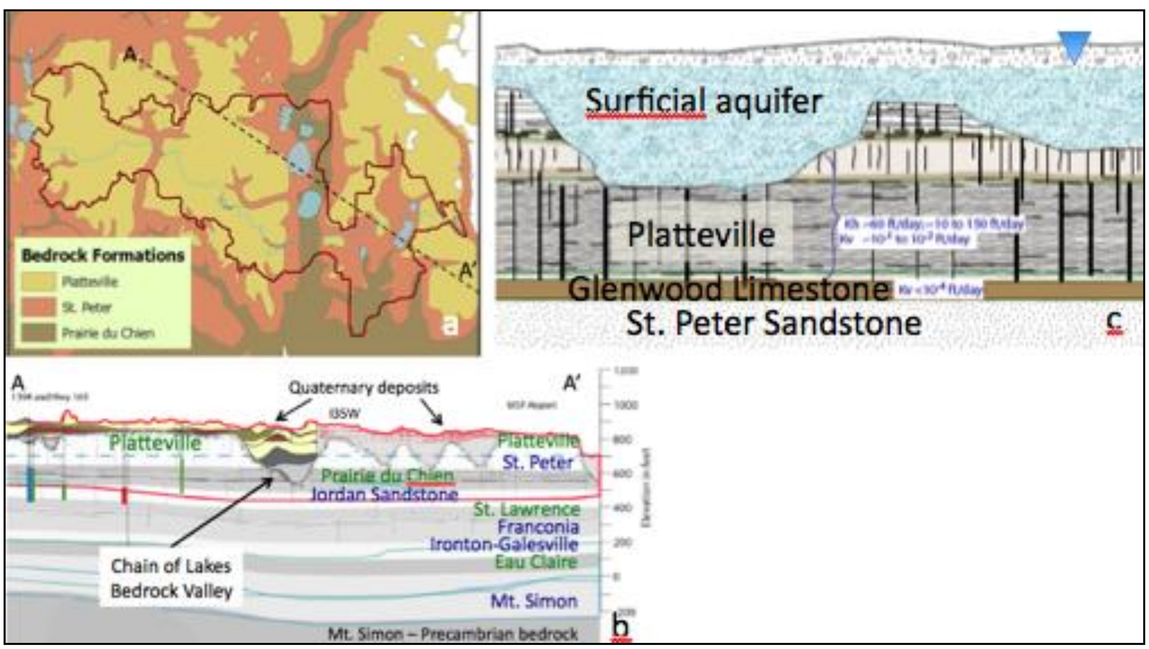


Figure 18. Bedrock geology underlying lower Minnehaha Creek watershed. (a) distribution of Platteville (Yellow), St. Peter (Salmon) and Prairie du Chien (Brown) aquifers. (b) Section A-A', illustrating "Bedrock Valleys" where Platteville and/or St. Peter formations have been eroded, creating direct contact between the surficial and Prairie du Chien aquifers, most notably below the Chain of Lakes (from Tipping, 2011). (c) detail of the Platteville and low-conductivity Glenwood Limestone formation of this unit, which may play an important role in perching the groundwater table and slowing vertical leakage to the underlying bedrock aquifers (from Runkel et al., 2011).

We believe that, where present, the Platteville-Glenwood shale formation plays an important role in perching the groundwater table in the surficial aquifer, supporting groundwater discharge to Minnehaha Creek when aquifer levels are high enough and preventing vertical leakage to underlying bedrock aquifers, most notably the Prairie du Chien. Field measurements of groundwater fluxes indicated predominantly upward fluxes above Browndale Dam along the most continuous expanse of Platteville in the watershed. Both our field measurements and the drop in the water table relative to the land surface in Figure 4.1 indicate strong potential for channel losses below Browndale Dam. Geologically, this region of the watershed is characterized by a discontinuous Platteville layer and direct contact with the Prairie du Chien in some areas. These areas of direct contact likely serve as a conduit from which water from the surficial aquifer (and which is available for discharge to Minnehaha Creek) is lost to the bedrock aquifer system. The series of cartoons in Figure 19 illustrate this concept.

To determine if this hypothesis was tenable in terms of the annual water budget, we calculated aquifer properties required to supply the remaining 6.5 in/year of annual recharge to the Prairie du Chien. This calculation was made using the Darcy flux approach and a hydraulic head dataset developed by Tipping (2011). Darcy flux calculations are described in Appendix 4. The uppermost formation of the Prairie du Chien aquifer is the Shakopee, which is characterized by low vertical conductivities on the order of 0.0003 to 0.3 ft/day (Runkel et al., 2003). In order for leakage from the surficial aquifer to the Prairie du Chien to account for the remaining 6.5 in/year of annual recharge, the effective vertical conductivity between the surficial and Prairie du Chien aquifers would need to be 0.076 ft/day assuming minimal leakage across the Platteville or St. Peter formations. This value falls within the expected range of vertical conductivities for the Prairie du Chien, so the supposition that leakage from the surficial aquifer accounts for over 95% of total recharge is not unreasonable. Furthermore, it helps explain the lack of groundwater available for discharge to Minnehaha Creek.

Data compiled by Tipping (2011) pertaining to groundwater age provides another line of evidence to support our hypothesis of significant leakage to bedrock aquifers. Figure 20 illustrates tritium concentrations detected in groundwater from a series of wells across the lower Minnehaha Creek watershed. Tritium concentrations have been related to groundwater age, with lower concentrations (less than 1 Tritium unit) generally corresponding to waters that were recharged over 50 years ago. Groundwater within two wells located in the upper end of the watershed was characterized as such. Tritium concentrations tended to increase with distance downstream along Minnehaha Creek, suggesting that recharge rates are higher and/or hydraulic residence time in the surficial aquifer is lower in this region. Rapid transit of water from the surface to underlying bedrock aquifers suggests leakage from the surficial aquifer is occurring, with the effect of a loss of recharge available for discharge to Minnehaha Creek.

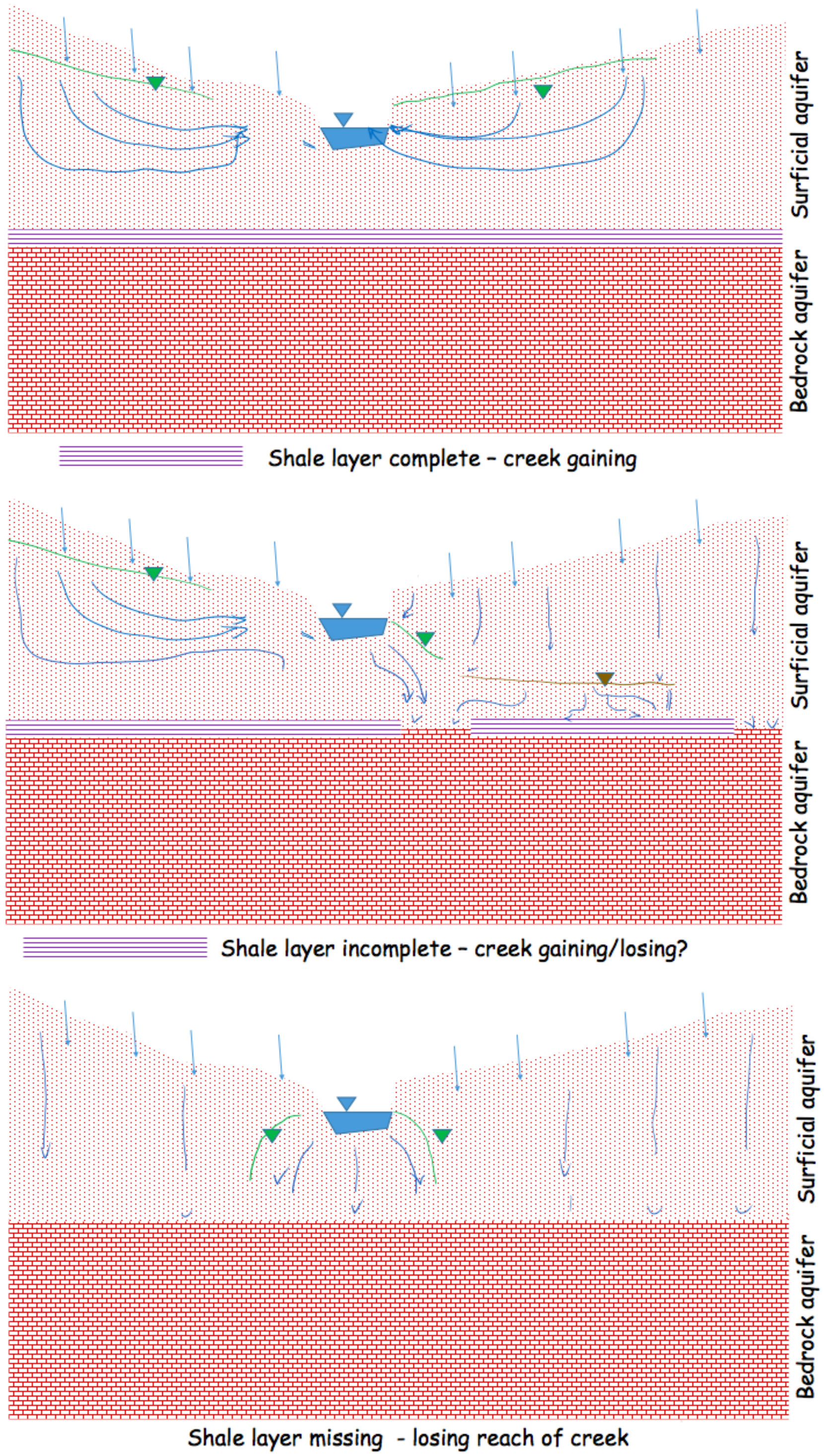


Figure 19. Conceptual illustration of losing and gaining reaches of the stream as influenced by underlying geology. The Platteville-Glenwood-Decorah Shale formation is thought to function as an aquitard, perching the surficial water table and supporting groundwater discharge to Minnehaha Creek (top). This shale layer has been eroded from some areas of the watershed so that the surficial aquifer is in direct contact with underlying bedrock aquifers, namely the Prairie du Chien. Such conditions are thought to permit leakage from the surficial aquifer and losses from the creek (middle). Discontinuous extents of the Platteville-Glenwood-Decorah shale formation could support either surface water gains or losses (bottom).

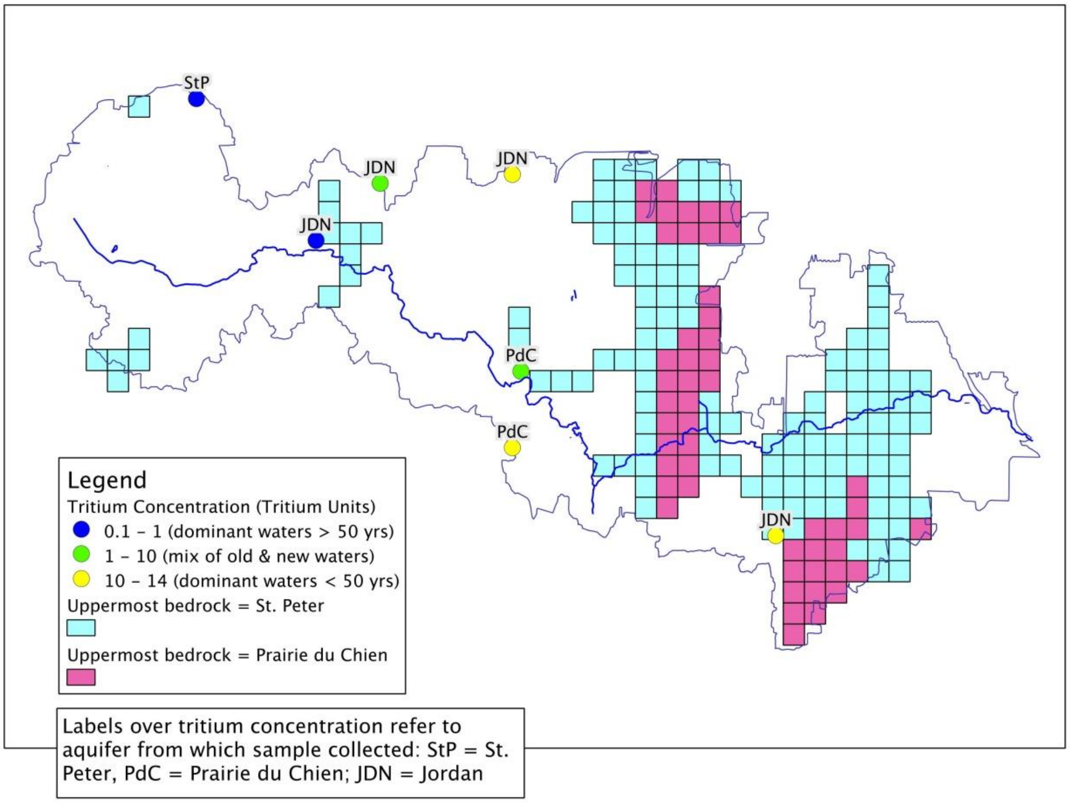


Figure 20. Distribution of tritium in groundwater across the lower Minnehaha Creek Watershed. Tritium concentration is used as an indicator of groundwater age. Concentrations less than 1 Tritium unit indicate water was recharged over 50 years ago. Concentrations greater than 10 indicate water recharged from the surface to aquifer less than 50 years ago. Intermediate values indicate a mix of older and newer waters. Groundwater age tends to decrease with distance downstream along Minnehaha Creek indicating more rapid recharge and, likely, reduced residence time in the surficial aquifer.

As a final line of evidence, we applied a systems model developed by Brutsaert and Nieber (1977) through which physical properties of the aquifer system may be inferred through recession analysis of stream flow data. The details of this analysis are described in Appendix VI. A major outcome of interest to this study was an approximation of the area of the watershed underlain by stream-feeding aquifers in order to support observed baseflow recessions in the Minnehaha Creek stream flow record. This area was equal to 5% of the watershed area, which can be visualized as a 250-ft buffer on either side of the creek. While the influence of Grays Bay was removed from this analysis, other sources of baseflow, such as discharge from wetlands or the Chain of Lakes, were not. If the groundwater fraction of baseflow determined through isotopic analysis during recession periods (0.05 to 0.16) is applied to better represent the groundwater portion of baseflow, then the area of groundwater source contributions may be as little as 2-3% of the total watershed area.

4.2 Other Factors Influencing Groundwater-Surface Water Interactions

Existing geologic controls are believed to exert the dominant influence on observed losses from Minnehaha Creek's shallow groundwater system. In many ways, geologic factors are beyond control and may have limited sustained baseflows in Minnehaha Creek even in its predevelopment state.

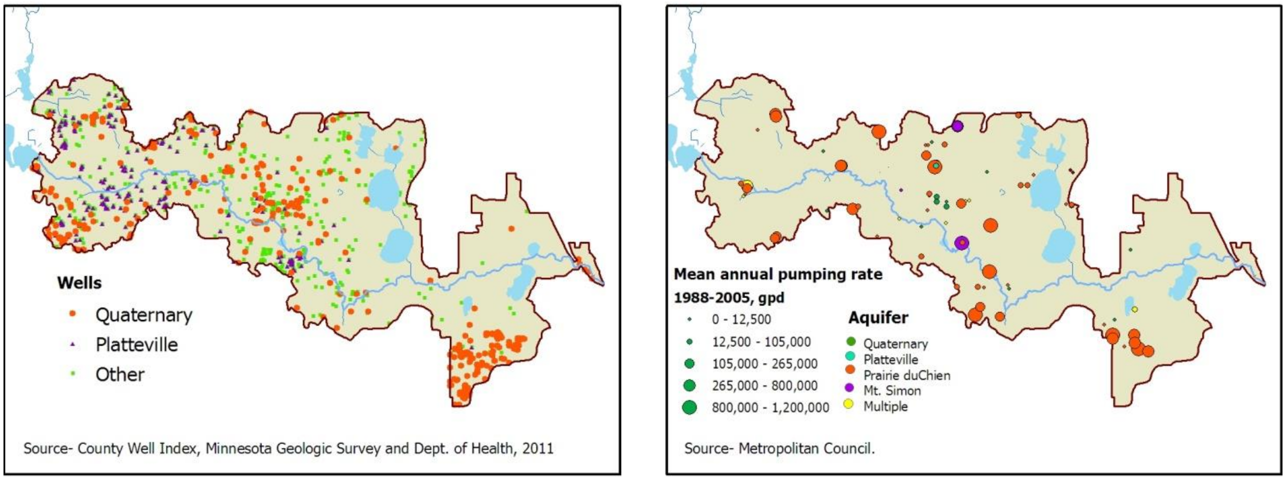


Figure 21. Left: Distribution of active wells in the lower Minnehaha Creek watershed. The color of closed circles indicates the aquifer from which water is drawn (Quaternary/surficial = orange; Platteville = purple; Other aquifers = green). Right: Mean annual pumping rate in high capacity commercial and muncipal wells. Relative marker size denotes pumping rate while color denotes aquifer from which withdraws made. The majority of high capacity wells draw from the Prairie du Chien (orange) aquifer.

However, other anthropogenic factors may be exasperating surficial aquifer losses. Three factors are briefly discussed here, including (1) groundwater pumping, (2) drainage effects of deep stormwater and sanitary sewer infrastructure, and (3) expansion of impervious area.

4.2.1 Groundwater Pumping

The County Well Index, an online database of wells installed in the state maintained by the Minnesota Department of Health, reports a total of 845 active wells (that is, not sealed) throughout the lower Minnehaha Creek watershed (Figure 21, left). Well installation dates range from 1937 to 2008. Of these wells, 317 draw water from the quaternary aquifer. The rest are open to the Platteville (248), St. Peter (44), Prairie du Chien - Jordan (16), or to multiple aquifers (220). The majority of these wells were drilled for domestic purposes and do not have publicly available pumping records. Historic pumping data is available for a number of "high capacity" wells used for industrial and commercial purposes. Annual withdraws from these wells from 1988 to 2005 range from less than 30 gallons per day (gpd) to 1,200,000 gpd (Figure 21, right). Considering just those wells from which pumping rates are known, total annual groundwater pumping may range from 4.1 to 8.5 inches (Table 4), with the majority of this volume is drawn from the Prairie du Chien aquifer. Compared to the annual total recharge of 6.7 inches per year, groundwater pumping and subsequent drawdown could accelerate leakage from the surficial aquifer.

Table 4. Range of groundwater pumping volume over lower Minnehaha Creek watershed. Total pumping is substantial relative to annual bedrock recharge (approx. 6.5 in/yr) and may exacerbate losses from the surficial to Prairie du Chien aquifer

Pumping rate (gpd)	Number of wells	Yield (10^6 ft^3/yr/well)		Total Yield (10^6 ft^3/yr)	
		Low	High	Low	High
0-12,500	24	0	0.006	0	14.6
12,500-105,000	13	0.006	0.051	7.90	66.4
105,000-256,000	7	0.051	0.129	35.8	90.7
265,000-800,000	9	0.129	0.389	116	350
800,000-1,200,000	8	0.389	0.584	311	467
		TOTAL (million ft^3/yr)		470.7	988.7
		TOTAL (inches/yr)		4.1	8.5

4.2.2 Drainage along Municipal and Stormwater Sewer Pipes

This factor was discussed briefly in the first interim report, and continues to of interest as a means through which groundwater may be shunted away from Minnehaha Creek. Preferential flow paths are known to develop along the high conductivity materials comprising backfill around sewer infrastructure. As a result, groundwater may be effectively removed from the system through horizontal drainage along preferential pathways. Preferential flow along most stormwater pipes may not constitute a great concern since the terminus of these pathways is typically Minnehaha Creek. However, preferential flow along sanitary sewer interceptors or deep stormwater tunnels (Figure 1) may serve to exacerbate groundwater losses, particularly below the Chain of Lakes, if groundwater drains horizontally to the Mississippi River. In addition to this French Drain effect, infiltration into sewer systems may serve as another loss mechanism. While leakage into deeper bedrock aquifers likely comprises a greater loss, drainage along and infiltration into sewer infrastructure may be a source of local groundwater losses.

4.2.3 Expansion of Impervious Surfaces

Presently, the average impervious area across Minnehaha Creek is about 30%, most of which is concentrated in the lower 2/3 of the watershed. Impervious surfaces restrict infiltration and, in turn, groundwater recharge. It is likely that expansion of impervious surfaces, particularly near the stream, have decreased groundwater recharge and subsequent discharge as stream baseflow. Regardless, one thing is certain: the annual contribution of stormwater runoff to flow in Minnehaha Creek is much higher than in the watershed's predevelopment state. We estimated that runoff constitutes about 18% of annual flow in Minnehaha Creek as compared to the 13% provided by baseflow sources other than Lake Minnetonka. The rapid manner with which runoff is conveyed to Minnehaha Creek is contrary to the sustained release delivered by groundwater, wetlands, or other surface reservoirs in the periods between storm events. Capturing stormwater runoff piped to the creek and releasing it in a manner that mimics baseflow sources could potentially double current stream baseflows. Can this be done? This is the focus of the next section of the report, in which key findings and their practical application are highlighted.

5. On the Ground Application of Knowledge Gained from the Minnehaha Creek Baseflow Study

Based on field measurements of groundwater fluxes and supporting evidence from hydrogeologic conditions and stream flow recession analyses, we have developed an understanding of groundwater contributions and loss mechanisms in the Minnehaha Creek watershed. As illustrated in Table 3., groundwater represents about 5% of the total annual stream flow in Minnehaha Creek. From these field measurements, we have developed the following key conclusions and recommendations:

- The current baseline contribution of groundwater to flow in Minnehaha Creek is 0.2-0.3 inches per year. Complete capture of stormwater runoff and redistribution through storage and release from the shallow aquifer would increase this contribution to about 2.3 inches per year, or roughly half of the annual flow in Minnehaha Creek. Spread over the open water season (April through November), this would equate to an additional 10 cfs of flow during non-storm periods.
- We believe that the *greatest opportunity to augment groundwater contributions to stream baseflow through focused stormwater infiltration exist in areas where the Platteville-Glenwood shale formation is relatively continuous and/or where an underlying sandy-clay till layer is present to constrain seepage loss* (Figure 18). This includes relatively impervious areas such as the Knollwood Shopping area and Hopkins Cold Storage site.
- *Baseflow augmentation via stormwater infiltration may be limited below the Chain of Lakes*. Hydrogeologic conditions and measured groundwater flux rates between the Chain of Lakes and Minnehaha Falls indicate groundwater flow is predominantly in a downward. Downward groundwater flow is likely related to leakage from the surficial aquifer system to the underlying Prairie du Chien bedrock aquifer. This condition does not necessarily preclude baseflow benefits from stormwater management projects. However, the design of systems intended to promote baseflow would likely require placement of an impervious liner to prevent vertical seepage losses.

5.1 Potential Future Steps

5.1.1 Development of a Decision Support Tool

Develop a decision support tool that provides applicable data and useful steps needed to determine the ability for baseflow augmentation or baseflow management at a site for future planning along Minnehaha Creek. Applicable data (i.e. GIS layers, modeling results, field work results, permitting requirements, etc.) would be organized and adequately provided to the user at each specific step. The potential inconsistencies or the margin of error in all provided data would also be adequately outlined. This could involve creation of an interactive tool that includes applicable data links on a map of Minnehaha Creek during each step or just consist of direct links to applicable data within some form of document. Although an interactive tool may not be feasible, some sort of map element would be incorporated into the overall tool in order to allow a user to determine possible data needs for specific locations along the creek. The specific steps within the tool will most likely be formulated during the compilation of all available data for the tool. Each step might include a list of helpful tips or literature to consider after completion of the step and/or links to contacts that may be useful to involve in the decision process. After a basic outline for the tool has been created, a literature review could be completed to locate any currently available support tools. If decision support tools are located, the development, use, and overall formatting of the tools would be heavily considered and used in the formation of the tool for Minnehaha Creek. Following the initial formulation of the tool, the initial outline and literature review would then be discussed with John Nieber, Joe Magner, John Gulliver, and Karen Gran to determine the steps needed to move forward. It would also be beneficial at this stage to discuss the initial/revised outline of the tool with MCWD to best integrate their overall goals for the creek. Once a final rendition of the tool has been created, the tool would be tested on an example site along Minnehaha Creek to determine any further edits needed and also to provide an example of correct use of the tool that can be provided to future users at MCWD.

5.1.2 Investigate Where Groundwater is Going (e.g. 'French Drain' Effect of Sanitary Sewer Interceptors and I-35W Storm Sewer Tunnel)

- <u>Modeling Effort</u>: Create a groundwater model or group of models that can be used by MCWD following the completion of the current baseflow project to continue to adequately determine overall groundwater flux into the future. This model would go further than the models and analysis already being completed for the report this December by attempting to include as much relevant information from the watershed as possible. Some parameters might include estimates of evapotranspiration (based on a relevant measurement methodology), bed material or storage changes along the reach and stormwater inputs and/or potential losses. A literature review in conjunction with input from John Nieber, Joe Magner, John Gulliver, and Karen Gran would help improve the list of parameters and likely determine the feasibility of including each. The overall goal of the model or group of models would be for staff at MCWD to be able to input up-to-date flow data and precipitation data and new field data to keep groundwater flux estimates current and to build a record of the flux from year to year in conjunction with changes in landuse, climate, and stream morphology.
- Additional GIS comparison of stormsewer locations relative to channel 'losing' areas.
- Mapping of I-35W storm sewer tunnel structure during winter to locate and GPS any potential leaks.

5.1.3 Further Geo-Tech Exploration and Piezometer Installation at Several Sites of Interest (e.g. MPRB BMP Sites)

- Determination of locations for further exploration based on seepage measurements collected this fall.
- Preclude to pilot studies on sites before future stages of construction of infiltration basin to augment baseflow.
- Further exploration will allow for more adequate constraining of data collected and presented within this report and will help to improve all future steps presented (fieldwork efforts, modeling efforts, and decision support tool).

5.1.4 Addition of Injected Tracer Studies to Several Sites of Interest

- Completion of an injected tracer study will help to answer the following specific questions:
  - *Is shallow groundwater flow near the stream primarily horizontal or vertical?*
  - *Do vertical gradients preclude discharge to stream as horizontal distance from the channel increases?*

5.1.5 Completion of Pilot Studies on Several Sites of Interest to Determine Potential for Artificial Baseflow Augmentation

- Use data from seepage meter measurements at MPRB locations to target sites for pilot studies (i.e. are any of the MPRB sites adequate for baseflow augmentation?)

5.1.6 Completion of Study to Determine Potential Effects of Stream Restoration Efforts on Groundwater Connectivity throughout Minnehaha Creek

- Summarized history and location of restoration efforts on the creek (detailed account of scale and techniques used).
- Potential effects on baseflow within each location based on the specific techniques used.

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Appendices

Appendix I. Flow Error Analysis

Grays Bay Flow Error Analysis

As noted in Section 2.1, a flow error analysis was completed using stage differences and specific D_{calc} (i.e. height of dam opening) values provided by MCWD for the outlet of Grays Bay. Results from the analysis indicated that actual flow levels out of Grays Bay differ considerably from those reported by MCWD, in between periods of dam opening height change. The equation used by MCWD to calculate a D_{calc} value for an input discharge (Q) and stage difference (H) is:

$$D = \frac{Q}{CNBH}$$

$$Q = CNBDH$$

Q= discharge (cfs)
H= $\sqrt{LL-TW}$
N= # of gates open
B= width of gate= 10'
D= height of gate opening (notches)
LL= lake elevation
TW= wetland elevation

C= 1 gate= 6.56; 2 gate= 6.40; 3 gate= 7.05

All values in the above equation were provided by MCWD and all values were held constant during periods of constant dam opening height, with the exception of stage difference, when calculating representative discharge values. Specific periods of constant dam opening height were chosen to calculate error in recorded discharge due to the potential for a fluctuating stage relative to the specifically set dam opening height in between management actions by MCWD. In general, discharge values recorded at the time of dam opening height change were accurate. This was to be expected based on the specific formulation of the equation for the Grays Bay outlet structure. Results of the analysis for years 2008 through 2013 are presented in Figure A.1.

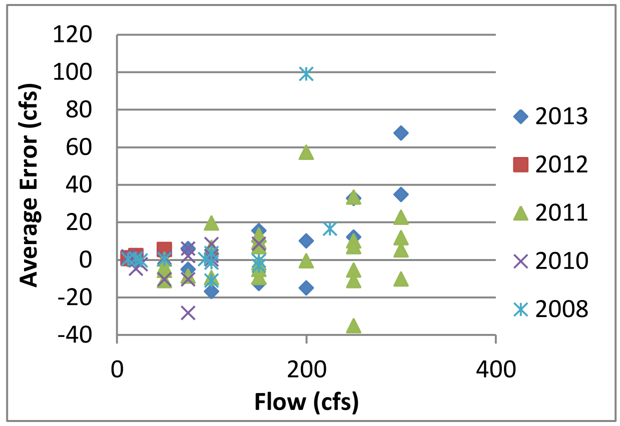


Figure A.1 Grays Bay flow error analysis results. Negative values indicate actual discharge values above those recorded by MCWD. Flow error results for years 2006 and 2007 are not included due to lack of continuous stage difference data. 2009 was also not included due to errors in discharge measurements over the course of the year.

In general, it can be noted that the difference between recorded and actual discharge values increases with increasing flows through the Grays Bay outlet structure. This is to be expected with relatively rapid flow changes during precipitation events and the inability of MCWD staff to constantly change dam opening height relative to all changes. Constant calculation of exact flow levels is likely not of concern to MCWD from a management standpoint, but was very important in determining the flow balance for the Minnehaha Creek Watershed. All results have been tabulated within MS Excel and are available upon request.

Watershed-Scale Flow Error Analysis

In addition to Grays Bay, flow error was also analyzed for several other gauging stations along the length of Minnehaha Creek. Specific gauging stations included (listed from upstream to downstream): CMH 19 at the Interstate 494 crossing, CMH03 at Browndale Dam, and the USGS gauge at Hiawatha Ave. For each gauging station, a nearby direct measurement of discharge using a Flow Tracker was used for comparison and determination of potential error in recorded flows. A direct measurement of discharge near the Grays Bay outlet structure was also included for comparison. All direct measurements of discharge were provided by MCWD (Figure A.2). It is important to note that additional error could be possible at each gauging station and was considered as possible given available information for each specific station. However, in general it was not possible to determine potential errors in measurements at each station due to a lack of active management compared to the Grays Bay outlet structure.

Although many factors could account for the difference between recorded discharges, including small differences in location of measurement, the results in Figure A.2 indicate that discharge can change significantly across the length of Minnehaha Creek, even within a small distance. In general, small differences were noted for both I-494 and Hiawatha Ave compared to Browndale Dam and Grays Bay. The large difference at Browndale Dam was likely due to backwatering effects from the dam and a resulting overall reduction in discharge recorded at the downstream permanent gauge. At Grays Bay, differences could be due to storage effects in the large wetland complex downstream of the outlet structure. At both locations, differences increased during the months of high spring flows. A more in-depth review and synthesis of results will be presented in the final report. During the flow error analysis, tabulated flows were also used to calculate volumes of flow at each permanent gauge during specific time periods of consistent dam opening height at Grays Bay (Figure A.3). With a fixed dam opening height, changes in volume across the length of Minnehaha Creek could be attributed to various storage effects, changes in channel morphology, differences in impervious surface percentages and/or stormwater inputs, and other factors. Preliminary results were used to guide further research into potential factors affecting flow and will be presented more thoroughly in the final report.

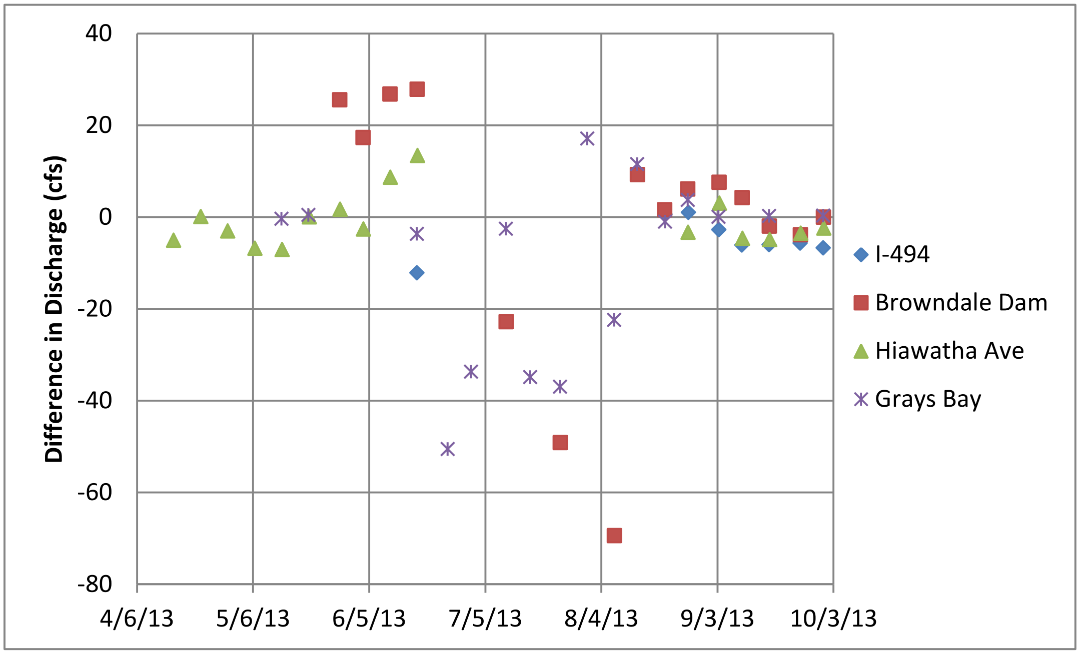
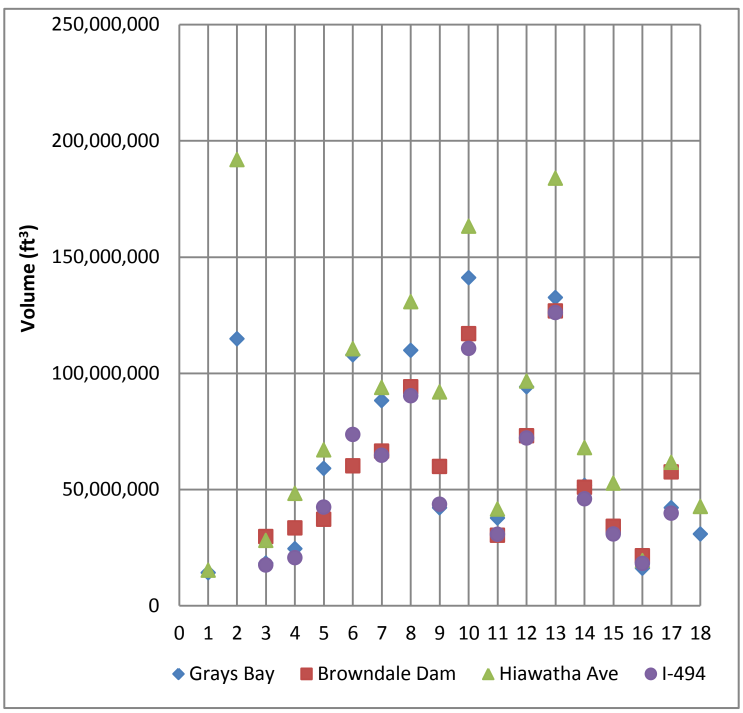


Figure A.2. Difference in recorded discharge between permanent gage locations and Flow Tracker measurements by MCWD staff. Negative values indicate a higher discharge value at the Flow Tracker measurement location.



Time Periods	
1	5/6-5/17/2013 - 12 cfs
2	5/22-6/18/2013 - 50 cfs
3	6/18-6/21/13 - 75 cfs
4	6/21-6/23/13 - 150 cfs
5	6/23-6/26/13 - 250 cfs
6	6/26-7/1/13 - 300 cfs
7	7/1-7/5/13 - 250 cfs
8	7/5-7/12/13 - 200 cfs
9	7/12-7/15/13 - 150 cfs
10	7/15-7/22/13 - 300 cfs
11	7/22-7/24/13 - 250 cfs
12	7/24-7/29/13 - 200 cfs
13	7/29-8/9/13 - 150 cfs
14	8/9-8/14/13 - 100 cfs
15	8/14-8/19/13 - 75 cfs
16	8/19-8/23/13 - 50 cfs
17	8/23-9/16/13- 20 cfs
18	9/16-10/16/13- 12 cfs

Figure A.3. Volume of flow change across the length of Minnehaha Creek for specific time periods of constant dam opening height at the Grays Bay outlet structure. In several time periods, volume appears to decrease in the upper portion of the watershed (I-494 & Browndale Dam) before increasing to a final flow volume at Hiawatha Ave. Smaller scale changes between gauges could be a result of factors described in the text above.

Appendix II. Isotope End-Member Mixing Analysis

To quantify relative contributions of multiple sources (e.g., surface waters, precipitation/runoff, and groundwater; also known as end-members) to a mixture (e.g., Minnehaha Creek), an end-member mixing analysis (EMMA) was applied. EMMA entails the use of linear mixing models to partition a composite mixture into contributing end-members. Both 2- and 3-member mixing models were utilized in this study. An example calculation is provided for each.

2-Member Mixing Model: Partitioning Meteoric and Surface Waters in the Jidana Wetland Groundwater

Minnehaha Creek riparian groundwater samples formed two distinct clusters on the basis of their isotopic compositions (Figure 4). Given the position of groundwater samples from the Jidana wetland between surface water samples and all other groundwater samples, it was hypothesized that riparian groundwaters at the Jidana site were comprised of (1) recharged meteoric waters and (2) surface water originating from Lake Minnetonka. To test this hypothesis, a 2-member mixing model was applied with the following system of equations:

$$Q_{gw} = Q_p + Q_M$$
$$Q_{gw}\delta O_{gw} = Q_p\delta O_p + Q_M\delta O_M$$

where Q = fraction of flow, δO = mean oxygen-18 isotopic fraction (relative to standard of mean ocean water), and subscripts *gw, p,* and *M* indicate groundwater (mixture), precipitation (end-member #1), and Minnetonka (end-member #2), respectively. The relative fractions of flow contributed by precipitation (Q_p) and Lake Minnetonka (Q_M) are simultaneously solved as:

$$Q_p = Q_{gw} - Q_M$$
$$Q_p = Q_{gw}\frac{\delta O_{gw} - \delta O_M}{\delta O_p - \delta O_M}$$
$$Q_M = Q_{gw} - Q_p$$

Q_p and Q_M were solved in Excel as:

2-member model		
Near stream Jidana wells (Group A): Mixture of Minnetonka and meteoric waters.		
		$\delta^{18}O$
Source 1	Precipitation (mean)	-8.05
Source 2	Minnetonka (mean)	-2.08
Mix, Jidana wells		-6.92
		Fraction of total
Source 1, Precipitation =		**0.8**
Source 2, Minnetonka =		**0.2**

Thus, the isotopic signature of riparian groundwater at the Jidana wetland site indicates the aquifer is composed primarily of meteoric waters (rainfall and snowmelt recharge; about 80% by composition) with additional contributions from Minnehaha Creek waters originating from Lake Minnetonka (about 20%).

3-Member Mixing Model: Partitioning Surface Water, Groundwater, and Runoff in Minnehaha Creek Waters

Minnehaha Creek and source water samples were collected on May 28, 2012 following a 5-day series of rain events during which approximately 4.5 inches fell over the watershed. Subsequent sampling was conducted during the hydrograph recession of this storm series (June 6, 2012) and again on Aug. 22, 2012 following the closure of Grays Bay due to drought. On any of these sampling dates, it was hypothesized that Minnehaha Creek waters were comprised of a mixture of (1) runoff, (2) surface waters, and (3) groundwater. To test this hypothesis, a 3-member mixing model of following system of equations was applied:

$$Q_{RO} + Q_{SW} + Q_{GW} = Q_{MC}$$

$$\delta O_{ro} Q_{ro} + \delta O_{sw} Q_{sw} + \delta O_{gw} Q_{gw} = \delta O_{MC} Q_{MC}$$

$$\delta D_{ro} Q_{ro} + \delta D_{sw} Q_{sw} + \delta D_{gw} Q_{gw} = \delta D_{MC} Q_{tMC}$$

where Q = fraction of flow, δO = mean oxygen-18 isotopic fraction (relative to standard of mean ocean water), δD = mean deuterium (hydrogen-2; relative to standard of mean ocean water), and subscripts *MC*, *ro* (collected from stormwater pond, n=3) *sw* (collected from outlets of Lakes Minnetonka and Harriet, n=6) and *gw* (collected from piezometers at Lahti wetland and Blake sites, n=12) denote Minnehaha Creek (mixture), runoff (end-member #1), surface water (end-member #2), and groundwater (end-member #3), respectively. The relative fractions of flow contributed by runoff (Q_{ro}), surface water (Q_{sw}), and groundwater (Q_{gw}) are simultaneously solved as:

$$Q_1 = \frac{(C_t^1 - C_3^1)(C_2^2 - C_3^2) - (C_2^1 - C_3^1)(C_t^2 - C_3^2)}{(C_1^1 - C_3^1)(C_2^2 - C_3^2) - (C_2^1 - C_3^1)(C_1^2 - C_3^2)} Q_t$$

$$Q_2 = \frac{C_t^1 - C_3^1}{C_2^1 - C_3^1} Q_t - \frac{C_1^1 - C_3^1}{C_2^1 - C_3^1} Q_1$$

$$Q_3 = Q_t - Q_1 - Q_2$$

The relative flow fractions Q_{ro}, Q_{sw}, and Q_{gw} were solved in Excel for Minnehaha Creek samples collected upstream and downstream of Lake Hiawatha for each of hydrologic conditions represented by the sampling date summarized in the set of tables below. Note that the runoff portion (Q_{ro}) of streamflow on the June 6 recession and August 22 drought sampling dates were collected from a stormwater pond that drains to the creek, and thus represent a prolonged release of runoff that has undergone evaporative fractionation.

Storm, hydrograph peak: upstream Lake Harriet. 5/27-5/28 2012 data.	d^{18}O	d^{2}H
Source 1, Runoff (n=2)	-4.93	-26.67
Source 2, surface water (Minnetonka, n=3)	-2.08	-27.84
Source 3, groundwater (n=12)	-9.51	-66.44
Mix, Minnehaha Creek (n=4)	-5.09	-31.36

	Fraction of total
Source 1, Runoff	**0.76**
Source 2, Surface water	**0.13**
Source 3, Groundwater	**0.11**

Storm, hydrograph peak: downstream Lake Harriet. 5/27-5/28 2012 data.	d^{18}O	d^{2}H
Source 1, Runoff (n=2)	-4.93	-26.67
Source 2, surface water (mean, Lakes Minnetonka (n=1) & Harriet (n=1)	-2.73	-30.47
Source 3, Groundwater (n=12)	-9.58	-65.53
Mix, Minnehaha Creek (n=3)	-4.49	-30.47

	Fraction of total
Source 1, Runoff	**0.6**
Source 2, Surface water	**0.34**
Source 3, Groundwater	**0.06**

Conclusions, stormflow peak (May 27-28, 2012). Isotopic composition of creek indicates flow dominated by runoff, as would be expected following the series of storms that took place before sampling. Runoff contributions based on the isotopic composition of creek samples downstream of Lake Harriet (60%) agrees will with the runoff estimate from a baseflow filter applied to flow data collected at Hiawatha Avenue (65%). Groundwater is estimated to contribute 6 to 11% of flow in the stream.

Post-storm, hydrograph recession: upstream Lake Harriet. 6/6/2012, 9 days since last rain event	$d^{18}O$	$d^{2}H$
Source 1, runoff (pond, n=1)	-3.68	-22.75
Source 2, surface water (Minnetonka, n=1)	-2.08	-27.84
Source 3, Groundwater (n=12)	-9.58	-65.53
Mix, Minnehaha Creek, upstream Harriet	-3.77	-33.89
Source 1, runoff (pond)	**0.20**	
Source 2, surface water (Minnetonka)	**0.61**	
Source 3, Groundwater	**0.18**	
Source 3, Groundwater	**0.18**	

Post-storm, hydrograph recession: downstream Lake Harriet; 6/6/2012, 9 days since last rain event	$d^{18}O$	$d^{2}H$
Source 1, surface water (Minnetonka, n=1)	-2.08	-27.84
Source 2, surface water (Harriet, n=1)	-3.52	-33.46
Source 3, Groundwater (n=12)	-9.58	-65.53
Mix, Minnehaha Creek, downstream Harriet	-3.94	-33.89
Source 1, Minnetonka	**0.11**	
Source 2, Harriet	**0.78**	
Source 3, Groundwater	**0.11**	
Source 3, Groundwater	**0.11**	

Conclusions, hydrograph recession (June 6, 2012). Despite collection 9 days following last rainfall, creek waters still seem to retain some stormwater runoff signature. This could be water released from other surface storages (e.g., headwater wetlands). Above Lake Harriet, Minnetonka's flow contribution is similar among different end-member combinations, ranging from 60-66%. Groundwater estimates range from 10-20%. Downstream of Lake Harriet, Harriet waters are consistently a greater contributor than Minnetonka, in agreement with flow.

Drought flow, hydrograph recession: upstream Lake Harriet, 8/22/12, 7 days since last rain event (0.75 in)	$d^{18}O$	$d^{2}H$
Source 1, surface water (Minnetonka)	-2.10	-26.61
Source 2, runoff (pond)	-5.76	-26.67
Source 3, Groundwater	-9.33	-64.94
Mix, Minnehaha Creek, US Harriet	-2.08	-28.68
	Fraction of total	
Source 1, surface water (Minnetonka)	**1.13**	
Source 2, runoff (pond)	**-0.16***	
Source 3, Groundwater	**0.02**	

Drought flow, hydrograph recession: downstream Lake Harriet, 8/22/12, 7 days since last rain event (0.75 in)	$d^{18}O$	$d^{2}H$
Source 1, surface water (mean, Minnetonka & Harriet)	-2.65	-29.85
Source 2, runoff (pond)	-5.76	-39.04
Source 3, Groundwater	-9.33	-64.94
Mix, Minnehaha Creek, DS Harriet	-3.32	-32.45
	Fraction of total	
Source 1, surface water (mean, Minnetonka & Harriet)	**0.83**	
Source 2, runoff (pond)	**0.13**	
Source 3, Groundwater	**0.04**	

*the negative value calculated for the runoff component indicates that the 3-member model is not the best fit given the data points collected. Various combinations of end-members were tried without success. Therefore, a 2-member model was applied to explain source components in creek water upstream of Lake Harriet:

2-member model, upstream Lake Harriet, 8/22/12.		$d^{18}O$
Source 1	Minnetonka	-2.08
Source 2	Runoff (pond)	-5.76
Source 2	Groundwater	-9.38
Mix, Minnehaha Creek, US Harriet		-2.08
		Fraction of total flow
Source 1, Minnetonka		1.00
Source 2, Groundwater		0.00
Source 1, Minnetonka		1.00
Source 2, Runoff		0.00

Conclusions, 8/22/12 drought period: Insignificant groundwater at drought-flow upstream of Lake Harriet. Although Grays Bay dam was closed two days prior, it appears that nearly all water in the channel originated from Lake Minnetonka. **Groundwater estimated to contribute < 5% of flow downstream of Lake Harriet**. Lakes Harriet and Minnetonka supply majority of baseflow.

Appendix III. Temperature-Based Approximation of Groundwater Fluxes

Groundwater flux rates were approximated based upon streambed temperature profiles using both steady state and transient models. Stallman (1965) described heat and fluid flow through a fully saturated, porous medium with the following general differential equation:

Equation 1

$$\frac{\partial^2 T}{\partial x^2}+\frac{\partial^2 T}{\partial y^2}+\frac{\partial^2 T}{\partial z^2}-\frac{c_w p_w}{k}\left[\frac{\partial(v_x T)}{\partial x}+\frac{\partial(v_y T)}{\partial y}+\frac{\partial(v_z T)}{\partial z}\right]=\frac{cp}{k}\frac{\partial T}{\partial t}$$

With application to groundwater flux through porous streambed material, T is the temperature at any point in time t; c is the specific heat of the sediment-water matrix; p is the density of water; k is the thermal conductivity of saturated streambed materials; v_x, v_y, and v_z are components of groundwater velocity in the x, y, and z directions; c_w is the specific heat of groundwater; p_w is the density of groundwater; and x, y, and z are Cartesian coordinates. Assuming groundwater and heat fluxes are predominantly in the vertical direction, the differential equation above may be simplified to:

Equation 2

$$\frac{\partial^2 T}{\partial z^2}-\frac{c_w p_w v_z}{k}\left[\frac{\partial T}{\partial z}\right]=\frac{cp}{k}\frac{\partial T}{\partial t}$$

Following this assumption, groundwater velocity v_z may be determined by measuring the temperature T at any depth z within the streambed and assigning typical values for parameters c_w (4.18 J $g^{-1}C^{-1}$), p_w (1x10^6 g m^{-3}), k (0.85 to 1.68 J $m^{-1}s^{-1}C^{-1}$ for saturated fine- to coarse-grained sediments, respectively), c (0.6 to 0.85 Cal $cm^{-3}C^{-1}$ for coarse to fine-grained sediments), and p (1.4x10^6 to 2.3x10^6 g m^3 for fine- to coarse-grained sediments) and applying either the steady-state or transient solutions for the differential equation. In this study, both solutions were applied; a description and example calculation for each follow.

Steady-State Solution Applied to Groundwater Flux Calculations

Assuming steady-state conditions, that is, that temperature is constant with time, simplifies the solution to Equation 2 considerably as the left-hand side of the equation reduces to zero. Following the boundary conditions illustrated in Figure A2.1, Equation 2 may be solved as:

Equation 3

$$\frac{\partial^2 T}{\partial z^2}-\frac{c_w p_w v_z}{k}\left[\frac{\partial T}{\partial z}\right]=0$$

$$\frac{T_Z-T_o}{T_L-T_o}-\frac{e^{\beta(z/L)}-1}{e^{\beta}-1}=0 \quad where\ \beta=\frac{c_w p_w v_z L}{k}$$

The value of β was approximated using the numerical iterative algorithms built into Microsoft Excel Solver as demonstrated by Arriaga and Leap (2006). Groundwater velocity v_z, defined positive in the downward z direction, was determined assuming typical values of c_w, p_w, and k given the total vertical distance L over which temperature T was measured.

Steady-state solution, applied at Blake Road site in Hopkins, MN, August 15, 2013. (Vertical depth z defined positive in the downward direction.)

z (m)	T_z (C)	z/L (m/m)	β	$\frac{T_z - T_o}{T_L - T_o} = \frac{e^{\beta(z/L)} - 1}{e^{\beta} - 1}$
0	22.1	0.00		
0.25	17.2	0.38	-1.526	0
0.3	16.3	0.45	-1.684	0
0.66	13.4	1.00		

Constants	Value	Units
c_w (specific heat of groundwater)	4.18	J/g-C
p_w (density of groundwater)	1E+06	g/m3
k (streambed thermal conductivity)	0.85 to 1.62	J/m-s-C
	V_z low (k=0.85)	V_z high (k=1.62)
$V_z = \beta k/(c_w p_w L)$ where L = 0.66 m	**-4.3 cm/d**	**-8.1 cm/d**

The steady-state solution for the profile taken at this location within the Blake site indicates upward discharging groundwater on the order of -4.3 to -8.1 cm/d. This range represents upper and lower bounds for velocity based upon the expected range in thermal conductivity of streambed materials reported in the literature (Constantz et al., 2008; Stonestrom and Blasch, 2003; Stonestrom and Constantz, 2003). Though thermal conductivity of streambed sediments was not measured in this study, literature values for the sand/gravel textured sediments encountered at this site range up to 1.62 J/m-s-C, suggesting groundwater discharge rates at this site may be on the upper end of the calculated range.

Transient Solution Applied to Groundwater Flux Calculations

Steady-state solutions for all sites represent temperature profile measurements taken at a discrete point in time. At the Blake site, groundwater flux calculations based on discrete measurements were compared with temperature data recorded every 15 minutes by a data logger installed at 2 depths within the streambed (0.15 and 0.2 meters). Temperature was also recorded just above the sediment-water interface. A transient solution to the 1-dimensional heat flux equation (Eqn. 2) was solved using these continuous temperature data to compare to steady-state approximations of groundwater flux.

Equation 2 was solved numerically following the explicit finite-difference scheme for combined convection and diffusion outlined by Gulliver (2007) and Lapham (1989):

Equation 4

$$T_i^{n+1} = \frac{k\Delta t}{pc\Delta z^2}\left(1 + \frac{p_w c_w v_z \Delta z}{2k}\right)T_{i-1}^n + \frac{k\Delta t}{pc\Delta z^2}\left(1 - \frac{p_w c_w v_z \Delta z}{2k}\right)T_{i+1}^n + \left(1 - \frac{2k\Delta t}{pc\Delta z^2}\right)T_i^n$$

where T_i^{n+1} is the temperature at node *I* at time step *n+1*, T^n_{i-1} is the temperature at node *i-1* at time step *n*, T^n_{i+1} is the temperature at node *i+1* at time step *n*, Δt is the time increment between time steps, and Δz is the spacing between nodes. Variables p_w, c_w, *k*, *c*, and *p* are as defined previously. The numerical stability of the solution requires that the unitless parameter $k\Delta t/c\Delta z^2$ is less than 0.5; to fulfill this requirement, the values of Δt and Δz were set to 60 minutes and 7.5 cm, respectively.

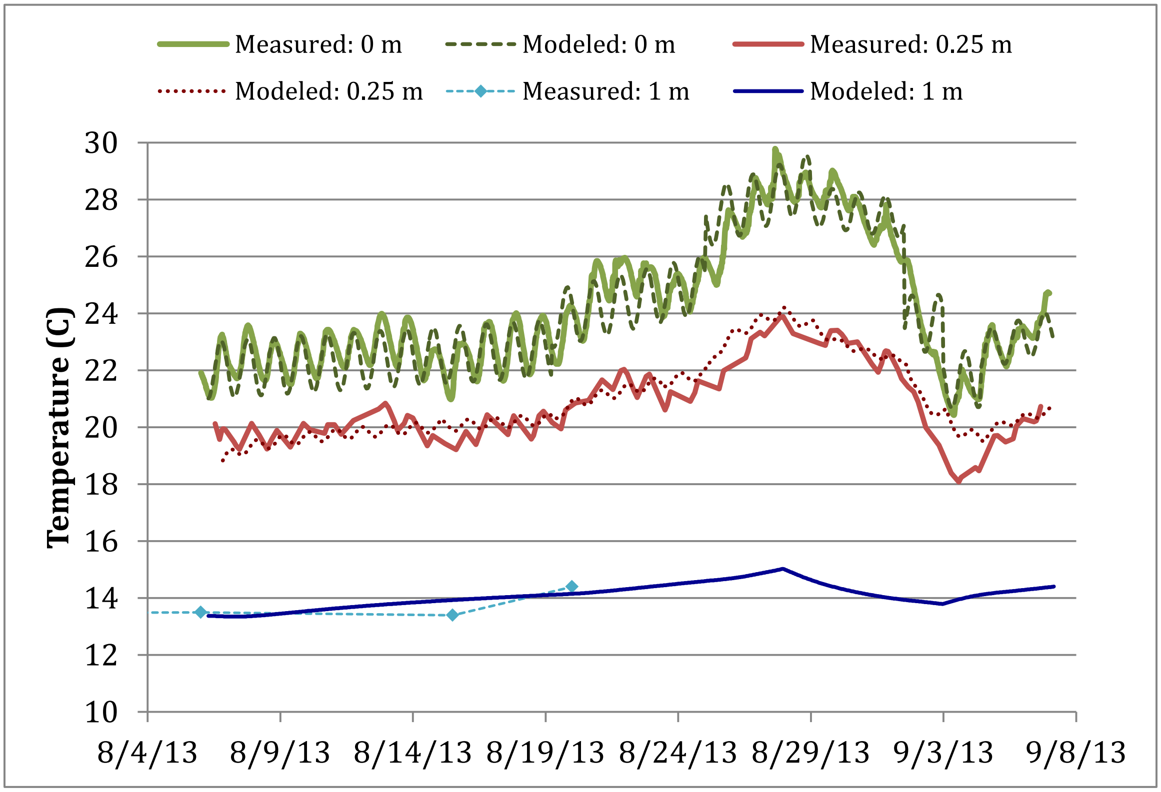


Figure A.4. Measured and modeled surface water and streambed temperatures at the Blake Cold Storage site, as approximated by solving numerically the explicit finite-difference scheme for combined convection and diffusion. Modeled curves were fit as close as possible to measured temperatures by adjusting the groundwater velocity term v_z in Equation 4 over the range of expected streambed thermal conductivities *k* (0.003 to 0.006 Cal cm^{-3}C^{-1}) . Groundwater flux ranged from 1.8 to 6.1 cm day^{-1} in the upward direction to produce the fit seen above.

Computations were carried out in Microsoft Excel. Model boundaries included the stream surface temperature, which was modeled as a sinusoidal curve fit to 15-min surface temperature measurements, and groundwater temperature at depth *L* (0.7 m), which was allowed to vary linearly to match weekly temperature measurements of adjacent riparian wells at the Blake site. Groundwater velocity was then approximated across the range of expected streambed thermal conductivities by adjusting the velocity term to fit the observed temperature profile. Measured and modeled temperatures are displayed in Figure A.4.

Summary: Temperature-Based Approximations of Groundwater Flux by Site and Reach

As approximated using steady-state and transient methods for solution of the differential equation describing heat flux through saturated porous media, groundwater discharge on the order of 2 to 6 cm/d (transient) or 4 to 8 cm/d (steady-state) was calculated for this site. Included in the uncertainty in the magnitude of groundwater flux is thermal conductivity of streambed sediments, which was not measured but assigned a range of expected values from the literature. Despite differences in the approaches, flux estimates overlap in range, indicating that the steady-state solution to discrete temperature probe measurements may be an adequate surrogate for more expensive continuous data required for application of transient models. In a similar comparison of methods, Arriaga and Leap (2006) found that the steady-state assumption compared favorably to fluxes obtained through transient models during a period in mid- to late summer when differences between surface and groundwater temperatures were greatest. Though continuous subsurface temperature data were not collected from any of the other sites, we believe that the direction (upward or downward) if not the magnitude of groundwater fluxes calculated by the steady state solution to numerous temperature profiles measured along the length of the creek are valid. The results of these measurements are summarized in Figure 11.

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Appendix IV. Seepage Meter Analysis

Shallow monitoring wells were installed at 4 sites along the creek as described in Section 3.3. At each site, three to four 2-in diameter, PVC wells were installed in the riparian zone approximately perpendicular to flow in the creek. A plan view of piezometer locations is provided in Figure 12. The following sections provide greater detail as to piezometer installations and observed stratigraphy for each of the sites.

Jidana Wetland

All wells at the Jidana wetland site were hand-augered to a depth ranging from 3 to 5.5 ft below the surface. Vegetation at the site transitioned from cattails (edge of the channel to piezometer 2 as labled in Figure A.5.), to *Phragmites* (piezometer 1), to trees (piezometer A). All piezometers were screened in the sandy aquifer underlying up to 4 feet of organic material at the site. Piezometers were screened across the bottom-most 10-inches of the PVC pipe. The aquifer was comprised predominantly of coarse sand interspersed with gravel and small rocks (up to 3-inches in diameter). With the exception of piezometer 1, which was dry from August 2012 to March 2013, the water table remained above screened sections.

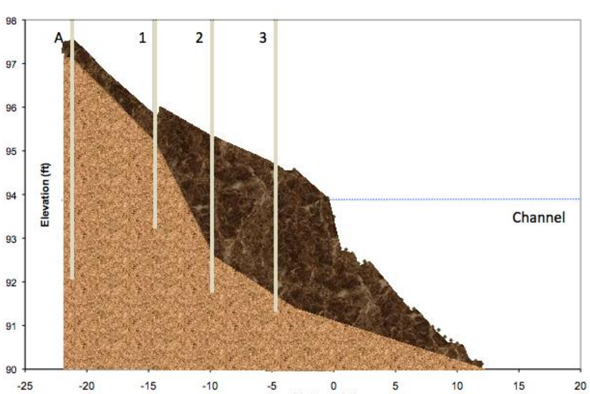


Figure A.5. Cross-section of wells installed at the Jidana wetland. The cross section is comprised of a layer of organic material (dark brown shading) up to 4-ft thick near the stream underlain by a layer of coarse sand and gravel/cobble (light brown shading) to which the 10-in screened interval at the bottom of all wells is open.

Lahti Wetland

Two sets of piezometers were installed at the Lahti wetland (Figure 12). Piezometers at the upstream end of the site were installed during the spring of 2013. Piezometers 1 and 3 were installed by hand while a drill rig was used to install piezometers 2s and 2d. Cattails were the dominant vegetation type from the channel to piezometer 1. A layer of organic material with a relatively uniform thickness of 4 to 5 ft was encountered at this site. Although at different depths (Figure A.6.), all piezometers were open to the same sand and gravel aquifer underlying the layer of organic material. An additional bore hole was augered near the location of piezometers 2s and 2d to discern the presence of any low permeability layers within the aquifer. Such a layer, consisting of silty-clay till, was encountered at a depth of 45 ft. The water table remained perched above the ground surface at all piezometers from June to early August, 2013.

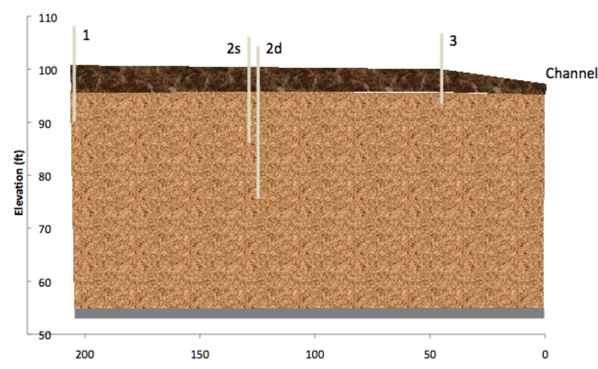


Figure A.6. Cross-section of wells installed on the upstream end of the Lahti wetland site. A relatively uniform, 4-ft thick organic layer (brown shading), overlays the sandy aquifer (light brown shading). The 10-in screened interval of all piezometers is open to the sandy aquifer. A confining sandy clay layer (dark gray shading) was encountered at a depth of about 45 ft in a boring conducted near piezometers 2s and 2d. Note that the extension of this layer across the rest of the site is assumed.

The second set of piezometers was installed approximately 1000 ft downstream (Figure A.7.) Grasses, namely *Phragmites,* were the dominant vegetation type across this site. A relatively thick (about 6 ft) organic layer was encountered immediately below the ground surface. A 10-inch screened section at the bottom of all piezometers was open to the sand and gravel aquifer underlying this organic layer. A thin clay layer was encountered between the organic and sandy aquifer at piezometers 1 and 2.

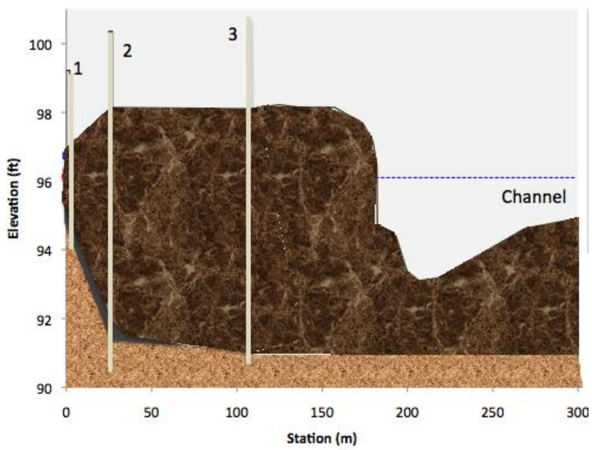


Figure A.7. Cross-section of wells installed on the downstream end of the Lahti wetland site. A thick layer (up to 6 ft) of organic soil (brown shading) overlays a layer of gleyed, silty sand (light brown shading) to which the 10-in screened interval of all piezometers is open. A thin clay layer (solid gray shading) capping the sand layer was observed at Piezometers 1 and 2. The piezometric head in piezometer 3 was greater than the ground surface throughout monitoring in 2013.

Blake Cold Storage Site

Soil characteristics within the riparian area immediately adjacent to the site were examined with a hand auger (Figure A.8.). Piezometer installation was also completed with a hand auger in July 2012.

A silt layer ranging in thickness from 1 to 3 feet overlays a relatively compacted till layer (Figure A.9.) Compared to the other sites, this gravely sand layer was more difficult to penetrate with the hand auger. Additional soil explorations of the lawn area between the wooded riparian area and parking lot of the Cold Storage plant were conducted by a drill rig (Figure A.8.). Borings in the lawn area indicated the presence of a 7 to 12 ft layer of silty- to clayey- sand fill material overlying a silty-sand aquifer.

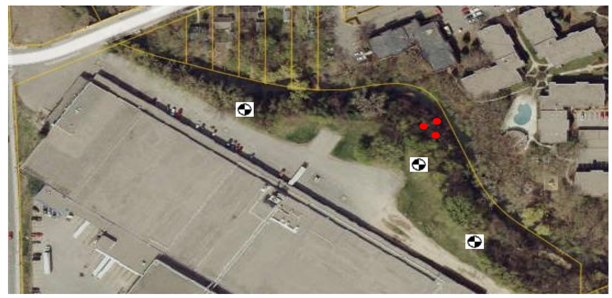


Figure A.8. Approximate locations of piezometer installations (solid red circles) within wooded riparian area of creek and soil borings completed with a drill rig (black and white circles) in the upslope lawn area.

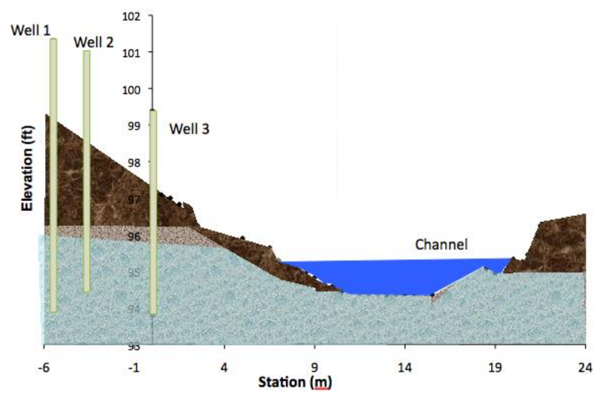


Figure A.9. Cross-section of wells installed at the Cold Storage site on Blake Road. Underlying a 1-2 foot layer of silt (dark brown shading) is a thick layer of compacted loamy sand till with large gravel and stones embedded throughout. The 10-in screened interval of all wells is open to this layer.

Utley Park

Soil stratigraphy was initially explored by hand auger during 2012 in the lawn area immediately adjacent the stream. In general, the site is overlain by about 0.5 ft of top soil, underlain by about 2 ft of compacted clay. A graveley sand layer was encountered below the clay layer; however, the diameter of gravel in this layer was too large to permit penetration with the hand auger. Due to interest in this site as a location in which groundwater may be perched, subsequent borings and piezometer installations were conducted during the spring of 2013. Figure A.10. illustrates the location and depth of piezometers relative to the stream channel. A relatively low conductivity till layer was encountered at a depth of 50 ft.

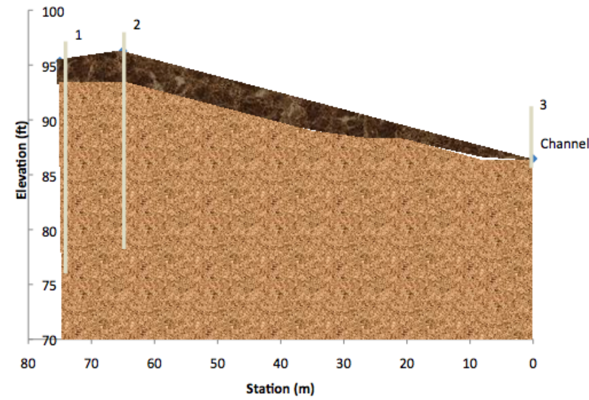


Figure A.10. Cross-section of wells installed at the Utley Park site in Edina. Underlying a 1-2 foot layer of silty-clay fill material (dark brown shading) is a thick layer of compacted loamy sand till with large gravel and stones embedded throughout. The 10-in screened interval of all wells is open to this layer.

Appendix V. Channel Width Analysis

As indicated in Section 3.4, a channel width analysis for length of Minnehaha Creek was initially completed to confirm a historic reduction in channel width due to straightening and channelization. A reduction in channel width would indicate an overall decrease in channel storage and a resulting lower baseflow. However, overall results did not indicate a large or conclusive historic decrease in channel width from 1892 and 1912 survey maps to current conditions. Results did indicate a large reduction in sinuosity due to straightening and channelization and a resulting much lower overall channel length. This finding supports an overall decrease in channel storage, but a historic decrease in channel sinuosity is the main factor, not a decreased channel width. Because of inconclusive results and inability to confirm whether channel conditions were drawn anatomically correct on survey maps, on-the-ground analysis of areas where historic channel conditions may be preserved should be conducted where possible. This would help to confirm results and/or provide representative, historic conditions for future comparisons. Specific areas where channel conditions could be preserved may include relict floodplain areas where the channel used to be present as indicated by 1892 and 1912 survey maps. Results of this analysis are presented in Table A.1.; specific locations for on-the-ground confirmation of channel width could be located through future analyses.

Table A.1. Channel width analysis results for Reaches 1-12 of Minnehaha Creek. The largest calculated channel width for each reach is indicated by the red text. The total at the bottom of the table indicates an average channel width across Reaches 1-12 for each year.

Reach	***1892-Width (ft)***	***1912-Width (ft)***	***2012-Width (ft)***
1	**37**	-	35
2	29	**43**	34
3	38	49	**80**
4	**43**	-	39
6	34	-	34
7	33	31	**34**
8	**34**	29	33
9	33	31	33
10	**38**	32	32
11	15	26	**36**
12	29	-	**33**
Total (average)	31	31	**38**

As indicated in Table A.1., historic channel width could only be confirmed for Reaches 1 through 12 due to historic survey map limitations. Current channel widths (and channel area) were calculated for all reaches for use in reach-representative groundwater fluxes.

Appendix VI. Evidence of a "Leaky" Aquifer: Darcy Flux Calculations and Recession Analysis

Darcy Flux Calculations: Leakage between Surficial and Prairie du Chien Aquifers

Annual estimates of groundwater discharge to Minnehaha Creek (0.2 to 0.3 inches per year as determined through corroboration of seepage meter measurements, temperature-based approximations, and isotope-based groundwater partitioning) is much less than annual groundwater recharge estimates of 6.7 inches per year over the watershed (Barr, 2008). We hypothesized that the difference between annual groundwater recharge and groundwater discharge to Minnehaha Creek could be attributed to leakage to the underlying bedrock aquifer system. The surficial aquifer system of the lower Minnehaha Creek watershed is underlain by a series of bedrock formations, the uppermost of which are (in order of descent) the Platteville-Glenwood-Decorah shale association, the St. Peter sandstone, and the Prairie du Chien dolomite. Low vertical conductivity units within the Platteville and St. Peter formations are believed to restrict vertical leakage from the overlying surficial aquifer (Runkel et al., 2003; Runkel et al., 2011). Therefore, to test our hypothesis we calculated leakage rates between the surficial and Prairie du Chien under the assumption that significant leakage only occurred thorugh direct contact between these two aquifer systems. Such areas of contact underlie approximately 9% of the watershed based on Minnesota Geologic Survey mappings.

Leakage rates were calculated using the Darcy Flux approach, illustrated in Figure A.11:

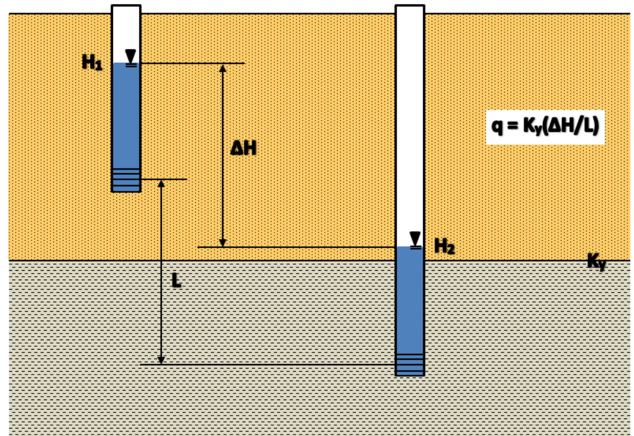


Figure A.11. Darcy flux approach used to calculate value effective k_v to supply 6.5 inches/yr leakage between the surficial and underlying Prairie du Chien aquifers in regions of the watershed where these aquifers are in direct contact.

Where q = flux (in feet per day), k_z is the effective vertical hydraulic conductivity (in feet per day), h_1 and h_2 are the hydraulic head (in feet) of the surficial and Prairie du Chien aquifers, respectively, and L is the distance (in feet). Values for h_1, h_2, and L were obtained from a gridded dataset (250 x 250 m^2) developed by Tipping (2011). Using Tipping's data, the hydraulic gradient $(h_1 - h_2)/L$ was calculated for each 250 x 250 m^2 grid cell in which the surficial and Prairie du Chien aquifers are in direct contact (Figure A.12.). The effective vertical conductivity required to support a leakage rate of 6.5 in/year (0.54 ft/year) over the entire watershed (equal to 70.2 in/year over just the 9% in which the surficial and Prairie du Chien are in direct contact and assumed to permit leakage) was calculated by solving for k_v such that the sum of leakage through each grid cell highlighted in Figure A.12. summed to 70.2 in/year (5.85 ft/yr; Table A.2.). An effective k_v of 0.076 ft/d was required to meet the hypothesized leakage loss of 6.5 in/year. This value falls within the range of k_v expected for the Prairie du Chien. Thus, losses of 6.5 in/year to underlying bedrock aquifers is a plausible explanation for the lack of groundwater discharge to Minnehaha Creek.

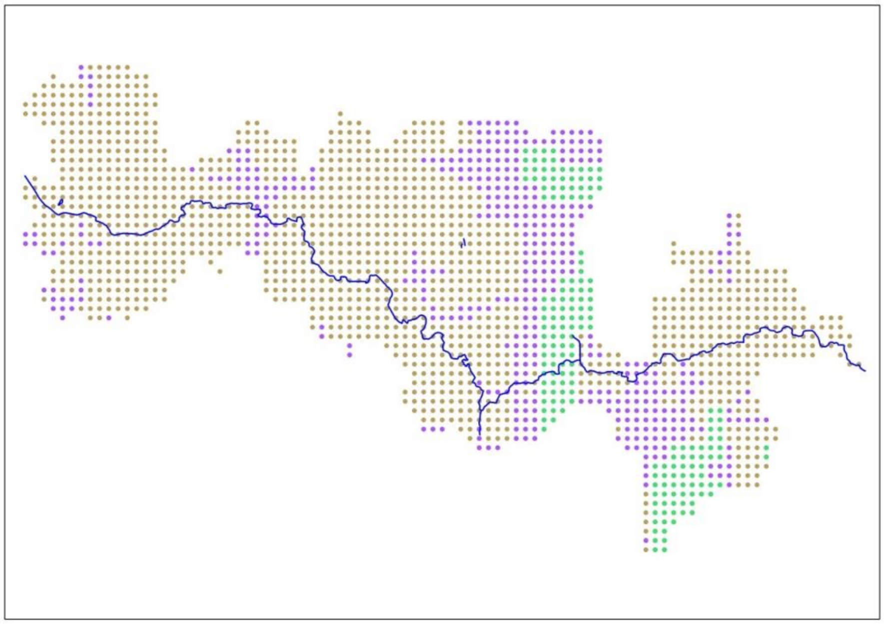


Figure A.12. Map depicting gridded data points developed by Tipping (2011) from which hydraulic gradient (h_1 – h_2)/L was calculated. Green points denote grid cells for with the surficial and Prairie du Chien aquifers are in direct contact. Vertical leakage through points where the surficial aquifer is in direct contact with the St. Peter (purple) or Platteville-Glenwood-Decorah shale formations (brown) are assumed to be minimal.

Table A.2. Example data set used to calculate required effective k_v based on hydraulic gradient as calculated for 180, 250 x 250 m^2 grid cells (representing the 9.2% of the lower watershed in which the surficial and Prairie du Chien aquifers are in direct contact) from hydraulic head and distance values provided by Tipping (2011)

Cell	**h_1**	**h_2**	**L**	**dH/L**	**Kv_interface**	**Darcy flux, q**		**Volume**
	(ft)	**(ft)**	**(ft)**	**(ft/ft)**	**(ft/d)**	**ft/d**	**in/yr**	**ft3/yr**
1	811.1	746.7	153	0.421	0.076	0.032	140.2	7856984
2	810.0	745.3	199	0.325	0.076	0.025	108.3	6073426
3	811.0	749.3	143	0.431	0.076	0.033	143.6	8048920
4	810.0	748.0	174	0.356	0.076	0.027	118.5	6643759
5	810.9	751.0	142	0.421	0.076	0.032	140.3	7865209
6	809.4	750.2	168	0.353	0.076	0.027	117.4	6579725
7	811.6	752.7	151	0.390	0.076	0.030	129.9	7279712
8	811.4	751.9	177	0.336	0.076	0.026	112.0	6277093
9	812.1	751.1	216	0.282	0.076	0.021	94.0	5270860
	□	□	□	□	□	□	□	□
	□	□	□	□	□	□	□	□
	□	□	□	□	□	□	□	□
180	812.1	751.1	216	0.282	0.076	0.021	94.0	5270860
SUM (ft^3/yr), between PdC and surficial aquifer (9.2% watershed)								708231504.7
SUM (in/yr), between PdC and surficial aquifer (9.2% watershed)								70.2
SUM (in/yr), net leakage over entire watershed (100%)								**6.5**

MINNEHAHA CREEK WATERSHED DISTRICT
QUALITY OF WATER QUALITY OF LIFE

MEMORANDUM

To: MCWD Board of Managers

From: Tiffany Schaufler

CC: James Wisker

Date: November 6, 2014

Re: 2014 flood damage

Purpose:
To provide a status report on 2014 flood damage assessment as requested at the October 23, 2014 Board Meeting.

Background:
2014 was the wettest January 1-June 30 on record with 25.32 inches of precipitation. This record precipitation pushed some lakes and creeks to the highest they have ever been. Being the wettest spring on record in MCWD's existence, District programs came together to gather important information throughout the flood event.

Project History:
District staff along with Wenck Associate staff is developing a report which will summarize all data collected during the 2014 flood event, including the hydrologic system response, District response, community response, infrastructure damage, financial implications, District program recommendations, and future planning needs.

Recent Board Action/Discussion:

- During the event, daily and weekly updates were provided to the Board of Managers by Operations and Communications staff.
- June 26, 2014 Board Meeting: Staff provided a high water update memo and presentation on conditions across the District.
- September 11, 2014 Board Meeting: Board authorized Resolution 14-074 to contract with Wenck Associates for $29,800 to develop at 2014 Flood Report which includes performing an assessment of the six major creeks within the District.

Current Status:

- September 9, 2014: Kick-Off Meeting with FEMA, began 60 day window to report damage to FEMA.
- September 18-October 2, 2014: Carried out stream assessments for the six major creeks as well as inspections on all the District's projects and infrastructure to identify damage.
- October 14, 2014: Site visits with FEMA to inspect and document damage.
- October 23, 2014: Site visits with FEMA to inspect and document damage.
- October 31, 2014: Site visits with FEMA to inspect and document damage.

Next Steps/Board Meetings:

- October 31, 2014: Final site visit with FEMA to inspect and document damage.
- November 13, 2014 Board Workshop: Staff will be providing a review of the 2014 flood damage, proposed repairs, and FEMA process.
- Final Flood Report presented to Board in December 2014.

Attachments:

- June 26, 2014 High Water Memo
- June 26, 2014 High Water Presentation

If there are questions in advance of the meeting, please contact: Tiffany Schaufler, 952-471-4513 or Tscaufler@minnehahacreek.org

MEMORANDUM

To: MCWD Board of Managers

From: Tiffany Forner, Kelly Dooley, Brandon Wisner, Telly Mamayek, Laura Domyancich

CC: Jeff Spartz

Date: June 26, 2014

Re: High Water Update

This memorandum is intended to serve as a brief informational update regarding high water conditions within the Minnehaha Creek Watershed District. Included is a high-level summary of recent rainfall, Minnehaha Creek and Lake Minnetonka Statistics, and information regarding how each District department is involved in responding to local communities and the acquisition of data.

Once high water conditions recede, a final report will be drafted summarizing all acquired data, including hydrologic system response, District response, community response, infrastructure damage, financial implications, District program recommendations and future planning needs.

I. Summary Statistics

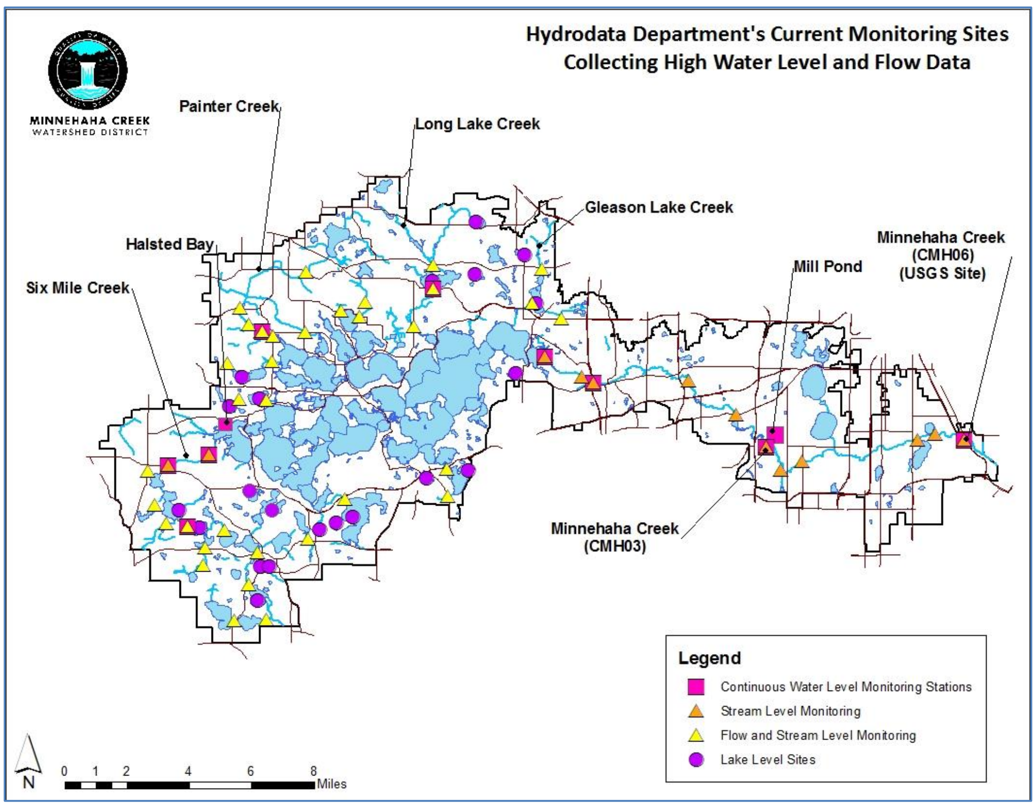
a. Precipitation to date: 25.32 inches; 2014 will be the wettest January 1-June 30 on record
b. Lake Minnetonka level record: 931.11 on June 23, 2014
c. Creek level record:
    i. Flow at Hiawatha estimated 893 cfs at 9:45am on June 19, 2014
    ii. Creek reached highest level recorded since the USGS gauge was installed in 2006
d. Lake Minnetonka level predictions: See June 25, 2014 Lake Minnetonka Level Prediction (Attachment A); assuming normal precipitation:
    i. Elevation will drop below 930.30 on July 12, 2014
    ii. Elevation will drop below 930.00 on July 19th
    iii. Reach "Goal" elevation on August 12
e. Estimated number of high water phone calls fielded to date: 200

II. Hydrodata Department

a. Data gathering

i. Staff are able to continue monitoring on the majority of our lake and streams sites (see map 1). Staff also recorded water elevation via tape down method, staff gage or pressure transducers at each stream and selected lake sites on a weekly basis. The elevation can be used later to get an estimated flow using a stage-discharge rating curve for the sites that we were not able to monitor.

On Thursday, June 19, 2014, staff from Hydrodata, Operations and Maintenance and Permitting departments drove throughout the watershed to sites of importance (i.e., lake and stream monitoring sites, capital project sites, and restoration project sites) to mark the high water elevation with flags. Due to thunderstorms and heavy rain occurring that day, Wenck and MCWD staff waited to survey the marked sites on June 20th and 23rd.



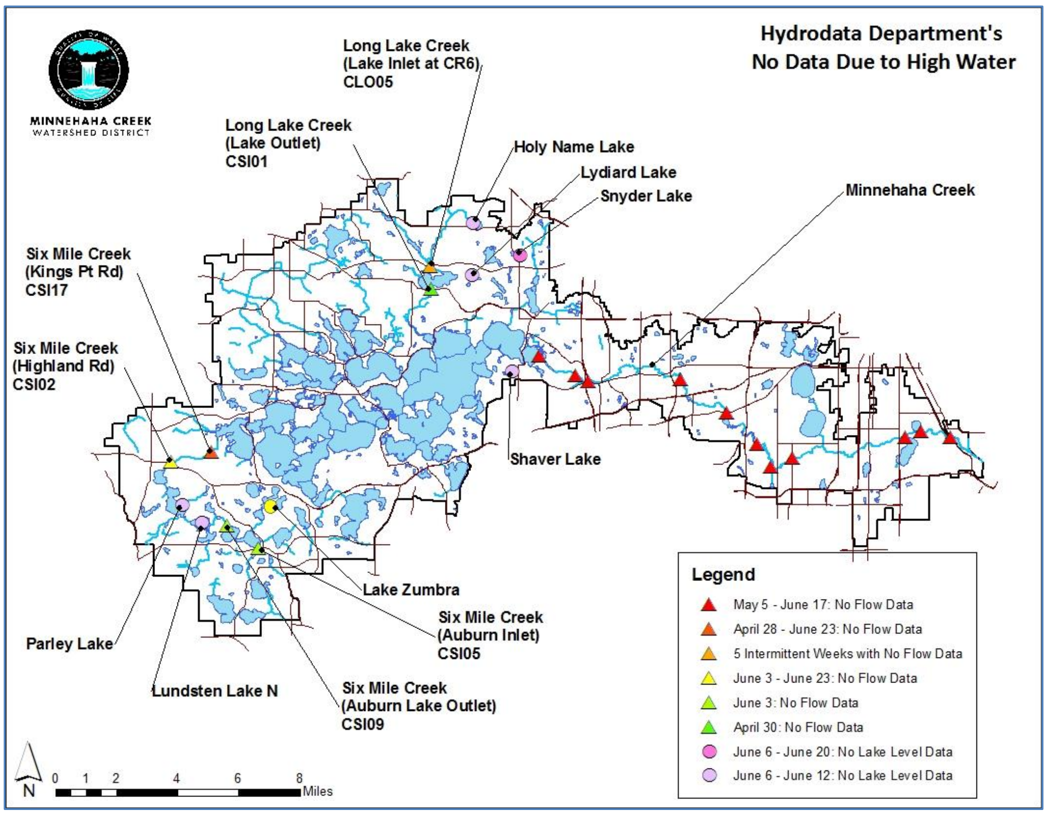
Map 1. Current Monitoring Sites Collecting High Water Level and Flow Data

b. No flow and lake level data collected due to high water

i. Minnehaha Creek, Six Mile Creek and Long Lake Creek flows and water levels became unsafe for staff in late April – early May (See map 2). Staff purchased high flow monitoring equipment, but unfortunately, the equipment was backordered and shipping delayed for several weeks. Staff borrowed Wenck's equipment twice, but the first time the equipment was not functioning. The second time was the week of June 23rd. In addition, the District hired Wenck to monitoring water levels on Minnehaha Creek in order to fill in data gaps for the rating curve.

Six of the 21 lake gages staff read on a weekly basis were unread for only two weeks due to high water (exception – Snyder Lake - 3 weeks) (See map 2). Staff began the week of June 16th to use kayaks to read the underwater gages safely.

Staff will continue to borrow high flow equipment until the new equipment arrives. Staff will also read lake gages that are underwater by kayak until the high water levels have subsided.



Map 2. Sites and dates where no data collected due to high water

c. New equipment installed

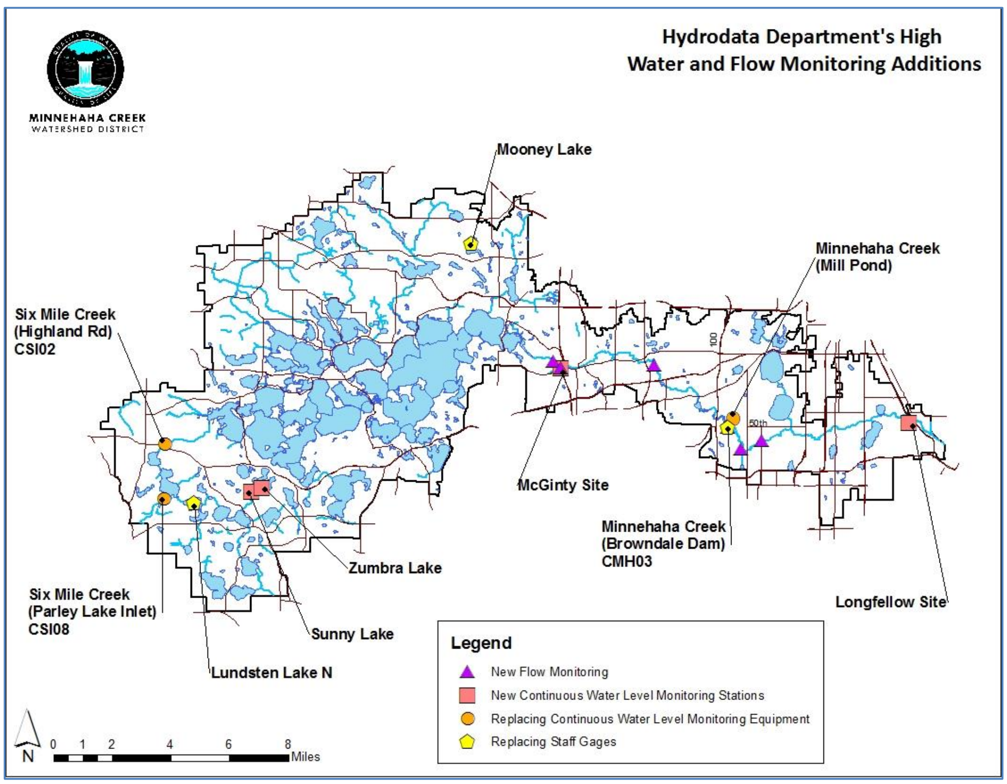
   i. New continuous water level monitoring equipment was installed at both main bays on Zumbra-Sunny Lake, McGinty Road on Minnehaha Creek and at Longfellow in Minneapolis. High lake levels and a culvert issues at the outlet of Zumbra-Sunny Lake have warranted staff to more closely monitor the lake levels.

   McGinty Road site is acting as the new control for Lake Minnetonka; therefore, water level data is very important for understanding the function of Lake Minnetonka and Minnehaha Creek during this high water period.

The Longfellow site is also important, because it is additional data just before the falls.

Due to the high waters, at least two existing level monitoring unit and one automated flow monitoring unit were damaged and have been sent back to the manufacturer for repair (see map 3). In the meantime, staff has ordered new equipment to replace the damaged equipment. Staff is also reevaluating all locations with sensitive equipment to prevent further high water damage.

As mentioned above, high waters have overtopped existing DNR gages that MCWD staff read weekly. One site where a kayak is not possible, Lundsten Lake North, staff installed new gage and surveyed the zero reading. The other site, Mooney Lake, staff installed and surveyed a new gage to assist the volunteer gage reader (see map 3).



Map 3. Water and Flow Monitoring Additions

d. Data reporting
   i. Staff report water levels and flow readings to Telly Mamayek and Tiffany Forner to ensure accurate communications about the high water conditions throughout the watershed.

III. Permitting Department

The Permitting Department is working with local communities and contractors to identify and evaluate infrastructure issues associated with high water, provide technical advice, permit repair work, and perform routine site inspections following rain events. Below is a brief summary of activities to date.

a. As part of the regular activities of the permitting program, over 200 construction site inspections have been conducted since June 1, 2014.

b. 7 slope failures have been reported to District staff and are in various stages of permitting and repair. These are located along CSAH 44, near Crane Island Minnetrista, Casco Point in Orono and near Cedar Point Road in Minnetrista.

c. Staff is working actively with shoreline contractors to gather additional information regarding shoreline and streambank issues associated with high water conditions. This data will be aggregated and summarized in the final report. Approximately 70 inquiries have been made to date regarding damaged shorelines.

d. Staff is also working to obtain data from local communities, regarding emergency response and infrastructure damage. A questionnaire has been distributed to local communities requesting information so that the District can assist in long term initiatives that may help member communities mitigate and prepare for future flooding. Information requested includes, locations of high water, impact to local roads, pipe/culver capacity issues, water level measurements, pictures, video, measures taken and resources spent responding to emergency issues.

IV. Communications Department

a. Email updates to communities/information coordination
    i. Began outreach effort on 5/30/14 with a proactive email to communities about flooding potential
    ii. Continued to issue regular email updates on water levels, dam discharge rates, weather conditions, etc.
    iii. Participated in 6/19/14 news conference at the Hennepin County Emergency Operations Center
b. Website, social media, Splash e-newsletter updates
    i. Daily updates of high water messaging on home page of website
    ii. Frequent updates on District's Facebook and Twitter pages, including sharing photos of flooding
    iii. Distributed several Splash e-newsletters to subscribers
c. Documentation
    i. Created photo and video archive of flooded areas
    ii. Catalogued aerial photos of flooding from Erdahl Aerial photos
    iii. Collected information from cities on structures impacted by high water
d. Internal communications

i. Developed talking points and a list of flood-related resources for staff to use when asked about high water.

e. Respond to media requests
   i. Fielded dozens of media requests for information
   ii. Granted numerous interviews with at least 12 media outlets, including the Weather Channel.

f. LMCD coordination
   i. Daily report of lake elevation to LMCD.
   ii. Shared information on minimum wake restrictions on the District website, social media channels, Splash e-newsletter and email updates to communities
   iii. Provided updates for LMCD Board

f. Wastewater discharge info coordination (Mound and others)
   i. Shared information on the District website, including links to City of Mound and Metropolitan Council websites.
   ii. Responded to citizen inquiries for information

V. Operations & Maintenance Department

The Operations and Maintenance (O&M) Department is working closely with the Communications Department to communicate precipitation events and high water concerns. The O&M Department is also working closely with local communities and Hennepin County Emergency Management to evaluate the District's infrastructure under high water. O&M staff is also performing regular inspections of District's projects to identify needed repairs. When water levels begin to recede, O&M staff will evaluate all of the needed repairs and prioritize the repairs. Below is a brief summary of the activities to date.

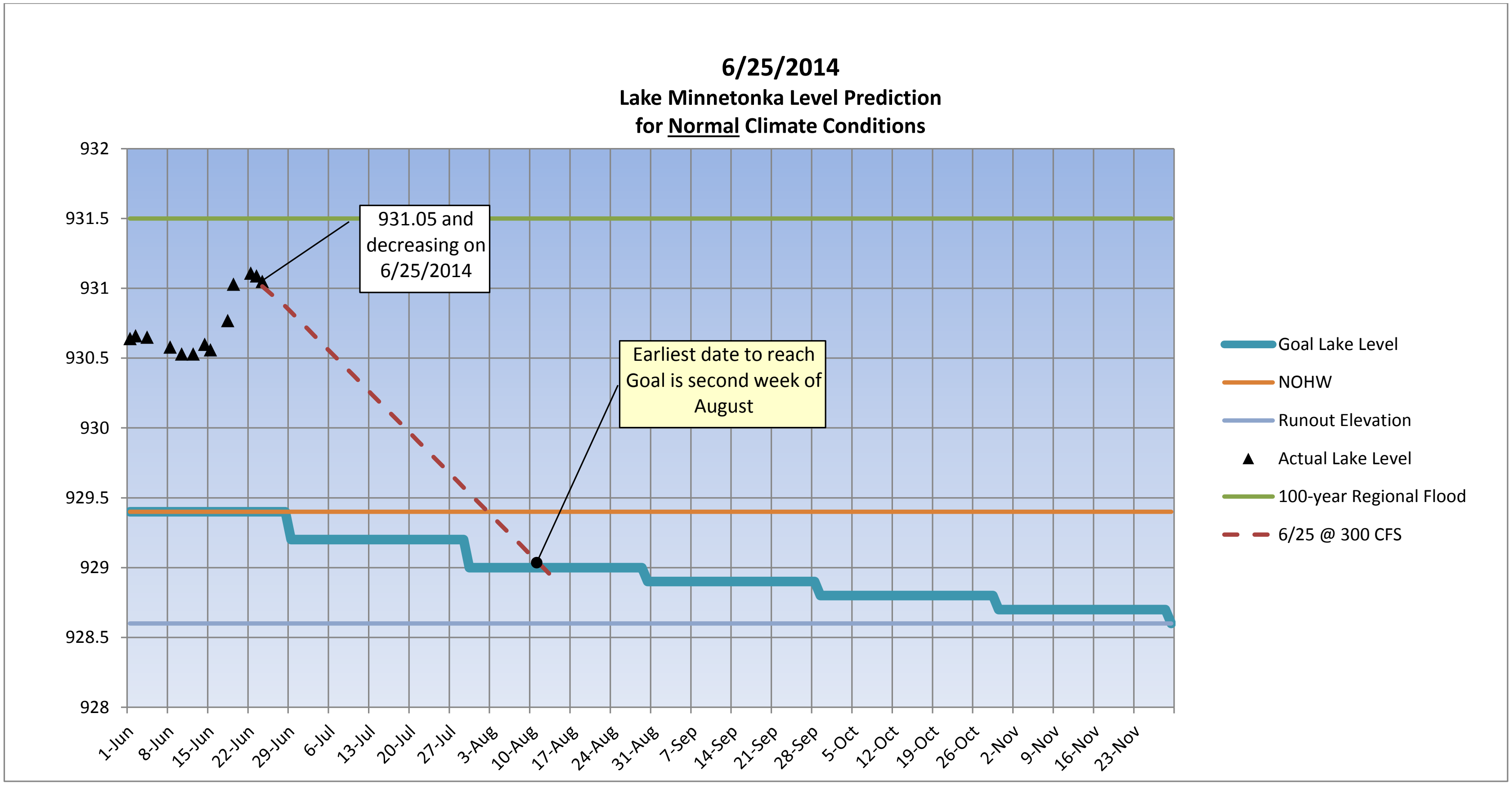
a. Dam operations & McGinty Road culverts
   i. Difficult to estimate how much water is being discharged since the lake and wetland are nearly the same level.
   ii. Discharge is no longer a function of the hydraulic characteristics of the outlet structure but rather a function of the capacity of the dual box culverts at McGinty Road.
   iii. On June 25, 2014 the creek was flowing at 474 cubic feet per second at McGinty Road.

b. District infrastructure
   i. Painter Creek culverts at Creekwood Trail
   ii. Mooney Lake pumping

c. District capital project inspections
   i. Recent inspections revealed erosion at Steiger Wetland and Long Lake Shoreline, hypoxic vegetation at Steiger Wetland and Nokomis Ponds, inundated vegetation, erosion, and bare ground throughout sites at Reach 14, inundated vegetation and inundated areas of the boardwalk below the 100 year flood elevation at Reach 20.
   ii. Six-Mile Marsh Prairie Restoration, Headwaters Shoreline Restoration, Independence Wetland, Chelsea Woods channel restoration, and Saunders Raingardens are functioning well.

d. Coordination with Hennepin County Emergency Management and National Weather Service
    i. Coordinating several times a week since May 29th
    ii. Working on gathering information for a Preliminary Damage Assessment for Hennepin County
e. Aerial photography
    i. Captured aerial photographs of priority areas across the District to identify areas of flooding. Use these images to coordinate with communities to identify potential future project sites.

ATTACHMENT A



Prepared by Wenck Associates, Inc., for the Minnehaha Creek Watershed District

MINNEHAHA CREEK WATERSHED DISTRICT

High Water Update

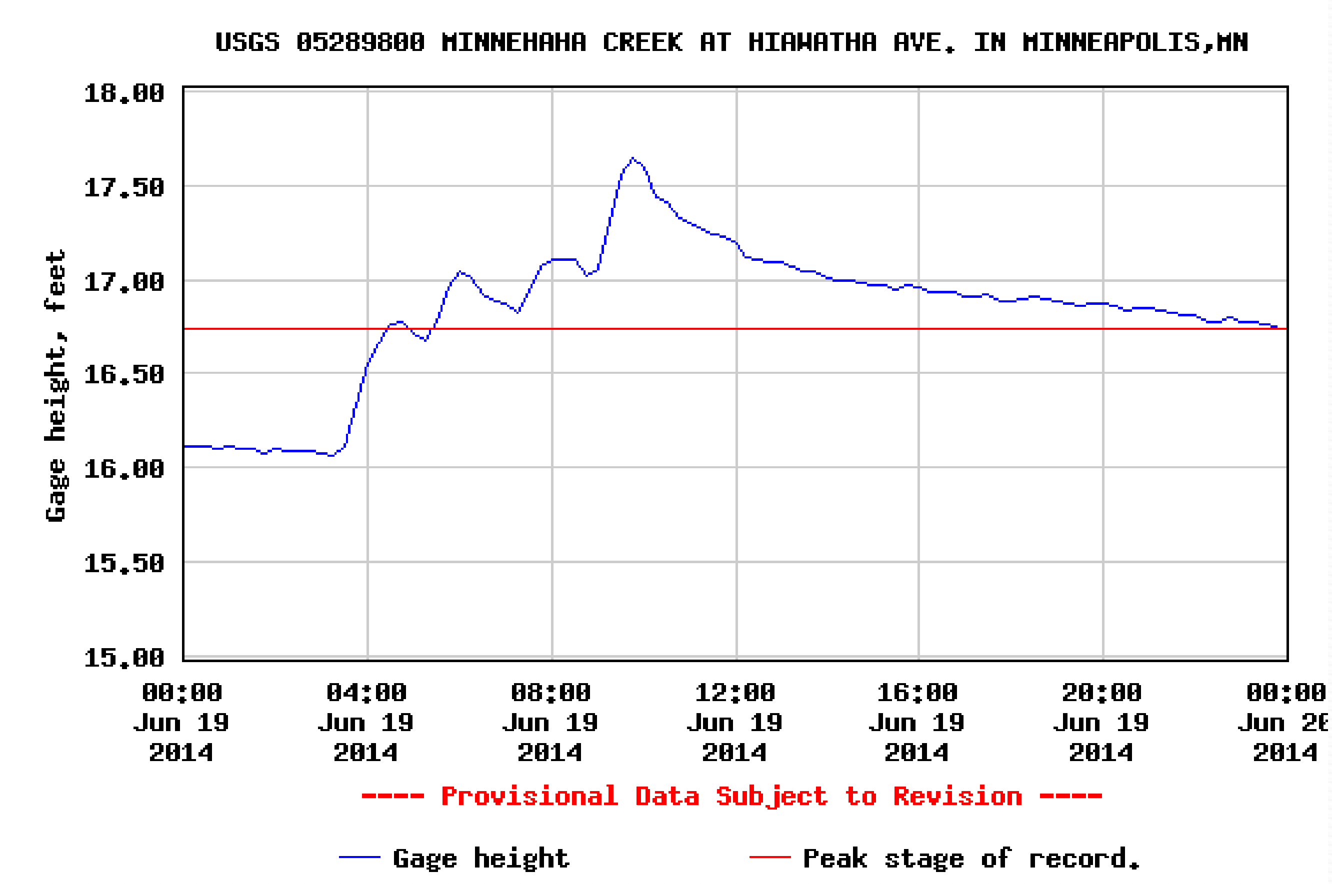
June 26, 2014

MCWD Board of Managers Meeting

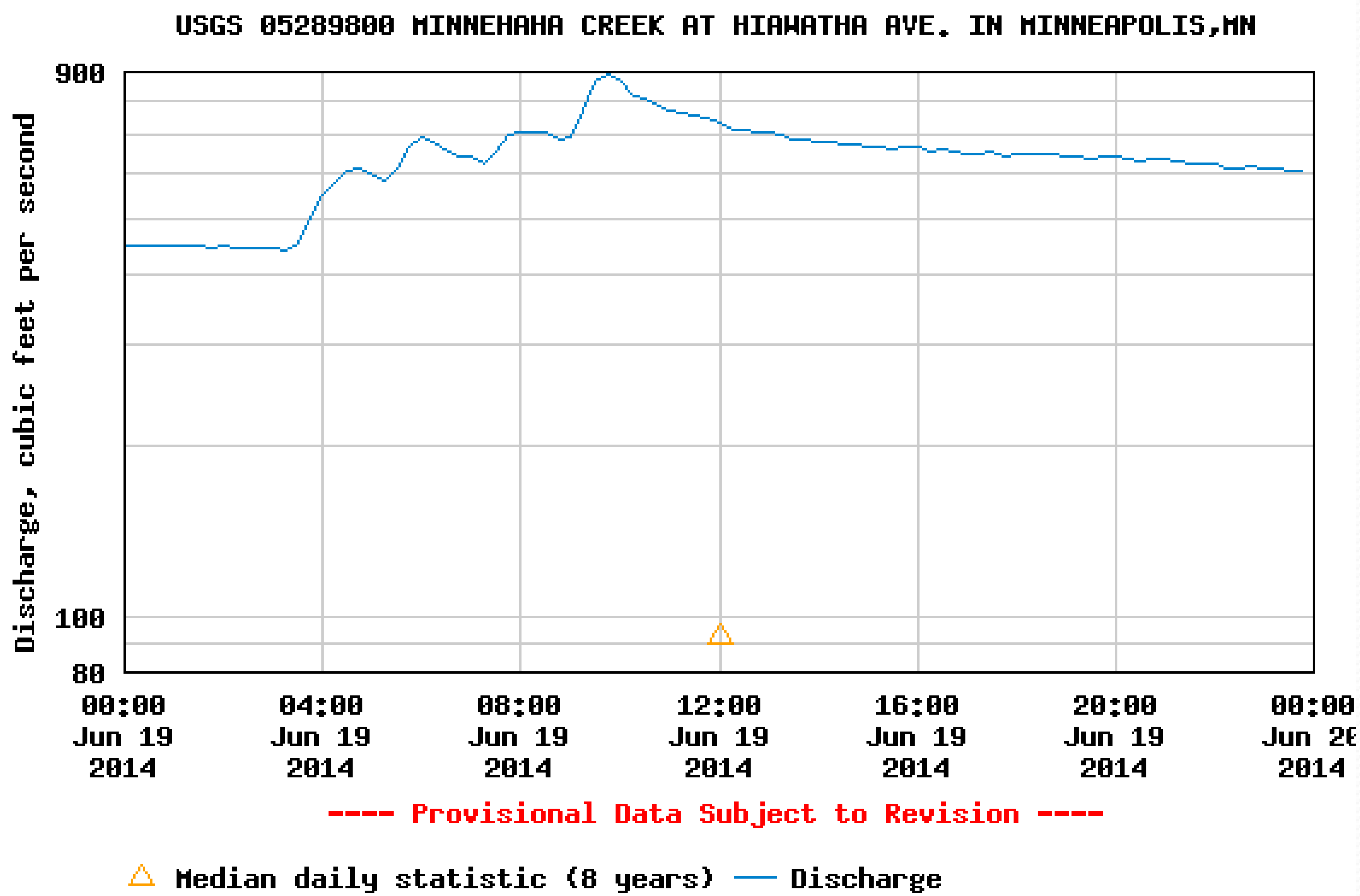
Outline

- Current Conditions/ Statistics
- MCWD Department Coordination
  - Water Quality
  - Permitting
  - Communications
  - Operations & Maintenance
- MCWD Project Status
- Next Steps

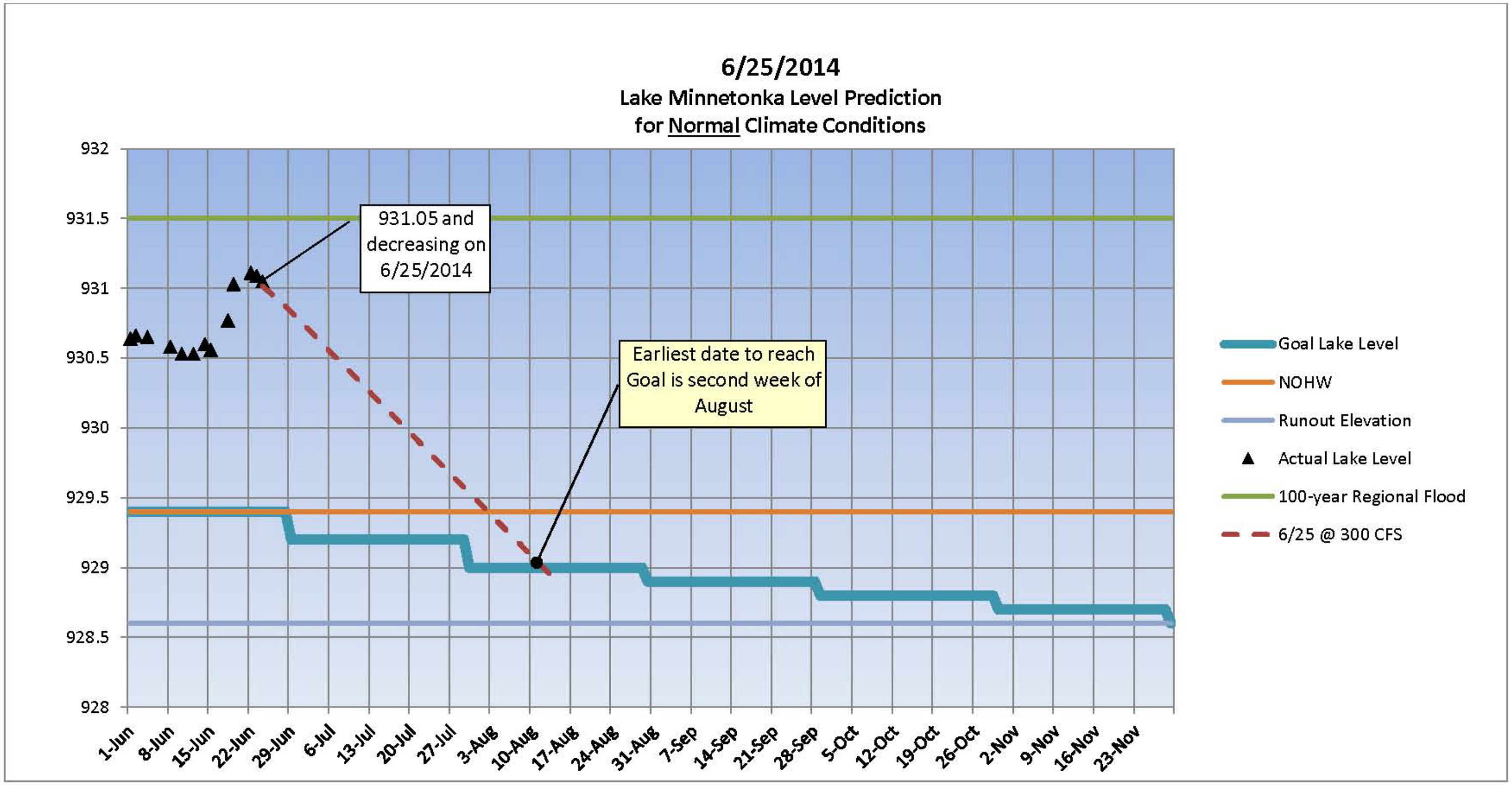
Minnehaha Creek Height



Minnehaha Creek Flow



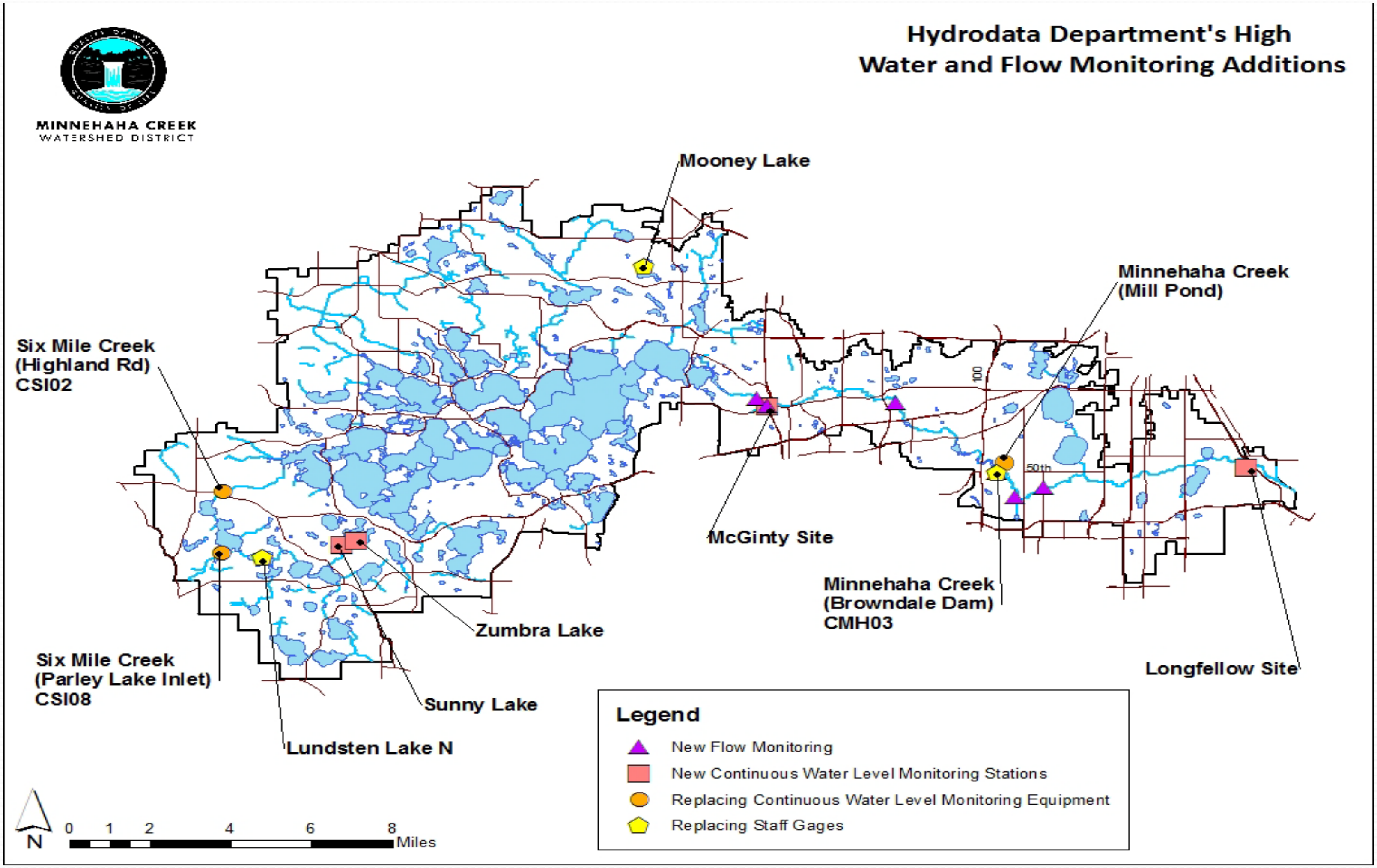
Lake Minnetonka Level Prediction



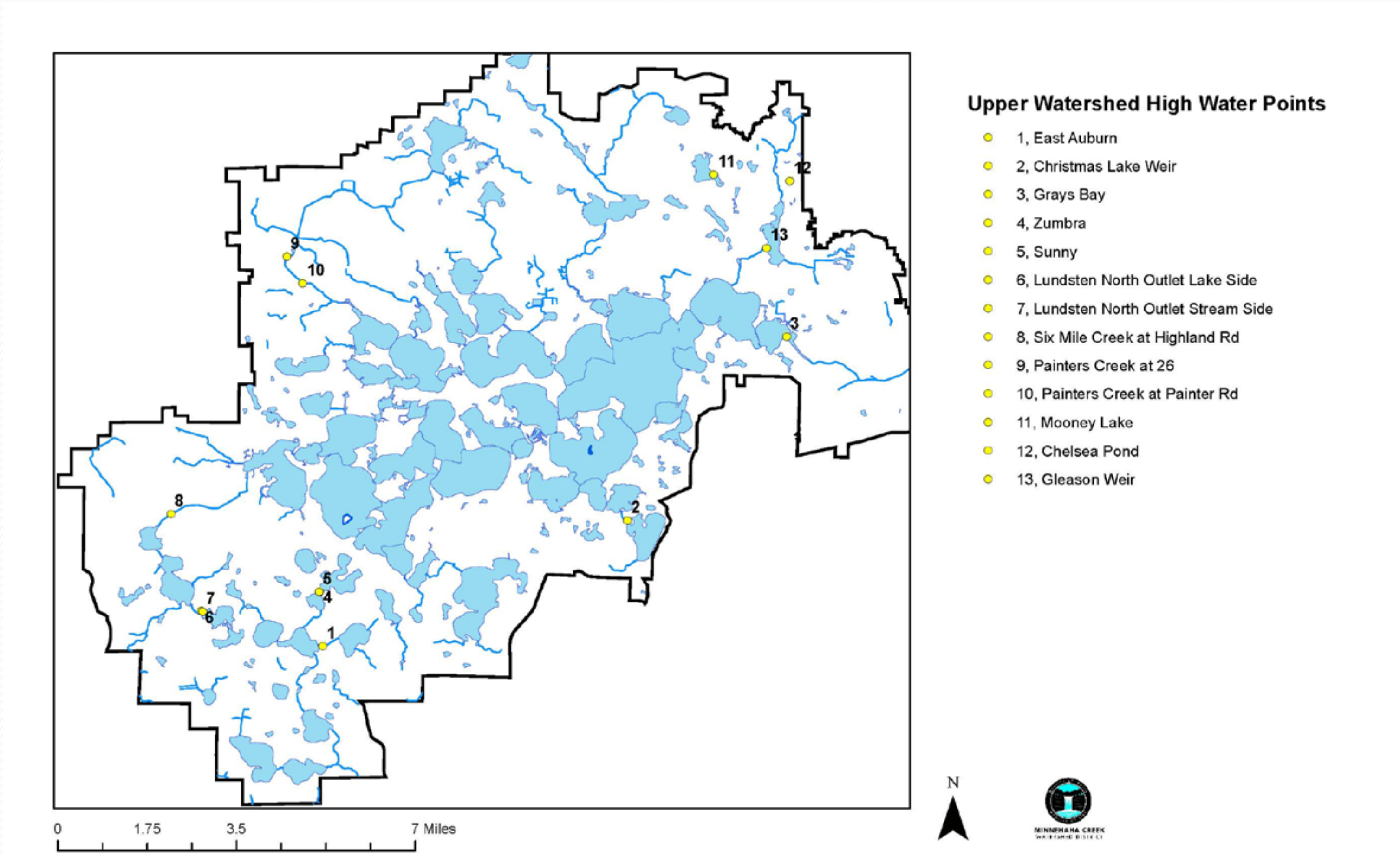
Prepared by Wenck Associates, Inc., for the Minnehaha Creek Watershed District

MINNEHAHA CREEK WATERSHED DISTRICT

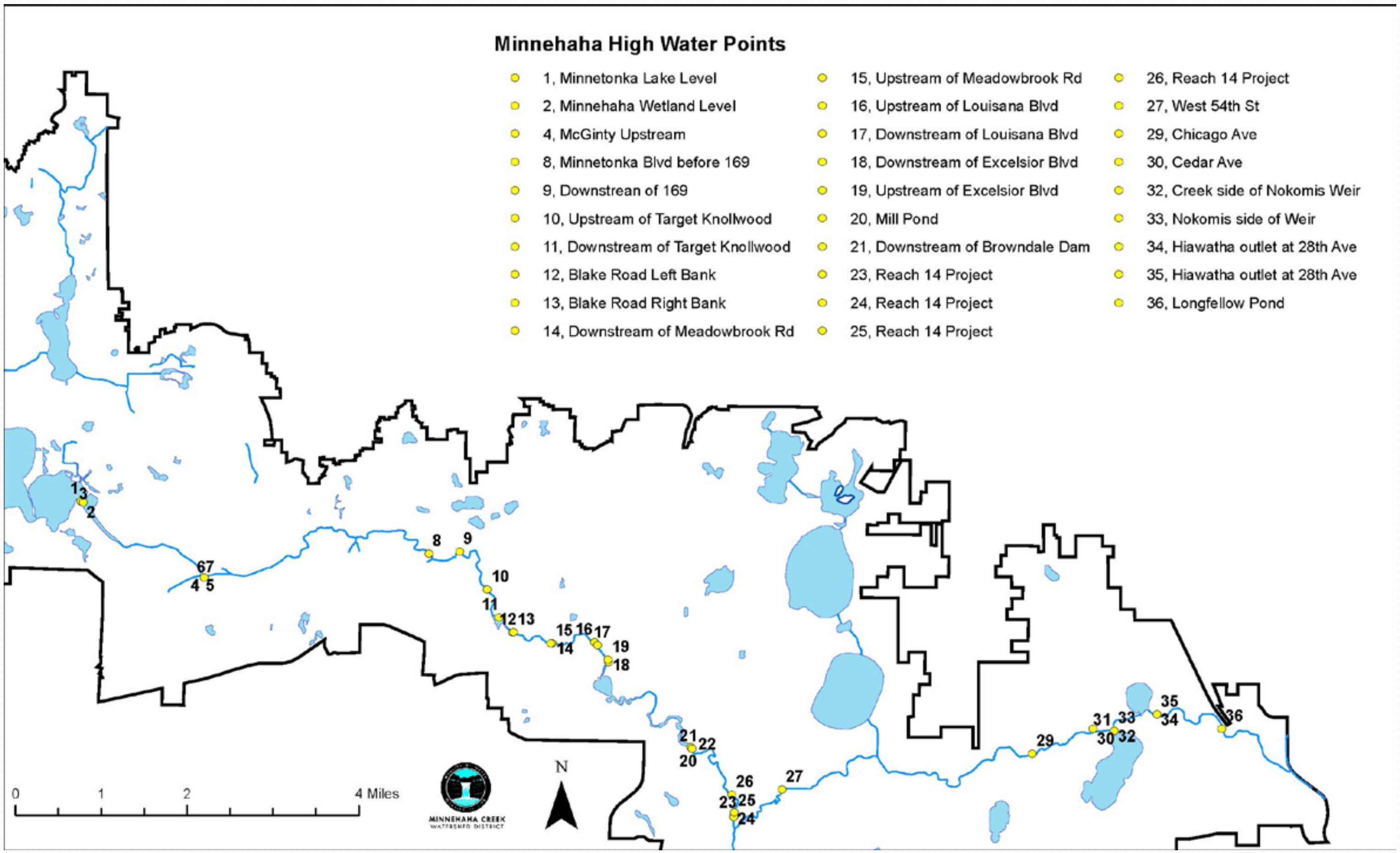
Additional Monitoring Sites



High water survey points



High water survey points



MINNEHAHA CREEK WATERSHED DISTRICT

City Information

City	Structures Impacted	# of sandbags used
Deephaven	1	
Edina	54	11,000
Excelsior	5	
Medina	0	
Minneapolis	13	
Mound	27	
Plymouth	12	
Richfield	0	
Shorewood	26	
St. Louis Park	50	50,000
Wayzata	4	

La

May 1, 2014

June 20, 2014

Gray's Bay Dam

May 1, 2014

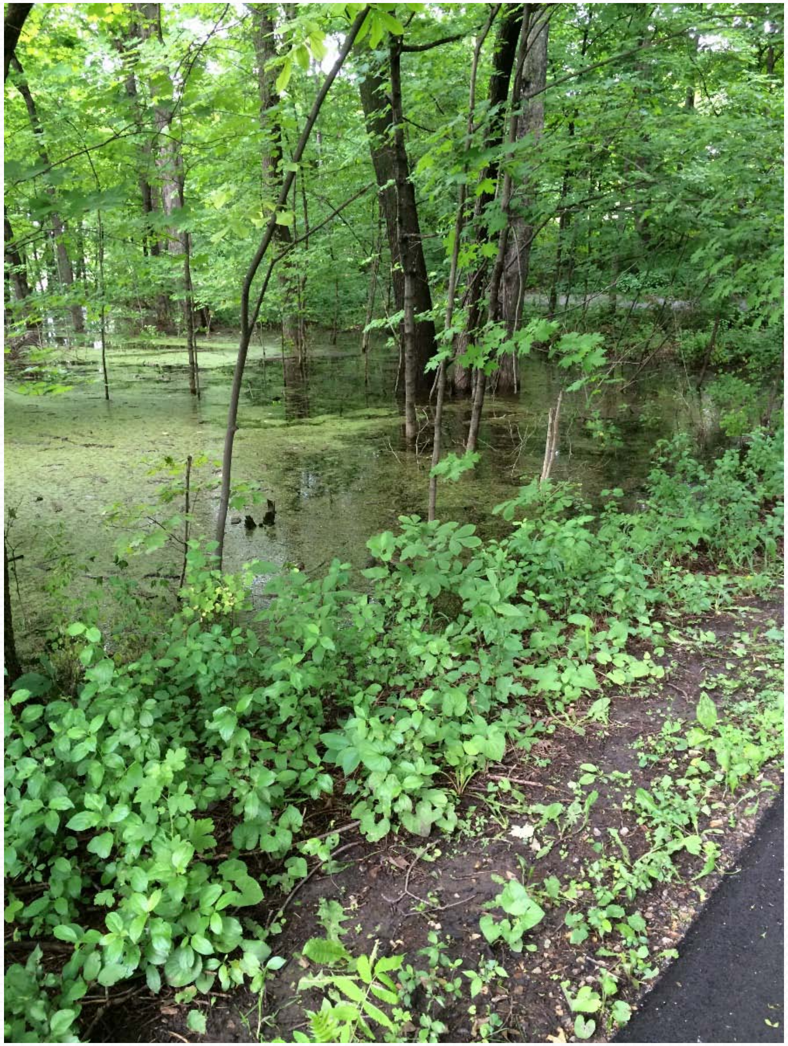
June 20, 2014

Lake Katrina & Painter Creek

MINNEHAHA CREEK WATERSHED DISTRICT

Lake Katrina & Painter Creek

Painter Creek Culvert



MINNEHAHA CREEK WATERSHED DISTRICT

Steiger Wetland

Steiger Wetland

Reach 14

MINNEHAHA CREEK WATERSHED DISTRICT

Six Mile Marsh Prairie Restoration

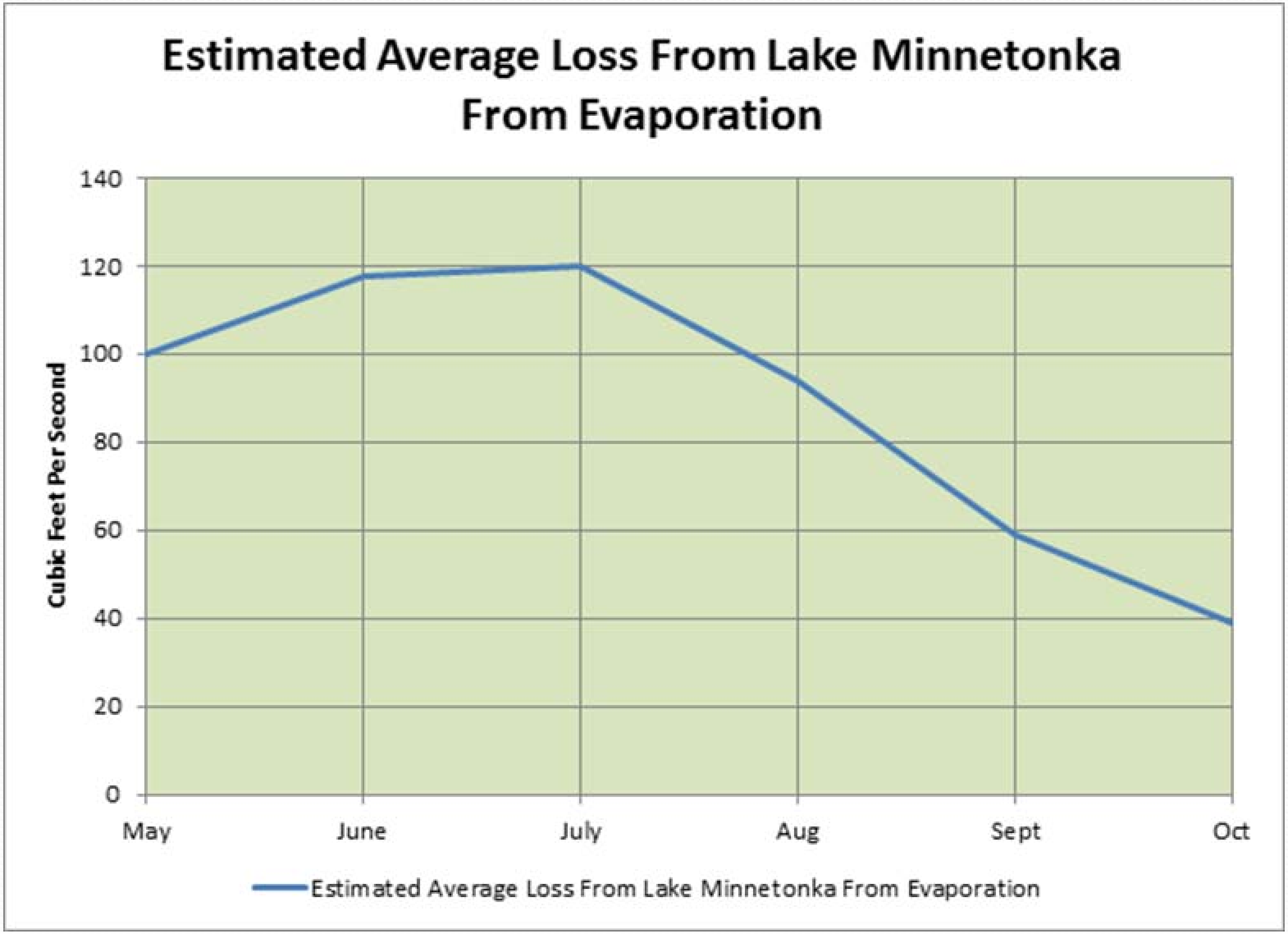
Nokomis Weir

Amelia Pond at Lake Nokomis

Lake Hiawatha

MINNEHAHA CREEK WATERSHED DISTRICT

Meadowbrook Golf Course


Estimated Average Loss From Lake Minnetonka From Evaporation
Cubic Feet Per Second
140
120
100
80
60
40
20
0
May
June
July
Aug
Sept
Oct
Estimated Average Loss From Lake Minnetonka From Evaporation

MINNEHAHA CREEK WATERSHED DISTRICT
QUALITY OF WATER QUALITY OF LIFE

MEMORANDUM

To: MCWD Board of Managers

From: James Wisker

Date: November 6, 2014

Re: Groundwater infiltration and sanitary sewer

Purpose:
To provide a status report regarding groundwater infiltration and sanitary sewer issues, as requested at the October 23, 2014 Board Meeting.

Background:
In June 2014, MCWD received inquiries and a request for information regarding the District's role in working with communities and the Metropolitan Council on infiltration and inflow into sanitary sewers. Specific requests were also made by Mr. Tom Casey, regarding the City of Mound.

In response to these requests, District staff compiled the attached memorandum, and the District Engineer attended the Citizen's Advisory Committee to answer questions.

Attachments:
June 20, 2014 Memorandum

If there are questions in advance of the meeting, please contact James Wisker at 952-471-4509 or Jwisker@minnehahacreek.org

MINNEHAHA CREEK WATERSHED DISTRICT
QUALITY OF WATER QUALITY OF LIFE

MEMORANDUM

TO: Tom Casey

FROM: MCWD Staff

RE: **Mound Wastewater Discharge**

DATE: June 20, 2014

In response to your inquiry regarding the wastewater discharge in the City of Mound on June 1, 2014, District staff compiled the following reply.

1. Did the MPCA make the correct call?

Like many cities around Lake Minnetonka, the City of Mound's sanitary sewer collection system drains by gravity to several lift stations or manholes where the sewage is pumped into the interceptor system – a system owned by Metropolitan Council Environmental Services which sends the wastewater to a central treatment facility. During wet weather conditions, these sanitary sewer systems often experience infiltration of shallow groundwater into the collection pipes. This increases the flow in the collection pipes and the amount of water and sewage required to be handled by the interceptors.

The record rainfall received on May 31 and June 1, 2014 overwhelmed the ability of portions of the sewage collection and interceptor systems within the City of Mound to accommodate the flow. This is not unique to the City of Mound and was reported to have happened in dozens of Minnesota cities at the same time Mound experienced problems.

The City of Mound Public Works Department monitored these functions and discovered the pumps were not keeping up with the incoming flow, in part due to the volume of flow as well as pressure in the interceptor. A vacuum truck was employed to remove excess water and sewage from the lift stations. When that equipment broke down, a second truck was employed but the City was left with two unattractive options:

1. Allow excess water and sewage to continue to accumulate in the lift stations. This would cause the wastewater to back up into the collection pipes and flood up to a thousand homes and businesses. Actual backups were limited to less than thirty. Or, …

2. Use additional portable pumps to pump the excess water and sewage from the lift stations, preventing backups into living spaces and discharge the wastewater into Lake Minnetonka.

Since sewage backups into living spaces present direct human exposure to wastewater and could result in unknown but substantial property damage, the discharge to the lake was deemed more protective of human health, posed less exposure risk and less property damage potential. The impact to the lake is mitigated by dilution and natural degradation of bacteria in the environment. The wastewater release was a difficult decision, but the public health threat and property damage were minimized as a result.

2. Was the MPCA following all of the laws? Under what legal authority did the MPCA act?

The Minnesota Pollution Control Agency regulates wastewater treatment operations under Clean Water Act authority delegated to it from the federal government and state law (Minnesota Statutes Chapter 115). State law prohibits the disposal of untreated sewage into any waters of the state. MPCA's guidance on the operation of wastewater treatment systems and facilities during flood events anticipates that bypass of the treatment system will be necessary under certain conditions[1]. An operator's obligations under such circumstances are to report a discharge (in accordance with Minnesota Statutes Chapter 115.061) and discontinue it as soon as possible.

[1] http://www.pca.state.mn.us/index.php/view-document.html?gid=2822

3. What infrastructure deficiencies created this problem? Who is responsible for those deficiencies?

The condition that caused the discharge of sewage and water to Lake Minnetonka was excessive infiltration of shallow groundwater into the sewage collection system, not only locally, but upstream as well. The capacity of lift station pumps in the City of Mound was limited by the head pressure in the interceptor resulting from the high flow.

4. Why was it that only the City of Mound had to release untreated sewage?

According to news reports, there were dozens of wastewater releases, not only within the City of Mound but in cities all across the state.

5. When will the untreated sewage flow stop?

According to a joint news release from the MPCA and the City of Mound issued on June 1, 2014, the discharge began at 10:30am on June 1, 2014. It continued over a period 12-13 hours.

6. What pollutants were released in the lake?

About 1+ million gallons of diluted sewage was discharged to waters. Sewage can contain heavy metals, organic pollutants like PAHs PCBs. Over 6,000 organic compounds have been found in raw sources from human activities. Some are easily biodegradable and some are not. Of course, the presence of pathogens is often indicated by fecal coliform and *e coli*.

7. Who will be monitoring water quality (health)?

The City of Mound is conducting monitoring in coordination with the Minnesota Department of Health using MPCA prescribed methodology. According to an announcement from the City of Mound, as of Friday, June 13, 2014, test results showed all but one of the six discharge locations

(Langdon Lake) had bacteria levels below a level of concern. Langdon Lake has long-standing water quality issues unrelated to the recent discharges.

8. What steps are being taken to ensure that this never happens again – in my city or any other Minnesota city?

Metropolitan Council Environmental Services (MCES) and cities with infiltration issues have programs to update and maintain their systems. According to the City of Mound, it budgets about $1 million each year for that purpose and MCES has ongoing projects to upgrade the interceptor system. However, it is expected that bypasses and discharges could occur again in the future, if precipitation events cause similar issues to occur.

The City of Mound addressed emergency response steps at a Council meeting on Tuesday, June 10th.

9. What role does the MCWD intend to take in this matter? Of course, I believe that MCWD needs to get to the bottom of the questions posed above.

Matters of public health are under the jurisdiction of the Minnesota Department of Health. Generally, the Minnesota Pollution Control Agency regulates the construction and operation of sewage treatment systems in the state. While the Minnehaha Creek Watershed District (MCWD) takes a keen interest in ensuring that its significant investments in water quality improvements are protected and works with municipalities and other partners to address specific sources of contamination, it does not regulate the operation of wastewater treatment systems.

There is no indication that District rules were violated by the decisions made or the events that occurred in the City of Mound. MCWD will continue to provide coordination and have a cooperative role when these types of precipitation conditions cause issues with water resources within the MCWD.

10. How can citizens receive up-to-date information?

Throughout the situation, the City of Mound has been proactive in its messaging by issuing timely news releases. The first announcement came within hours of the wastewater discharge on June 1, 2014 and regular updates have been provided on the city's website. MCWD has kept citizens informed with postings on the District website that include links to the City of Mound's website and contact information for Mound City Manager Kandis Hanson.

Additionally, MCWD staff members have responded to citizen inquiries for information and provided them with contact information for the appropriate agencies as needed. The District has done its best, with limited resources, to be helpful and responsive during this time.

MEMORANDUM

To: MCWD Board of Managers

From: Brett Eidem

CC: James Wisker

Date: November 3, 2014

Re: Street Sweeping

Purpose:
To provide a status report on Street Sweeping, as requested at the October 23, 2014 Board Meeting.

Background:
In 2011, the Minnehaha Creek Watershed District initiated an effort to analyze the effectiveness of street sweeping as a best management practice (BMP), as performed by municipalities within the District. By providing technical, logistical and financial support, the District secured 11 project partnerships to collect and analyze sweepings collected by local communities. Due to the limited capacity of District staff, city staff were principally relied on to follow sweeping collection protocol and keep accurate records, preserving quality control and assurance. Despite best efforts to maintain adherence to protocol, during 2011 and 2012, inconsistencies in data collection were found, rendering data subject to difficulties in developing statistical comparisons.

At that time the District became aware that the City of Prior Lake was implementing its own comprehensive street sweeping study in coordination with the University of MN, with stronger controls and oversight. Consequently, the Board of Managers was advised, in a February 4, 2013 memorandum and presentation, to discontinue the program in favor of capitalizing on the Prior Lake results.

At the March 27, 2014, regularly scheduled meeting of the Board of Managers, Dr. Lawrence Baker presented the findings of the Prior Lake Street Sweeping Study. No Board action was taken, or direction provided.

At the April 23, Citizen Advisory Committee meeting, Cost Share Staff introduced a grant proposal to assist in funding the City of Edina's purchase of a new regenerative air sweeper, and the development of a street sweeping management plan for MCWD. The proposal requested 30% funding (approximately $11,000) from MCWD and 70% funding from Nine Mile Creek Watershed District.

During discussion concerns were raised regarding the precedence of funding municipal equipment, it was noted that the potential precedent issue should be reconciled by the Board, and that further investigation take place before a decision was made on funding. The consideration was tabled pending discussion by the Board of Managers.

Subsequently, the City of Edina purchased the regenerative air sweeper without MCWD funding, rendering the need for a project specific policy discussion unnecessary. Further, during 2014 Board discussion regarding the reconfiguration of the Cost Share Program, and subsequent budget discussions, it became clear that the program would increase focus in 2015 on education programming. Moreover, given fiscal limitations with the 2015 budget and levy, the potential to expand Cost Share programming was limited.

Next Steps/Board Meetings:

Should the Board of Managers wish to engage in a policy discussion regarding the long term implications of funding municipal public works equipment, the topic could be scheduled for discussion at the Policy and Planning Committee. Alternatively, discussion could take place during the final review of the 2015 Cost Share Workplan, scheduled for December.

Outside of immediate policy discussion, the Planning Department has developed a proposed schedule of policy discussions in the context of the Comprehensive Planning effort. Included in this schedule are discussions related to local government unit (LGU) load reduction requirements, best management practices, and model ordinances/minimum standards.

Attachments:

- Quantifying Nutrient Removal by Street Sweeping
- User Support Manual: Estimating Nutrient Removal by Enhanced Street Sweeping

If there are questions in advance of the meeting, please contact Brett Eidem at 952-641-4523, or beidem@minnehahacreek.org

QUANTIFYING NUTRIENT REMOVAL BY STREET SWEEPING

Lawrence A. Baker[1], Sarah Hobbie[2], Paula Kalinosky[1,3]
Ross Bintner[4], and Chris Buyarski[2]

[1]Department of Bioproducts and Biosystems Engineering,
University of Minnesota

[2]Department of Ecology, Evolution, and Behavior
University of Minnesota

[3]EOR, Inc.

[4]Engineering Department, City of Edina

Final Report to the EPA 319 Program

MPCA Contract B43119

Introduction

The final report for the Quantifying Nutrient Removal by Street Sweeping project funded through the EPA 319 Program is presented as a short report summarizing the work completed, grant results, and project expenditures. The grant results section describes the project measurements, products developed and presented, public outreach impacts, and long-term results expected from the project. Individual products developed for the project are then attached as appendices.

Section I – Work Plan Review

Task 1: Conduct street sweeping, with field data collection on mass removed and costs. We worked with the City of Prior Lake to develop a protocol for collecting, subsampling, and storing street sweeping samples in the first month of the study, allowing samples to be collected almost immediately. The City of Prior Lake collected 392 sweepings samples over the first two years of the project, compiled GPS records for their sweepers, and conducted a financial breakdown of sweeping costs (labor, fuel, maintenance, capital). These costs were embedded in the Street Sweeping Planning Calculator (Task 2).

Task 2. Conduct literature review, analyze street sweeping samples, analyze data (Tasks 1 and 2), and interpret findings.
We completed a literature review on prior studies of street sweeping in relation to nutrient removal for the User Support Manual. Before analyzing sweeping samples, we developed a unique lab protocol to analyze nutrients in very heterogeneous material, using flotation to separate coarse organic matter (leaves, etc.) from other large particles that did not pass through a 2 mm sieve. The procedure is described in our Users Manual and in the overview journal article. Using this procedure, we analyzed three fractions of each sweeping: fines, coarse organics, and soluble for total P, total dissolved P (soluble only), total N, total C, and dry mass. To interpret the relationship between nutrient and solids removal and tree canopy, we acquired a fine-resolution (0.6 m) land cover database developed for City of Prior Lake by the University of Vermont Remote Sensing Lab, using an expert system approach developed by Dr. Marv Bauer's research group at the University of Minnesota. This allowed us to determine tree canopy cover with a high degree of accuracy. It also enables users to "map" nutrient removal rates quantified in Prior Lake to any other city with similar land cover mapping.

We analyzed our data to determine the influence of number of sweepings/month, time of sweeping (month of the year), and tree canopy cover. This resulted in three one-equation models to predict (separately) total P, total N, and total solids removed, in kg/curb mile per sweep, and in kg/curb miles per year. This equation was embedded in our Street Sweeping Planning Calculator. We also conducted five-way cross validation statistical analysis to determine the robustness of our model within the City of Prior Lake, and found that it was extremely robust.

Our findings were summarized in a key document "User Support Manual: Quantifying Nutrient Removal by Street Sweeping". This includes our literature review, a brief summary of findings, including those from the decomposition study (next task), and guidance for using the Street Sweeping Planning Calculator. The Calculator itself is an open-source, Excel-based spreadsheet, now posted at the Stormwater U page (see Products, below).

Task 3. Develop and conduct a leaf litter decomposition experiment.
The goal of this experiment was to determine the potential for short- and long-term release of nutrients from tree leaves falling into streets. To conduct this experiment, we placed autumn leaves of five common species of trees into screen mesh bags, placed them along a curve, and sacrificed them periodically throughout a X month period. Retrieved samples were weighed and analyzed for dry mass, N, P, and C to determine losses. Results were published in the journal *Urban Ecosystems* (Hobbie et al., see Products) and, in summary form, in our Users Manual.

Task 4. Develop, evaluate, and disseminate a users manual on the topic of street sweeping for stormwater management. We convened a Technical Advisory Group (TAG), mostly stormwater management personnel from cities and MPCA, to advise us on development of the Users Manual. The TAG met every six months. The User Support Manual and accompanying Street Sweeping Planning Calculator were developed to enable professionals involved in stormwater management and/or street sweeping to estimate quantities of solids, N, and P that would be removed under various user-designated scenarios. The TAG was instrumental in providing advice to revise earlier versions of the calculator tool, allowing us to develop a final version that is especially useful as a planning tool, realistic enough to provide reasonable estimates of sweeping load removals, but simple enough to implement that it will be a useful operational tool.

We held four workshops, two with large groups of personnel from public works and street departments of several dozen municipalities, plus a few consultants, attending by a total of 78 individuals. Another workshop was developed for elected officials, part of the NEMO (Nonpoint source Education for Municipal Officials), and a final workshop was developed for MPCA staff, presented across MPCA offices statewide via teleconferencing.

Task 5. Write and submit administrative reports and invoices.
These were written in a timely manner throughout the project.
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Section II – Grant Results

Measurements:

In the field, wet sweepings loads were measured by weighing the sweeper before and after sweeping using a truck scale. The City of Prior Lake provided odometer readings and GPS-tracked routes to us so that we could compute “curb miles swept” for each of 12 routes swept.

In the lab, core measurements were analyses of 392 sweepings samples, plus appropriate QA samples. Samples were separated into fine solids, coarse organic matter, and water (soluble nutrients) using a novel separation procedure; the solid samples were then ground to powder and analyzed for N, P, and C; water samples were analyzed for soluble N, P, and C.

Street canopy cover was measured using the University of Vermont land cover data set mentioned above. We conducted an extensive analysis of which canopy cover metric best correlated with sweepings load removal, evaluating “over the street” and buffer distances of 5, 10, 20, 50, 100, and 250 feet). In the end, we selected “canopy over the street” as the metric of choice, because it gave good correlations with load removal and was robust.

<u>Products</u> (= required by work plan):**

Several products were developed and presented as a part of the project. The following list of products is grouped by product type. As noted above, the double asterisks identify products required in the project work plan.

Translational tool:

> ******User Support Manual: Estimating Nutrient Removal by Enhanced Street Sweeping. Kalinosky, P., L. Baker, S. Hobbie, R. Bintner. Report to the MPCA/EPA. Attached as **Appendix A.**
>
> ******Street Sweeping Planning Tool, an Excel spreadsheet, available for free and downloadable from the Stormwater U web site at (http://www.extension.umn.edu/environment/stormwater/pastNov13.html).

Peer-reviewed publications:

> ** Hobbie, S.E., L.A. Baker, C. Buyarski, D. Nidzgorski, J.C. Finlay. 2013. Decomposition of tree leaf litter on pavement: implications for urban water quality, *Urban Ecosystems*. DOI 10.1007/s11252-013-0329-9. Attached as **Appendix B**.
>
> Kalinosky, P., L. Baker, S. Hobbie, R. Bintner. In prep. Quantifying nutrient removal during enhanced street sweeping. Target journal: *J. Environmental Engineering.* This will also be Paula Kalinosky’s M.S. thesis, to be defended in October 2014. This paper will be included as an appendix when it is accepted for publication.

Magazine and web-based articles:

Baker, L., P. Kalinosky, S. Hobbie, R. Bintner, and C. Buyarski. Quantifying nutrient removal by enhanced street sweeping, *Stormwater Magazine*, Feb/March 2014. http://www.stormh2o.com/SW/Articles/Quantifying_Nutrient_Removal_by_Enhancd_Street_Sw_24833.aspx.

Kalinosky, P., L. Baker, S. Hobbie, R. Bintner. March 2013. Quantifying Nutrient Removal through Targeted Intensive Street Sweeping. *Stormwater Updates*, http://stormwater.safl.umn.edu/updates-march-2013.

Workshops:

**Quantifying Nutrient Load Recovery through Targeted, Intensive Street Sweeping . Kalinosky, P., L. Baker, S. Hobbie, C. Buyarski, R. Bintner. Stormwater U Workshops, Materials posted at *Stormwater U*, http://www.extension.umn.edu/environment/stormwater/pastNov13.html

Dates:

Workshop #1: Nov. 12, 2013
Workshop #2: Nov. 27, 2013
Workshop #3 (Presented by J. Biloti on April 26, 2014)
Workshop #4: Are trees an important source of nutrients to streets? The Prior Lake Street Sweeping Experiment. Videoconference at the Minnesota Pollution Control Agency, April 10, 2014. Slideshow attached as **Appendix C**.

Other Presentations primarily about the street sweeping study:

1. Baker, L. Removal of nutrients by street sweeping. Minnehaha Creek Watershed District Board Meeting, March 27, 2014. (attendance ~ 20).
2. Baker, L. Quantifying Nutrient Load Recovery through Targeted, Intensive Street Sweeping Washington County Water Consortium, Nov. 6, 2013. (attendance ~ 30).
3. Kalinosky, P. Quantifying Nutrient Load Recovery through Targeted, Intensive Street Sweeping, presented via a Chesapeake Stormwater Network Videoconference, October 29, 2013.
4. Kalinosky, P. Quantification of nutrient removal by street sweeping: the Prior Lake Street Sweeping Project. International Low Impact Development (LID) Symposium, St. Paul, MN, August 8-13, 2013. Posted at https://www.linkedin.com/profile/edit?trk=nav_responsive_sub_nav_edit_profile. (attendance ~ 40).
5. Baker, L. Moving Enhanced Street Sweeping from Prior Lake to St. Paul (presentation and discussion), St. Paul Public Works, June 4, 2013. (attendance =15)
6. Kalinoski, K. Quantifying nutrient load reductions through targeted, intensive street sweeping - a field study by the University of Minnesota in partnership with the City of Prior Lake, Minnesota Water Resources Conference, October 16-17, 2012. Slideshow posted at

http://larrybakerlab.cfans.umn.edu/research-projects/quantifying-nutrient-removal-by-street-sweeping/. (Attendance ~ 80)

Presentations based partially based on the street sweeping project:

1. Baker, L., S. Hobbie, J. Finlay, P. Kalinosky, and B. Janke. Moving upstream to reduce urban stormwater phosphorus loading (invited), Session on Water, Energy and Society in Urban Systems, organized by D. Jenerette, J. Loperfido, A. Watts and C. Welty, Dec. 9, 2013 AGU meeting, San Francisco. (attendance ~ 40)
2. Baker, L. Rethinking nutrient management in cities (invited). International Low Impact Development (LID) Symposium, St. Paul, MN, August 18-21, 2013. (attendance ~ 40).
3. Baker, L. The water environment of urban ecosystems: from theory to the street (invited). Minnesota Association of Landscape Architects Annual Education Conference, St. Paul, April 20, 2012. (attendance ~ 100)
4. Flowpaths of nutrients through urban ecosystems. Presented at a TMDL stakeholders meeting, Minnesota Pollution Control Agency, May 3, 2012. (attendance ~ 25).
5. Baker, L., S. Hobbie, D. Nidgorski, C. Fissore, S. Panzer, J. King, J. McFadden, K. Nelson. Movement of P through urban ecosystems. Am. Society of Limnology and Oceanography, San Juan Puerto Rico, Feb. 2011. (attendance ~ 50).

Guest lectures with some inclusion of project results (12 total):

1. Ecology, Evolution, and Behavior (EEB 3603 Science, Protection and Management of Aquatic Ecosystems) – "Managing nutrients in urban ecosystems: moving toward the metabolic city", Spring 2013 and 2014.
2. School of Design (Contemporary Sustainable Neighborhoods: Issues and Directions) – "The water environment of cities", Spring 2013 and 2014.
3. Environmental Studies Program (Cities, Sustainability, and Campus)- "Cities as Urban Ecosystems", Sept. 2011 (Macalester College).
4. Architecture (Ecology and Architecture)- "Planning for the urban water environment", March 2011, 2014.
5. Architecture (Sustainable Landscape Design) – "Biogeochemial perspectives on stormwater management", 2008, 2009, 2010, 2011, 2013.

<u>Photos</u>:

The photo on the title page is attached as a JPG in Appendix D.

<u>Public outreach and education (audiences)</u>:

Public outreach and education occurred through the development and presentation of the project products listed above. A brief description of the audiences reached by product type is given below.

> **Magazine and web-based articles.** Our article in *Stormwater Magazine* potentially reached 25,000 subscribers. The article posted on the *Stormwater Updates* webpage potentially reached 3,000 subscribers.
>
> **Academic journals**. We anticipate that several hundred people each will read two articles produced by this project, and cited 20-100 times each, over time.
>
> **Workshops.** Approximately 80 people attended each of the first two workshops. These were mostly professional public works staff and consultants. Post-workshop evaluation revealed that 93% responded that they found the planning calculator tool "helpful" or "very helpful"; 96% "strongly agreed" or "somewhat agreed" that our workshops provided them with "new skills to plan street sweeping for nutrient removal; and 86% responded that their cities would "very likely" or "somewhat likely to adopt enhanced street sweeping over the next 3-5 years. More evaluation details are presented in **Appendix E**.
>
> **Other talks.** We estimate that about 440 people attended other talks. Audiences were highly varied. Some audiences comprised mainly watershed managers and planners; others were mostly research scientists.
>
> **Guest lectures.** Classes were mostly upper division classes, which typically have about 20 students, on average, so we estimate that about 220 students attended 12 lectures across diverse disciplines.

In summary, it is very likely that our message has reached most of the public works or streets departments in cities in the Twin Cities region, as well as many watershed/water quality professionals in the region. The project has also acquired national visibility.

<u>Long-term results</u>:

This project has accomplished several things. First, it has quantified, for the first time, inputs of nutrients (nitrogen and phosphorus) and solids to streets in relation to overlying tree canopy cover throughout the entire snow-free part of the year. Second, it has shown the street sweeping can be economically efficient, in terms of $/lb P removed, with costs sometimes < 100/lb P for high canopy streets in the spring and fall, a far lower cost than for most structural BMPs. Third, we developed a user-friendly Street Sweeping Planner Calculator that enables public works and streets department staff to estimate quantities of nitrogen, phosphorus, and solids would be removed for each user-define sweeping route, with user-specified sweeping frequency and timing (by month). The calculator also calculates fuel, labor, and equipment costs for each scenario. This allows public works and streets departments to optimize planning scenarios, which they can present to their city councils with confidence, and allows city councils to make informed decisions regarding any additional expenses needed. The Planning Calculator therefore lowers the threshold for adoption.

The graduate student who worked on this project for her M.S. thesis, Paula Kalinosky, is now working at EOR, a local environmental consulting firm, where she has started several new projects to plan enhanced sweeping scenarios for the Browns Creek Watershed District (for areas in the city of Stillwater) and for the City of Edina. She has noted that enhanced street sweeping may be a recommended BMP in some watershed analyses that EOR is doing for the City of Crosby, Minnesota; the City of Thunder Bay, ON; and others. Two years ago, she worked on a graduate student project team with Minnehaha Creek Watershed District on a surface water quality improvement project that included enhanced sweeping.

With regard to the University's long-term effort regarding street trees and street sweeping, we (co-PIs Baker and Hobbie, along with others) are developing a conceptual model of flowpaths of nutrients in urban landscapes. Data from our sweeping study has informed this model, which we hope leads to better understanding of how to reduce nutrient inputs to storm drains. For example, we have found a strong correlation between tree canopy cover in six subwatersheds of the Capital Region Watershed District and modeled coarse organic P (COP) removal by sweeping.

As to "lessons learned", this has been one of the most rapidly translated projects that either the PI or co-PI has worked on, and an experience that we hope to repeat. This occurred for two reasons: (1) our research filled a void in knowledge that, once filled, had enormous practical application; and (2) we developed an accessible modeling tool that is simple enough to use that it is leading to rapid adoption by cities.

With regard to MPCA, we greatly appreciated Greg Johnson's (our project officer) effort to enable us to present our findings of two 319 projects to MPCA offices statewide, and have suggested that MPCA might in the future hold "319 workshops" for projects to share findings.

Section III – Final Expenditures

The final budget spreadsheet, showing expenses by task, is attached as **Appendix F.**

APPENDICES

Appendix A. User Support Manual: Estimating Nutrient Removal by Enhanced Street Sweeping. Kalinosky, P., L. Baker, S. Hobbie, R. Bintner. Report to the MPCA/EPA

Appendix B. Hobbie, S.E., L.A. Baker, C. Buyarski, D. Nidzgorski, J.C. Finlay. 2013. Decomposition of tree leaf litter on pavement: implications for urban water quality, Urban Ecosystems. DOI 10.1007/s11252-013-0329-9.

Appendix C. Workshop #4: Are trees an important source of nutrients to streets? The Prior Lake Street Sweeping Experiment. Videoconference at the Minnesota Pollution Control Agency, April 10, 2014.

Appendix D. Photo of street sweeping.

Appendix E. Workshop evaluations.

Appendix F. Budget and final expenditures.

User Support Manual:
Estimating Nutrient Removal by Enhanced Street Sweeping

Paula Kalinosky[1,3], Lawrence A. Baker[1], Sarah E. Hobbie[2],
Ross Bintner[4,5], and Chris Buyarski[2]

[1]Department of Bioproducts and Biosystems Engineering
University of Minnesota

[2] Department of Ecology, Evolution, and Behavior
University of Minnesota

[3]Current address: EOR, Inc.

[4]City of Prior Lake, Minnesota (during project period)

[5]Current address: City of Edina, Minnesota

Project Support:
Minnesota Pollution Control Agency
and the U.S. EPA

Contents

Tables

Figures

Chapter 1. Introduction

Nearly every city in Minnesota uses street sweeping to improve the appearance of streets, make them safe for bicyclists and walkers, and reduce the quantity of material entering storm drains. In a survey of street sweeping operations in Minnesota's cities, (Schilling 2005) reported that 57% of respondents swept more than one a year. The most common frequency for most types of roads was twice per year, but "sediment accumulation areas" were most commonly swept 3-6 times per year. Central business districts were swept most often: 27% were swept once a week or more often. In the same survey, 62% of respondents reported that they would sweep more often if it resulted in water quality benefits (and if funding were available). Whether street sweeping benefits water quality has been a recurring question since the inception of EPA's Stormwater Program in 2000, which places stormwater conveyances under the same general regulatory program (the National Pollution Discharge Elimination Program) that formerly include discharges from sewage treatment plants, with the moniker "Municipal Separate Storm Water System", known as the MS4 program.

As the MS4 program evolves, it is moving from operational mandates with no specific water quality goals to mandates based on water quality goals that are specific to the receiving water body. Ten years ago, a MS4 permit might have specified that certain best management practices (such as stormwater ponds) be used. In the near future, permits will specify allowable pollutant discharge limits much the way that limits apply to lakes and rivers that are designated as legally "impaired". This regulatory process has resulted in an increased interest in street sweeping. While it is generally felt that street sweeping must help reduce the quantities of nutrients being flushed from streets to lakes, there has not been a good way to quantify this effect.

For urban lakes, the most common type of impairment occurs because of an overload of nutrients, mainly phosphorus. Excessive phosphorus (and nitrogen) increases the algal abundance in a lake, reduces clarity, shifts the dominance of algae from green to blue-green types, and can result in anoxic conditions (absence or near absence of oxygen) at the bottom of the lake. This process, called eutrophication, also reduces the recreational value of a lake and reduces the value of lakeshore property (Baker and Newman 2014). Reducing the input of P to a lake reduces algal abundance, increases clarity, and generally reverses the process of eutrophication.

We conducted a unique experiment, the Prior Lake Street Sweeping Project, to address the question: what quantities of nutrients could be removed from streets by street sweeping under various conditions? This project provides new types of information that can be used to help cities upgrade their street sweeping operations to meet water quality objectives.

First, we addressed this issue in a novel way: rather than try to measure changes in stormwater loading with various sweeping routines, which is very difficult to do (and hence yields conflicting results; see Chapter 3), we developed a protocol for measuring solids and nutrients (nitrogen and phosphorus) *removed by the sweeper*. The very reasonable premise is that material removed from streets by sweepers does not enter stormwater conveyances: a pound of phosphorus removed by the sweeper is one pound less that enters the stormwater conveyance! Hence, city-engineering departments can compute the "load reduction" accomplished by street sweeping over a year. This makes it possible to incorporate street sweeping directly into TMDL "load reduction" programs intended to restore nutrient impaired waters.

Second, the Prior Lake study was a factorial experiment, in which we swept streets under varying tree canopy levels (low, medium, and high) and with different frequency (1x/month, 2x/month), and 4 times/month). In other words, some streets with low tree canopy cover were swept once a month, others twice, and yet others four times per month. The same was done with medium and high canopy streets. Hence, results can be "mapped" onto the streets of other similar cities to estimate nutrient and sediment load reductions expected under various tree canopy levels and sweeping frequencies.

Third, we started sweeping very early in the spring (as soon as the snow melted) and continued throughout the autumn leaf fall period – until the snows started. This is one of very few studies that have continued sweeping throughout the fall. This is important because our findings show that an important fraction of the annual loads of nutrients and sediments enters streets during autumn leaf fall.

Last, but certainly not least, we tabulated costs, including labor, fuel, and operations and maintenance of the sweepers. We could therefore compute the cost per pound for removal of nutrients and solids for each experimental treatment. This information would allow potential adopters to estimate costs of enhanced sweeping practices under various conditions (tree canopy and frequency).

The Prior Lake Street Sweeping Experiment was a collaborative experiment between the City of Prior Lake and the University of Minnesota, with financial support from the Minnesota Pollution Control Association via the U.S. Environmental Protection Agency's Nonpoint Source (319) Program.

How you might use this manual

This User Support Manual is intended to support municipalities that would like to improve the effectiveness and efficiency of street sweeping as a stormwater management practice to reduce the input of nutrients and solids to stormwater catch basins. The User Support

Manual was designed to support an Excel spreadsheet program **Street Sweeping Planning Calculator**: **Estimating Nutrient And Solids Load Recovery through Street Sweeping**, providing step-by-step instructions. This manual and spreadsheet can be used in several ways.

(1) Planning new sweeping operations. First, the manual and the accompanying spreadsheet can be used to estimate quantities of nutrients and solids removed in planning more intensive sweeping operations. For example, one could estimate, for a given level of tree canopy cover, the increase in quantities of nutrients and solids that would be removed by moving from once a year sweeping to monthly sweeping, for a given level of canopy cover.

(2) Quantifying actual load reductions from sweeping. The manual also steps you through the process of quantifying the load reductions for your current operations. In Chapter X, we outline a process for collecting swept material, drying and weighing it, and estimating the nutrient content at [several levels of effort and accuracy]. This process would allow you to compute the annual load of nutrients and solids actually removed during your ongoing operations.

(3) Estimating impacts on lakes. Many urban lakes in Minnesota are impaired for nutrients. This is a legal definition that triggers the development of TMDL (total maximum daily load) plans. TMDL plans include estimates of the current P loading to the lake, and the P load reduction that would be required to attain the legally mandated level of algal abundance (and clarity), stated as a percentage of the current P load, and as a load reduction (kg P per year). Cities could then use this Users' Manual to estimate the P load reduction that could be accomplished using various sweeping scenarios – that is, compute how much P is recovered through sweeping and therefore prevented from entering the stormsewer system...

(4) Increasing cost efficiency. One of the most important uses of this manual is that you could use it to estimate the cost of each sweeping scenario – $ per pound of P removed, and total cost of each scenario for an entire watershed or city. Combined with (3), one could estimate the cost of achieving various lake nutrient goals for a lake's watershed.

(5) Landscape planning. Finally, the manual could provide planners and landscape architects with a tool they could use estimate leaf inputs to streets for various types of tree plantings.

Audience

The primary audiences for this manual are the municipal public works, engineering, or streets departments that manage street sweeping operations and/or stormwater programs, along with water resource managers in the urban watershed districts with whom cities collaborate. The manual might also be useful to planners and landscape architects who design the intersection between streets and vegetated landscapes, and who might want to incorporate estimates of tree leaf inputs to streets in their design considerations. It might also be useful to urban foresters, who manage trees in public spaces, including boulevard plantings, for the same reason.

What is in this manual?

Chapter 2 is a summary of prior research on the effects of street sweeping as a method for reducing nutrient and solids loadings to stormwater. This chapter provides context for the Prior Lake experiment.

Chapter 3 is a summary of the Prior Lake Street Sweeping Experiment. This chapter provides details of the experimental design, the field (sweeping) measurements, the lab analysis, and the interpretation of findings.

Chapter 4 describes a Leaf Litter Decomposition Experiment, designed to quantify the rate of nutrient leaching from leaves left in the gutter. Findings from this experiment were used to estimate the quantities of nutrients that would be leached to stormwater over various time periods, from one day to twelve months.

This information can help street sweeping managers determine how quickly they need to sweep leaves before nutrients are "lost" to stormwater conveyances.

Chapter 5 documents the Street Sweeping Calculator, an Excel spreadsheet intended to allow users to compute nutrient loadings being achieved in their street sweeping programs and to estimate nutrient load reductions that might be achieved with more extensive sweeping programs.

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Chapter 2. Literature Review

Prior to the 1970's, the main goal of stormwater management was to drain urban watersheds quickly. Early sewer systems in US cities were most often built as combined systems, which carried sewage and surface runoff to a receiving surface water body with little or no treatment (Tarr 1996). As populations grew, increasing amounts of treatment were added to these systems to insure sanitary conditions in public drinking water supplies located downstream of the outfalls of these sewers. The cost of this additional treatment drove a movement to separate municipal and storm sewers (Burian et al. 1999). Ironically, diversion of stormwater from treatment with sanitary waste may have unmasked the pollution loads present in urban stormwater. The US Public Health Department became concerned about pollutants identified in urban runoff in the 1960s, but the original 1972 Clean Water Act focused mainly on point sources of pollution (such as municipal and industrial wastewater discharges).

Pioneering research into storm sewage, including using street sweeping as a pollution control measure, was completed during this era (Heaney and Sullivan 1971, Sartor and Boyd 1972, Pitt and Amy 1973, Shapiro and Hans-Olaf 1974). Initial conclusions regarding the value of street sweeping as a water quality tool were not always positive, but amendments to the Clean Water Act in 1987 and development of the EPA's Stormwater Program have prompted a re-evaluation of these conclusions and a renewed interest in street sweeping as a pollution control measure.

Early Street Sweeping Studies and NURP

Early street sweeping studies were concerned largely with characterizing street sediments and evaluating the performance of street sweepers. An extensive study by Sartor and Boyd (1972) characterized the accumulation and composition of street sediments in 12 urban centers around the country and found street sediments were composed largely of inorganic material such as sand and silt, 78% of which could be found within 6 inches of the curb. The fine fraction (< 43 µm) of these sediments contained a great portion of the overall pollution load. While this fraction was typically small, about 6% of the total solids, it contained one-fourth the total chemical oxygen demand (COD), one-third to one-half of the nutrients, and significant percentages of various heavy metals. Although sweepers were generally very effective at removing larger debris and sediments from roads (79% effective overall), removal efficiencies for the finest fractions were only 15-20%. The combined findings indicated that street sweeping, which removed less than 50% of the total sediment load on the street, would be relatively ineffective as a water quality management tool.

Sartor and Boyd did not monitor stormwater quality in their study, but the need to link source control practices to stormwater quality improvements would become the proving ground for street sweeping during the EPA-sponsored National Urban Runoff Program (NURP), conducted from 1979 to 1983. The NURP program provided technical support and management assistance for 28 projects across the United States, which investigated urban hydrology and water quality. Among these studies, street sweeping was evaluated at 17 sites in 5 cities across the United States. To show definitively the effectiveness of street sweeping in reducing stormwater pollutant loads, all NURP studies used a paired or serial basin approach in which swept (treatment) and unswept (control) basins or treatment phases were compared. The criteria for a positive result were documented reduction of 50% stormwater event mean concentrations (EMCs, EMC = flow-weighted mean concentration throughout a runoff event), with 90% statistical confidence. The final NURP report was not promising for street sweeping. Sweeping never caused a 50% load reduction with 95% confidence (EPA's criterion) for any of the five major pollutants monitored [lead (Pb), total Kjeldahl nitrogen (TKN), total phosphorus (TP), chemical oxygen demand (COD), and total suspended solids (TSS)], at any of the 17 study sites (EPA 1983).

The final recommendation was that street sweeping was generally ineffective as a water quality improvement tool. The lackluster conclusions of NURP appear to have derailed interest in street sweeping as a BMP for about the next decade. Literature on street sweeping from 1985-1995 is sparse. The intuitive appeal of street sweeping as a source reduction tool was, however, hard to ignore. The development of higher efficiency sweepers, better stormwater modeling software, and critical analysis of NURP methods would all contribute to a renewed interest in street sweeping as the enactment of NPDES permitting (1990, 2003) increased regulation on stormwater quality.

Street Sweeper Performance and Efficiency Studies

Street sweeper testing methods and data collected on sweeper efficiency by Sartor and Boyd provided a foundation for future sweeper performance testing (Burton and Pitt 2002). A variety of parameters influence street sweeper efficiency: the mass, particle size distribution and uniformity of the sediment load; the type and condition of pavement; pick-up broom type, diameter, angle and rotational speed; and the influence of other operational parameters including forward speed and number of passes. Sweeper pick-up performance and efficiency testing is a sub-class of street sweeping study which, although important to best practices, is not a focus in the current study. Sweeper studies have rated sweeper pick-up performance by total solids removed and percent removal by particle size classes, for various loading conditions, and under various operational parameters (Sutherland and Jelen 1997, Breault et al. 2005, Selbig and Bannerman 2007). Work in this area has addressed potential standardization of testing protocols for sweeper performance evaluation (Sutherland 2008) and development of resources for guiding street sweeper purchasing and program implementation (CT DEEP 2007, Kuehl et al. 2008, others). Evaluations largely agree that because regenerative air and vacuum type sweepers remove fine particles with greater efficiency than mechanical sweepers, these types are preferred when sweeping for water quality. Mechanical broom sweepers are preferred for removal of large debris and highly compacted material. High- efficiency sweepers combine various sweeper technologies with dust control systems and improve sweeper efficiency in removal of fine particles, but tend to cost considerably more than other sweeper types (Sutherland 2011).

Continued Work on Street Sediment Characterization

Data on street sediment characterization are used in stormwater modeling, sweeper efficiency modeling, and for determining the proper use and disposal of street sweepings. Chemical analysis of street sediments, most often analysis of metals and organic contaminants, has been performed in numerous studies (Pitt and Amy 1973, Wilber and Hunter 1979, Townsend et al. 2002, Zarriello et al. 2002, others). Fine sediments have frequently been found to contain a significant proportion of metal pollutant loads (Pitt and Amy 1973, Durand et al. 2003, Deletic and Orr 2005, Rochfort et al. 2009). Fewer studies have looked at the relationship between particle size and nutrient concentrations in street sediments and results are quite variable. The percent mass of phosphorus has been variously reported as highest in fine sediments (< 104 μm)(Sartor and Boyd 1972), silt and clay sized particles (Breault et al. 2005), and larger particles > 250 μm (Waschbusch et al. 1999).

Street sediment composition has been shown be to be influenced by season (Deletic and Orr 2005), land use area (Seattle Public Utilities 2009, Berretta et al. 2011), and street type ([X]-Absolute Value 1996). The distribution of sediments across the street can be affected by winter road applications and spring snow melt (Selbig and Bannerman 2007). Particle size distribution and pollutant concentration of sediment samples can be influenced by distance from the curb (Deletic and Orr 2005).

Although exceptions occur on a regional basis or for particular pollutants, concentrations of metals and organic pollutants in street sweepings have generally been found to be below soil contamination standards (Townsend et al. 2002, Durand et al. 2003, [X]-Absolute Value 1996, Land Technologies 1997). A sampling of best management practices for street sweepings indicates that screened sweeping material does not typically qualify as hazardous waste (CT DEEP 2007, Minnesota Pollution Control Agency (MPCA) 2010). Appropriate uses for street sweepings include construction fill, landfill cover, winter non-skid material, aggregate in asphalt and concrete, and compost (vegetative fraction) (Land

Technologies 1997, Minnesota Pollution Control Agency 2010, Clark et al. 2007, MWH Americas 2002).

Modeling Studies and Renewed Interest in Street Sweeping as a Water Quality Management Tool

Early street sweeping studies established mathematic models describing accumulation, wash-off, transport, and removal of street sediments, which were used to model theoretical stormwater load reductions from street sweeping. Due to the low efficiency of mechanical broom sweepers, particularly in the smaller particle size ranges, NURP-era models showed that streets must be swept at a frequency about equal to or greater than the inter-event dry period to have any effect on reducing the total solids load on the streets (Sartor and Gaboury 1984). The post-NURP decade brought new higher efficiency sweepers and improved stormwater modeling software into the market. These technological improvements prompted a number of papers that re-evaluated the value of street sweeping as a water quality management tool (Sutherland and Jelen 1997, Sutherland and Jelen 1996, Sutherland et al. 1998, Minton et al. 1998).

Among these modeling studies, (Sutherland and Jelen 1997) used the Simplified Particle Transport Model (SIMPTM) to compare the total suspended solids (TSS) removal capacities of the newer, high efficiency sweeping technologies with older sweepers. SIMPTM allowed the modeler to set base residual loads and sweeper removal efficiencies for different particle sizes and sweeper types. SIMPTM also had the capacity to continously model accumulation, washoff, and resuspension of particles and associated pollutants on an event-by-event basis. In this study, the model predicted TSS reductions of up to 20-30% for newer mechanical sweepers and up to 80% for the Envirowhirl™ technology. SIMPTM was also used to model targeted total solids reduction in Jackson County, MI (Tetra Tech 2001). Modeled load reductions for TS, COD, TP, Cd, Cr, Pb, Cu, and Zn ranged from 63 - 87% for high efficiency sweepers and 49 – 85% for regenerative air sweepers for a sweeping frequency of once to twice monthly with cleaned catch basins.

Modeling using the Storm Water Management Model (SWMM) in the Lower Charles River basin produced less promising pollutant load reductions from sweeping (Zarriello et al. 2002). A conservative assumption that 20% of the surface was unavailable to be swept (parked cars, other) was built into the model. Simulations predicted load reductions of less than 10 percent for total solids and less than 5% for fecal coliform and total phosphorus for a sweeping frequency of seven days or greater. These estimates improved when a lower value of the wash-off coefficient was used to model sediment removal during smaller storms, which resulted in larger residual loads being available for removal through sweeping. The discrepancy highlights the sensitivity of predictions to modeling assumptions and constraints. Improved stormwater quality modeling has been an active areas of research that includes empircal validation of modeling parameters (Breault et al. 2005), accumulation rates (Kim et al. 2006), and optimization of street sweeping practices for water quality improvement (Sutherland 2007b).

End of Pipe Studies – Promise and Pitfalls

Although modeling studies have shown various degrees of promise for sweeping as a water quality BMP, *measured* reductions in pollutant EMCs or loadings have continued to be the standard by which sweeping is gauged. An extensive study, which had both paired and serial basin aspects, was conducted in Madison, WI, from 2003-2007 (Selbig and Bannerman 2007). Street sediment yield and storm EMCs for 26 constituents were monitored during calibration and treatment (sweeping) phases in three residential basins. A fourth basin served as a control for all three swept basin comparisons. Sweeping was conducted from April through September during each year of the study, and was suspended when autumn leaf accumulations made vacuum sampling impractical. For a frequency of once per week, sweeping reduced street sediment yield by an average of 76%, 63%, and 20% respectively for regenerative air, vacuum assist, and high-frequency mechanical broom treatments but data on stormwater quality improvement was less encouraging.

Approximately 40 paired water quality samples were collected during the Madison study. Based on this sampling, the only significant change in stormwater concentrations was an increase in ammonia-nitrogen of 63% in one of the treatment basins (10% significance). Study authors reported that high variability in stormwater composition (as is typical in stormwater monitoring) made statistical comparisons of calibration and treatment phases difficult. Sources of variability in stormwater composition include differences in precipitation patterns, land use, street type, traffice patterns, maintenance practices, and sediment sources other than street dirt (ex. rooftops, lawns, driveways, and sediments transported in the sewer system), which are not controlled through street sweeping. Variability in stormwater loads dictates large sampling requirements to produce statistically relevant results at high levels of confidence. In the Madison study, for a coefficient of variation of 1.5 between control and test basins, a minimum of 200 paired samples would have been required to detect a 25% difference (at 95% confidence, 0.5 power) between calibration and treatment phase stormwater EMCs (Selbig and Bannerman 2007). For most constiuents, the sampling completed was not sufficient to demonstrate a significant change. More recent studies have abandoned attempts to quantify stormwater quality improvements associated with street sweeping due to insufficient sampling (Law et al. 2008) or because sufficient sampling was cost-prohibitive (Seattle Public Utilities 2009).

Given the difficulties in proving reductions in EMCs or loading at the end of the pipe, it is not surprising that contemporary studies have questioned the value of NURP criteria and conclusions (Minton et al. 1998, Sutherland 2007b, Kang et al. 2009). Critical review of data analysis methods has shown that many NURP-era studies lacked the statistical power required to draw statistically significant conclusions about water quality, making inferences about the influence of street sweeping on water quality only speculative(Kang et al. 2009). Others have argued that NURP criteria were unrealistic. Because EMC reduction of 50% or greater would be difficult to demonstrate at high confidence levels, results should be re-evaluated (Minton et al. 1998). Although there were no instances in which stormwater EMC reductions met the EPA criteria for a postive result, for the five pollutants studied, NURP data showed EMC reductions in 30 of 50 cases evaluated (range approximately 5%-55%). While EMCs increased in 16 cases, 9 of the increases occurred at the same two sites where rainfall intensity may have been an important factor (Minton et al. 1998). Reductions in stormwater EMCs, albeit less than 50%, have been also observed in highway cleaning studies (Sutherland 2007c).

Compounding these problems, the ability of automated samplers to collect representative stormwater samples has been called into question in recent years. In a simulation study, Clark and others showed that automated samplers failed to reliably to capture particles in the 250-500 mm (largest simulated) particle size range (Clark et al. 2007). Sampling is limited by particle diameter and intake velocity at the sampling tube. Large particles may settle out of the water column before reaching the sampler or bypass the system altogether. This problem can be addressed to some degree by supplementing with bedload sampling or by employing a cone sample splitter (Law et al. 2008), but tree leaves and other coarse organic particles, which tend to float near the surface, may still bypass sampling equipment. Furthermore, residual solids loads in unmaintained infrastructure may contribute pollutant loading to stormwater during low flow/base flow periods when stormwater is not being sampled.

Focus on Source Control and Maintenance Practices

The intuitive appeal of street sweeping as a source control measure is difficult to ignore. Material that is removed from the street system is not available for transport via storm sewers to surface waters. Considering the factors that limit the ability of stormwater monitoring studies to demonstrate treatment effects (swept versus control), a focus on measuring recovered solids rather than on stormwater monitoring makes sense. The cost effectiveness of street sweeping found in many studies is also appealing. In an early example, Heaney and Sullivan (1971) created a solids budget for a typical 10-acre area in Chicago that included dustfall loading, sanitary wastes, refuse, and unclassified solids (street sweepings and catch basin sediments). Monthly source loads for each class of solids were estimated based on literature values and public works records. Heaney and Sullivan found that the unit cost of solids removal though street sweeping compared favorably with removal through catch basin cleaning, sewer cleaning, and municipal garbage collection. Likewise, recent studies have found the unit cost of solids removal through street sweeping to compare favorably with catch basin cleaning and other structural BMPs (Seattle Public Utilities 2009, Berretta et al. 2011, Tetra Tech 2001, Sutherland 2007a).

In the big picture, TSS reductions are critical to urban stormwater management and several studies have concluded that sweeping reduces solids loading to streets or to receiving waters (Burton and Pitt 2002, Selbig and Bannerman 2007, Seattle Public Utilities 2009, Sutherland and Jelen 1996, Sutherland et al. 1998, Tetra Tech 2001). Yet due to insufficiencies in sampling methods, stormwater TSS loads have frequently been underestimated, leading to inadequate design of downstream stormwater control measures (SCMs) (Sutherland 2007b). Sediment recovery from structural SCMs is expensive; moreover, many Municipal Separate Storm Sewer System (MS4) communities have limited space for placement of structural SCMs. This highlights the importance of maintenance practices such as street sweeping and catch basin cleaning in urban watershed management (Bateman 2005, Sansalone and Spitzer 2008).

Given the importance of maintenance practices, MS4 communities would like tools to quantify load reductions achieved through maintenance practices for use in NDPES permits and TMDLs. To establish the link between maintenance practices and water quality improvements, documentation of recovered loads is of key importance (Bateman 2005). Work in street sediment characterization has shown that street sediments have a "typical" composition influenced by geography, land use, and other identifiable parameters. Typical pollutant concentrations could be applied to the dry mass of solids recovered to estimate recovered pollutant loads (Sansalone and Spitzer 2008).

Along this line of thinking, Sansalone and Rooney (2007) conducted a preliminary study to develop a method for incorporating MS4 maintenance practices into load reduction assessments Existing data on solids and pollutant loads recovered through maintenance practices were examined to determine whether the nutrient composition of urban solids could be categorized statisically by BMP type, land use, or other category. Analysis of existing data sets demonstrated that quantification of recovered pollutants loads based on the mass of dry solids recovered was possible, however, disparity in sampling and analysis methods, lack of QA/QC data, and geographic influence apparent among data sets meant that a more robust data set was required for the development of reliable metrics (Sansalone and Rooney 2007).

A follow-up assesment of particulate matter was carried out to develop a "yardstick" for quantifying pollutant load recovery in Florida cities (Berretta et al. 2011). Street sweepings, catch basin sediments, and particulate matter from a variety of BMPs were collected in hydrologic functional units (HFUs) representing commercial, residential, and highways land use areas in each of 12 MS4s from across the state of Florida. Because nutrient concentrations showed a consistent distribution pattern (log-normal) within land use and BMP categories, investigators concluded that MS4s need only track dry solids recovered through maintenance practices to estimate recovered nutrient loads. The metrics could also be applied to estimate maintenance requirements for target load reductions and the associated cost per pound of nutrient recovery (Berretta et al. 2011).

Street Sweeping and Nutrient Management

Innovations of the Prior Lake study are built on the mass balance approach taken in source control studies with a focus on the influence of tree canopy. Characterization studies focused on priority pollutants have largely overlooked the significance of leaves and other organic litter in street sediment pollutant loads. In some cases, leaves and larger pieces of organic litter were actively separated (by screening) and discarded; only the "fines" passing through the screen were chemically analyzed (Townsend et al. 2002, Rochfort et al. 2009). Similarly, in some studies, street sediment sampling or stormwater quality monitoring were conducted during short periods that did not include autumn leaf fall (Selbig and Bannerman 2007, Vaze and Chiew, 2004). Although the influence of leaf litter and organic matter on nutrient loads in street sediments is often noted (Waschbusch et al. 1999, Seattle Public Utilities 2009, Law et al. 2008, Sansalone and Rooney 2007, Minton and Sutherland 2010), few studies have attempted to quantify the effect of coarse organic material on nutrient fluxes to storm sewers.

Sartor and Boyd (1972) identified accumulations of decomposing vegetation in catch basins as a potential source of oxygen demand to receiving waters and accumulations on road surface as potential source of pollution from pesticides and fertilizers. Since then, a significant body of work has evolved which provides evidence for the influence of tree canopy and roadside vegetation on nutrient loads in street sediments and runoff.

As a solid source of nutrients, organic matter has been shown to contain a significant proportion of the nutrient load in street sediments. High nutrient contents have been noted in the leaf fraction when leaves were included in the sediment analysis (Waschbusch et al. 1999), or in sediments associated with leaf fall timing (Seattle Public Utilities 2009). Waschbusch et al. found that while leaves made up < 10% of the total mass of street dirt samples on average, they contributed approximately 30% of the total phosphorus. Leaves were the only fraction analyzed that had a total phosphorus contribution by percent that was significantly higher than its total mass contribution, by percent. Furthermore, leaves in each particle size contributed approximately 25% of the total phosphorus in that size fraction. Waschbusch also found a strong, linear correlation between percent tree canopy over streets and both total and dissolved P concentrations in street runoff.

Lawns, yards and the plant-soil complex have been identified as a dominant source of nutrients in stormwater monitoring and modeling studies (Waller 1977, Pitt 1985, Waschbusch et al. 1999, Easton et al. 2007), but leaching studies indicate that fresh leaf litter can also be a significant source of dissolved nutrients during storm events. Leaching rates of nutrients from freshly fallen leaves are species dependent and can be substantial over short periods of time (Cowen and Lee 1973, Dorney 1986, Qiu et al. 2002, Wallace et al. 2008). Cowen and Lee (1973) found that intact oak and poplar leaves leached 5.4 – 21% of their total phosphorus in a 1-hour leaching time. In a similar study of 13 urban tree species, leaves readily leached from 4.5% (Honey Locust) to 17.7% (Silver Maple) of total leaf phosphorus over a 2-hour period (Dorney 1986). Under field conditions, leaf litter leaching rates were observed to be highest during the "first flush" portion of the wet season (McComb et al. 2007) and measurable phosphorus has also been detected in the surface moisture of leaves collected after rain events (Cowen and Lee 1973).

Leaves that remain on street surfaces may be damaged by vehicle traffic or inundated with runoff channeled by curb and gutter lines. Damaged leaf tissue (cut, ground) was shown to leach significantly more phosphorus than intact leaves (Cowen and Lee 1973, Qiu et al. 2002). Consecutive leachings resulted in additional phosphorus extraction (Cowen and Lee 1973, Dorney 1986, Qiu et al. 2002) and increased leaching time was positively correlated to leachate concentration (Cowen and Lee 1973). These findings indicate that mechanical breakdown on street surfaces is likely to increase leaf litter leaching rates.

Summary

Prior research over more than 40 years has shown the following:

(1) Tree leaves and other vegetative debris can make a substantial contribution to nutrients entering streets and storm sewers.

(2) Removal of vegetation debris by street sweeping probably does reduce stormwater nutrient loadings, but better quantification is needed.

(3) Removal of solids by sweeping may also reduce maintenance costs for structural SCMs.

Chapter 3. The Prior Lake Street Sweeping Experiment

The main objectives of the Prior Lake Street Sweeping Experiment were to measure the total amount of sediment and associated nutrients removed by street sweepers and to quantify the influence of overhead tree canopy on the character and quantity of sediments found on the street. As noted in Chapter 1, the scope of data collection and focus on the role of vegetative inputs make the Prior Lake Street Sweeping Study unique among street sweeping studies. To address the project objectives, sweeper waste from 392 sweeping operations was sampled over a two year-period beginning in August 2010 and ending in July 2013. The influence of overhead tree canopy on street sediments was addressed through both an experimental design which varied percent tree canopy cover, and a novel fractionation scheme in which vegetative inputs were isolated from other sweeper waste fractions.

Study Area

The Prior Lake Street Sweeping Experiment was conducted within the city limits of Prior Lake, Minnesota, in collaboration with the City of Prior Lake's Public Works Department. Prior Lake is a rapidly growing suburban community located within the greater metropolitan area of Minneapolis-St. Paul, MN. Recreational waters are a central feature of the city landscape. Fourteen lakes lie within the city limits of Prior Lake. The three largest, Upper and Lower Prior Lake and Spring Lake comprise almost 1,940 acres of the city's 15,300 acres, 13% of the total area of the city.

The city population, approximately 22,300 in 2010, has doubled since 1990 and is expected to continue growing at a similar rate through 2030. Similarly, residential land use is expected to increase from approximately 27.5% (2005) to 56% of city lands by 2030 and commercial/industrial land use is expected to increase from approximately 1.8 % (2005) to 9.8% by 2030 (City of Prior Lake, 2007). Rapid development and land use changes represent potential stressors to area watersheds including nutrient loading of city lakes, which provided impetus for the study.

Study Design

The Prior Lake Street Sweeping Study was designed to examine the influence of two factors: overhead tree canopy cover and sweeping frequency. Each factor was investigated at three levels – tree canopy cover categories of high, medium and low percent canopy cover; and sweeping frequencies corresponding to 1 week, 2 week and 4 week sweeping intervals (i.e., 4x, 2x, and 1x/4-week interval, respectively). Nine street sweeping routes were chosen to accommodate the 3 x 3 design. The process of identifying these routes is described in the sections that follow.

Tree Canopy Cover

High, medium, and low tree canopy zones throughout the city were identified qualitatively by inspection of aerial photography by the City or Prior Lake at the beginning of the study (Appendix A). Well-established neighborhoods zoned as medium or low density residential with mature trees or areas with large tracks of forests stands were typically identified as high canopy zones. Newer residential and commercial developments and areas previously under agriculture land use were typically identified as low canopy zones. Medium canopy zones represented areas with average tree canopy cover between these two extremes. Figure 1 gives examples of each canopy zone.

<table>
<tr><th>LOW Canopy</th><th>MEDIUM Canopy</th><th>HIGH Canopy</th></tr>
<tr><td colspan="3"></td></tr>
<tr><td>1 X, 2X, 4X/(4 weeks)</td><td>1 X, 2X, 4X/(4 weeks)</td><td>1 X, 2X, 4X/(4 weeks)</td></tr>
</table>

Figure 1. Air photos showing examples of low, medium, and high canopy zones.

Late in the project we obtained high-resolution tree canopy data (discussed below) that allowed us to quantify percent canopy cover over streets and at various distances from curb lines along each route. Canopy cover categories determined through this quantitative analysis were largely consistent with the qualitative designations of high, medium and low canopy.

Street Sweeping Routes

The nine study street sweeping routes were identified by the Water Resources Engineer for the City of Prior Lake at the inception of the study. Routes were designed to be comparable in length, with high, medium, and low tree canopy zones distributed across the city. A naming convention for the routes using the letters H (high), M (medium), and L (low) to represent canopy type and 1, 2 or 4 to represent sweeping frequency was adopted for convenience (example H4 = high canopy, swept weekly). Sweeping frequencies of 1x, 2x, or 4x per four-week sweeping rotation (rather than per month) were assigned one each to H, M and L routes, creating a 3 x 3 experimental design.

Most sweeping routes were composed of 2-3 discrete stretches of road that were categorized as having similar tree canopy cover (qualitatively). The L1 route was the only route characterized by contiguous segments of roadway. Sweeping was performed largely in residential areas. Only the low canopy routes L2 and L4 contained light commercial/industrial areas. Detailed specifications for the nine sweeping routes are given in Appendix C and Appendix G.

Field Methods

Field Operations Data Collection

Vehicle operators collected and recorded all field operations data for the study. For each sweeping run, drivers filed a report detailing the date, time, distance, gross vehicle weight, and approximate composition of the sweeper load. A copy of the driver report form is included in Appendix D. Data recorded on the driver report was used to check the swept distance against GIS analysis of route curb-miles and to determine the fresh weight of each sweeper load. Vehicle gross weights were recorded after remaining dust control water was emptied and drivers had exited the vehicle. Calculation of the fresh weight of the sweeper load required an accounting of vehicle fuel mass. Because vehicle fueling could only be tracked per day (not by sweeping operation), fuel mass consumed during each sweeping operation was estimated based on the duration of vehicle operation. The method for the fuel mass estimate and determination of the sweeper load fresh weight is outlined in Appendix E.

Sweeping Protocols

A Tymco model 600 regenerative air street sweeper was used to complete all sweeping operations within the study areas. Under ideal conditions, high, medium and low frequency zones were swept once every 7, 14, and 28 days respectively according to a 4-week rotation designed by the City of Prior Lake Appendix F. Sweeping events were conducted during the entire snow-free period as weather and road conditions permitted. While there was little disruption to the normal sweeping schedule during the period of April-November, sweeping was conducted only sporadically in December thru early March due to winter road conditions.

Typically, the material collected in a given route was contained in one sweeper load and two routes could be swept during a single work day. Although sweeping operations had to be postponed during heavy rain, precipitation did not disrupt the overall sweeping frequency pattern. Analysis of field operation data shows that high frequency zones were swept on average every 7.2 days while medium and low frequency zones were swept on average every 15.2 and 27.0 days respectively during the regular sweeping season (April through October) over the two-year study. The biggest challenge to maintaining the sweeping schedule was long collection times for heavy seasonal loads when the usable hopper capacity of the vehicle (6 yd^3) might be reached two or more times before route sweeping was complete. The majority of sweeping events were conducted using a single sweeper pass on each side of the street. Occasionally, vehicle operators made a third pass down the center of the roadway when material loads were especially high. Prior Lake maintenance vehicles are equipped with GPS units that track vehicle location throughout the period of use. GPS data were made available for validation of sweeping operations.

Sample Collection Procedures

Sweeper loads were sampled immediately after each sweeping event. It was expected that vehicle motion during sweeping operations would result in some amount of settling and compaction of material collected in the hopper. For this reason, sweeper samples were collected after loads were dumped to take advantage of re-mixing. To insure collection of a representative sample, drivers were instructed to visually inspect the dumped load before sample collection to estimate the portions of soil-like material and plant debris, and to check the degree of consolidation of sediments from the bottom of the hopper. One representative handful each of sweeper waste was collected from four sides of the pile of dumped sweepings.

Vehicle operators were instructed to sample sediment fractions at proportions relative to their presence in the total load. Large pieces of trash and woody debris were avoided, but smaller pieces, which were easily picked up, were not separated from the sample. Samples were visually inspected after collection. The sampling procedure was repeated if drivers determined that a sample was not representative. When more than one sweeper load was required to complete route cleaning, composite samples were created from individually sampled sweeper loads. Vehicle operators wore nitrile gloves to prevent contamination of swept material and to protect operator's hands during sample collection. A volume of approximately ½ to ¾ gallons of sweeper waste was collected in 1-gallon sized plastic freezer bags. Samples were frozen on site after collection to preserve them for laboratory analysis.

Disposal of and Reuse of Sweeper Waste

Sweeper waste was initially dumped at a temporary stockpile at the facilities management building. The City of Prior Lake reuses street sweepings that cannot be composted as fill. Sweeper waste that is collected during the fall, or when loads are made up of predominantly organic material, is accepted at the city composting facility.

Laboratory Methods

The initial processing of all sweeper samples was conducted at the University of Minnesota Department of Ecology, Evolution and Behavior. Because we wanted to determine the nutrient content of both the organic material and the soil-like component of sweeper waste samples, we developed a novel classification scheme and separation technique. Frozen sweeper samples were thawed under refrigeration and thawed samples were separated into five fractions during processing: garbage, fines (< 2mm fraction), rocks (inorganics ≥ 2mm), coarse organics (organics ≥ 2mm), and soluble nutrients leached during isolation of the coarse organic fraction. The mass, moisture content (determined by oven drying at 65°C), and organic content (% OM) of each of the solid fractions was determined for all sweeper samples. Chemical analyses of total phosphorus (TP), total nitrogen (TN) and total organic carbon (TOC) were performed on the fine, coarse organic and soluble fractions. It was assumed that garbage and rocks did not contribute significantly to nutrient loads, so only the mass of these fractions was tracked.

Coarse material retained on the 2mm sieve went through a second separation step based on buoyancy to more thoroughly separate the coarse organic material from any adhered soils. Coarse material was added to 3 liters of deionized water in a clean 5-liter plastic bucket. During this process, organic material such as leaves floated, while attached soil particles settled. Suspended organics were gently agitated for about 1 minute until soil particles appeared to be dislodged. Material that floated during the process was classified as coarse organic matter. This material was collected by filtering wash water through a 2 mm sieve. To account for nutrients leached during the separation process, wash water was subsampled for nutrient analysis. Settled particles were collected, oven dried, and sieved to separate additional fines (<2mm) and the remaining rock fraction (>2mm). The coarse organic matter was then oven dried for nutrient analyses and to determine its dry weight.

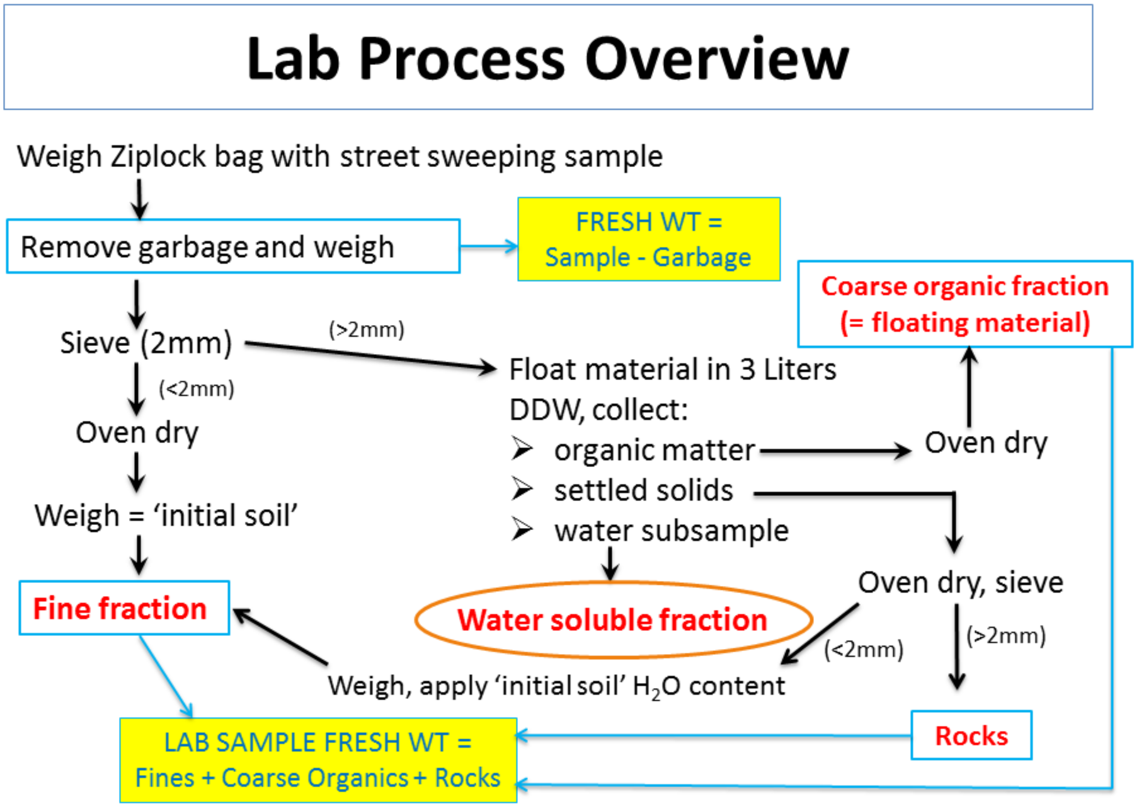


Figure 2. Overview of procedure for separating fine, coarse organic and soluble fractions.

Chemical Analysis

Prior to analysis, the course fractions were processed through a #40 screen on a Wiley Mill (Thomas-Scientific no. 3383L40). The fine fractions were pulverized by vigorously shaking them in plastic scintillation vials containing 3/8" steel ball bearings on a generic paint can shaker. Subsamples of dried fines and litter were ground and shipped to the University of Nebraska Ecosystems Analysis Laboratory for TN and TOC analysis. All other chemical analysis of sweeper waste was performed at the University of Minnesota Department of Ecology, Evolution and Behavior. Laboratory methods for all chemical analysis are summarized below.

Dry weight and water content (%) – The water content of each sample fraction was determined as the difference between the fresh (wet) weight and the oven-dried weight, divided by the dry weight, multiplied by 100.

Organic Content (%OM) – The % OM of fine and coarse organic fractions was determined by loss on ignition (incineration at 600˚C, 6hr) at the University of Minnesota.

Phosphorus (TP) – The phosphorus concentration in all fractions was determined by colorimetric method. Samples of coarse organic matter and fines were ashed prior to digestion in sulfuric acid; digests of fine samples were centrifuged at 2500 rpm for 10 min to remove remaining suspended particles that would otherwise interfere with the colorimetric analysis. Persulfate digestion was used for digestion of the soluble constituents in the leachate produced during the float separation step. Absorbance of digests was measured on a Cary 50 Bio UV-Visible spectrophotometer at 880 nm in 1 cm cells using molybdate blue/ascorbic acid reagent method. "Apple NIST 1515" reference standards (National Institute of Standards and Technology) were used to calibrate the analyses of coarse organic and fine fractions. K_2PO_4 standards were used to calibrate analyses for the leachate samples.

Nitrogen (TN) and Carbon (TOC) – TN and TOC analysis for the coarse organic and fine fractions was performed at the University of Nebraska using a Carlo Erba 1500 element analyzer. Leachate from the float separation was analyzed for TN and TOC at the University of Minnesota on a Schimazdu TOC/TN analyzer.

Data Analysis Methods

Tree Canopy Cover Analysis Methods

Tree canopy cover directly over the street and at variable distances from the curb was quantified through GIS analysis for each sweeping route. Tree canopy data were developed by the University of Vermont Spatial Laboratory using object-based image analysis that combines satellite imagery and LiDAR data to develop fine-scale land cover maps. Sweeping routes were first digitized using road polygon data provided by the City of Prior Lake, then overlaid onto tree canopy data. The reported percent tree canopy cover represents an average value for the specified route. Buffer analysis was used to find the average canopy cover for each route at various distances from the curb. Buffer distances were chosen somewhat arbitrarily, but were intended to represent near street (0, 5, and 10 ft), depth of front yard (street to house, 20 and 50 ft) and lot depth (street to back of property, 100 and 250 ft) distances.

Route Curb-Mile Analysis

Although drivers recorded an estimated miles driven and miles swept on driver reports, the low precision of the vehicle odometer made driver estimates of swept curb-miles impractical. Instead, the curb-mile distance swept for each route was determined from road polygon data using GIS software. The perimeter distances of road surface polygons associated with each route were summed to get the total curb-miles swept for each route. Perimeter lengths associated with median strips, which were not swept in most cases, were not included in the curb-mile calculation. The one exception being route L4, where medians were swept routinely, and were therefore included in the curb-mile calculation.

Statistical Analysis Methods

Statistical analysis was performed using both Excel and R software. Variations in annual, monthly, and seasonal values for different study parameters were quantified using ANOVA tests of the corresponding parameter means. Power Analysis was used to determine whether sufficient samples were collected to demonstrate statistical significance in such comparisons. Predictive models for nutrient and solids loads used in (the spreadsheet calculator tool), were developed using R software. These same predictive models were tested using a five-fold cross-validation procedure to quantify the error in model predictions.

Summary of Findings

Here we briefly summarize findings from 392 sweepings along nine routes over a two-year period of the Prior Lake Street Sweeping Experiment. More detail can be found in Kalinosky et al. (in progress). Findings presented here include a brief comparison of quantitative and qualitative assessments of tree canopy cover; summary statistics for recovered solids and nutrient loads; analysis of the influence of tree canopy cover, season, and sweeping frequency on recovered loads; and analysis of the cost and cost efficiency of sweeping for nutrient recovery.

Tree Canopy Cover Analysis

A key goal of this project was to relate tree canopy cover over streets to quantities of solids and nutrients removed. To do this, we first had to determine what metric of "tree canopy" would be most appropriate. Spatial analysis (GIS) allowed us to determine percent canopy cover for varying buffer distances from the curb. For example, a buffer distance of 0 represents the percent canopy cover directly over the street. Using a tree canopy raster data set developed at the University of Vermont Spatial Analysis Lab (see Data Analysis Methods), we determined percent canopy cover for buffers ranging from 0 to 250 feet from the curb.

This analysis revealed a consistent pattern in tree canopy distribution among the study routes (Figure 3). The percent canopy cover increased sharply as the buffer distance increased from 0 to 50'. In the City of Prior Lake, 50' is roughly the average depth of the front yard. As buffer distances increased (to include more of the side and back yards), percent canopy leveled off. This canopy cover pattern is likely characteristic of tree canopy distribution in outer ring suburban single-family residential developments where lot sizes are relatively large and sidewalks and alleyways are rare. There was good agreement between the quantified tree canopy and the earlier qualitative assessment, but some overlap in percent canopy cover between our 'high', 'medium' and 'low' categories. The canopy cover for routes H1 and M1, for example, might be better classified as a 'medium' and 'low' respectively under the qualitative scheme.

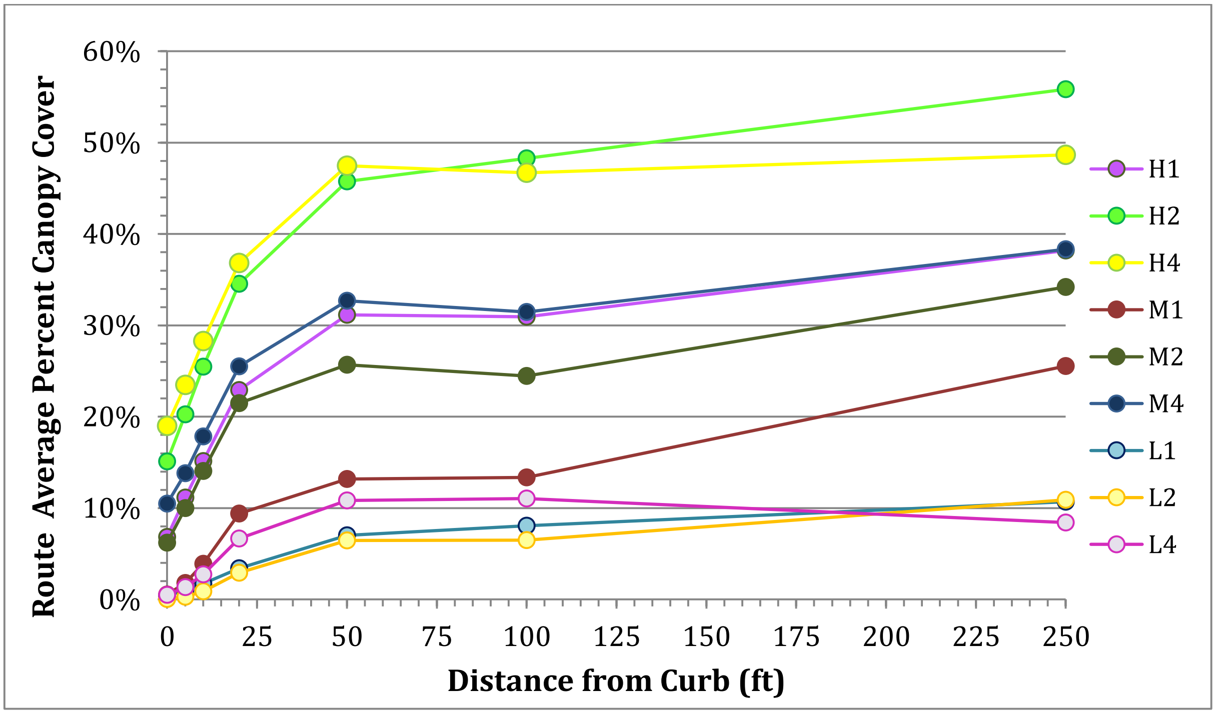


Figure 3. Tree canopy cover at various buffer distances from the curb for study routes.

To determine which buffer distance worked best as a predictor, we compared the goodness of fit (R^2) for regressions of measured loads vs. percent tree canopy cover at each of the seven chosen buffer distances. Patterns in goodness of fit varied somewhat depending on the load type (e. g. total solids, total phosphorus, fine sediment nitrogen, etc.), but in most cases, were not significantly altered when buffer distances within the front-yard scale distances (up to 50 ft) were compared. The canopy cover within a 20 ft buffer offered a slightly better overall fit than other buffer distances, but we decided that over-street canopy cover would be a more robust metric for mapping our findings into other neighborhoods. Hence, findings presented below are based on percent tree canopy over the street.

Where to Sweep *(The Influence of Tree Canopy of Recovered Loads)*

Street sediment composition and loading may be influenced by many factors, including traffic conditions, zoning, climate, soils and geology. Our findings show that the composition and mass of material recovered by sweeping is strongly influenced by percent canopy cover over streets.

This is best demonstrated when the nine study routes are lumped into the low, medium and high tree canopy categories initially assigned to each route. Since each category contains one route at each of the assigned sweeping frequencies (once, twice, or four times per four week cycle), the influence of sweeping frequency is minimized in this comparison.

Table 1 shows that recovered loads of both coarse organic solids and fine solids increase in relation to tree canopy cover. Because the coarse organic solids fraction includes tree leaves, fruits, seeds, etc., this relationship would be expected. However, the mass of fine solids also increased with increasing canopy cover, as did the % organic matter of the fine fraction. This strongly suggests that the fine fraction of recovered sweepings includes finely ground organic matter derived from tree debris.

Table 1. Comparison of Sweeping Fractions Recovered by Canopy Cover Category, Two-year Study Averages and Totals.

	Low Canopy (L1, L2, L4)	Medium Canopy (M1, M2, M4)	High Canopy (H1, H2, H4)
Total Number of Sweepings	128	134	128
Average Tree Canopy Cover over the Street*	0.33%	5.6%	13.9%
Total Route Curb-Miles	23.5	21.5	26.5
	Cumulative Recovered Loads (lb/curb-mile)		
Total Dry Fines**	5062	6513	7133
Total Dry Coarse Organics**	380	1496	2347
Total Fine + Coarse Organic Solids	5442	8009	9480
Total Recovered Phosphorus**	4.1	8.1	9.8
	Compositional Influences		
Ratio of Fines: Coarse by Weight	**13.3**	**4.4**	**3.0**
Study Average % OM, fine fraction	**5.6**	**9.3**	**9.9**

* **Weighted** average based on route curb-miles for routes in each category.

** Cumulative recovered load **=** sum of the dry mass collected for all sweeping events (2-year period), divided by total route curb-miles for each canopy category.

How Often to Sweep *(The Combined Influence of Tree Canopy Cover and Sweeping Frequency on Recovered Loads)*

We used regression analysis to characterize the combined influence of canopy cover and sweeping frequency on recovered loads. General trends are discussed below using both summary statistics by route and results of regression analysis.

Recovered Solids -

The total solids collected per year increased with increasing percent canopy cover and with increasing sweeping frequency, with the exception of route H4 (Table 3). On a per sweep basis (Table 3), recovered solids increased with tree canopy cover at any given sweeping frequency (exception route H4), and decreased with sweeping frequency for any given tree canopy (exception route M1). The M1 route was found to have a tree canopy cover similar to low canopy routes, which may explain the relatively low average dry solids load for that route. Route H4, however, was found to have the highest average tree canopy cover among the routes at front yard-scale distances, but had low average dry solids for reasons that are unclear.

Table 2. Total dry solids (annual average) collected by route (lb/curb-mile/year)

	Low Canopy	Medium Canopy	High Canopy
1x/mo	1748	2191	4088
2x/mo	2817	4245	5049
4x/mo	5332	7516	7251

Table 3. Average dry solids collected per sweep by route, (lb/curb-mile)

	Low Canopy	Medium Canopy	High Canopy
1x/mo	194.2	219.1	430.3
2x/mo	156.5	229.4	306.0
4x/mo	144.1	195.2	188.3

Patterns in coarse organic and fine sediment loads recovered per sweep (Table 4) were similar to those for recovered total dry solids. Relatively low average loading for route H4 is seen for both fractions.

Table 4. Average coarse organic and fine sediment loads (dry weight) recovered per sweep by route, (lb/curb-mile)

	Low Canopy	Medium Canopy	High Canopy
	Coarse Organic Recovered (lb/curb-mile)		
1x/mo	10.6	23.4	59.9
2x/mo	10.7	35.3	89.2
4x/mo	8.1	33.0	49.1
	Fine Fraction Recovered (lb/curb-mile)		
1x/mo	151.2	115.8	331.9
2x/mo	126.8	167.1	143.8
4x/mo	113.96	136.7	120.3

Recovered Nutrients

Similar relationships between frequency and percent canopy cover were seen for nutrients recovered from streets by sweeping (Figure 4 and Figure 5). Nutrient loads recovered by sweeping increased with increasing percent canopy cover for a given sweeping frequency (individual regressions in Figure 4 and Figure 5). As sweeping frequency increases, the slope of regression lines decreases. Sweeping more frequently decreases the average material density (lb/curb-mile) recovered on a per sweep basis, but increases the total mass of solids recovered.

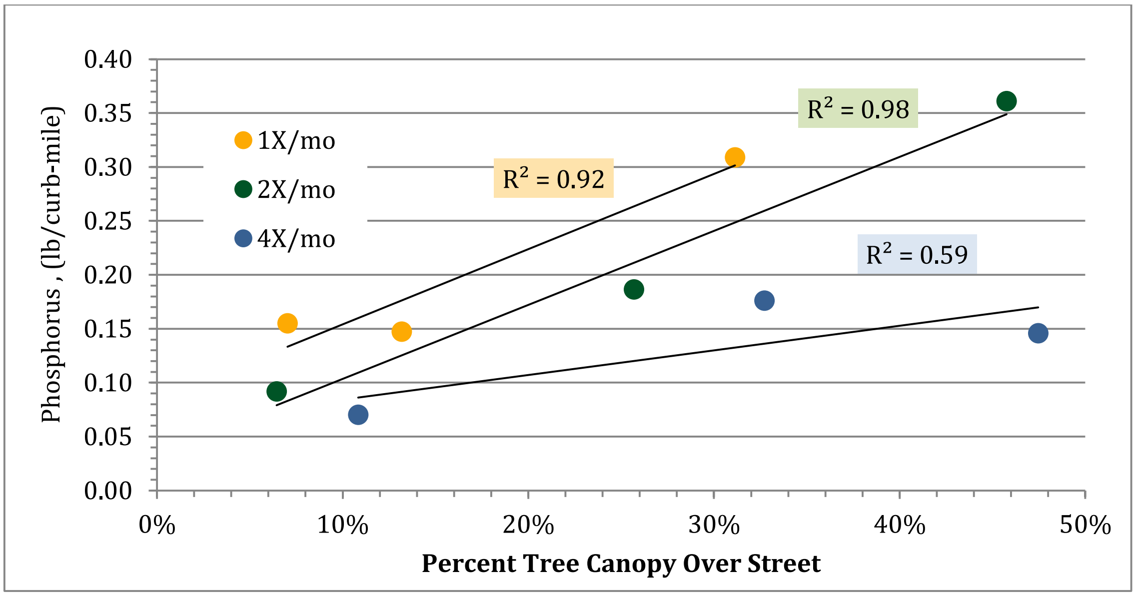


Figure 4. Average phosphorus recovered per sweep vs. tree canopy cover by sweeping frequency.

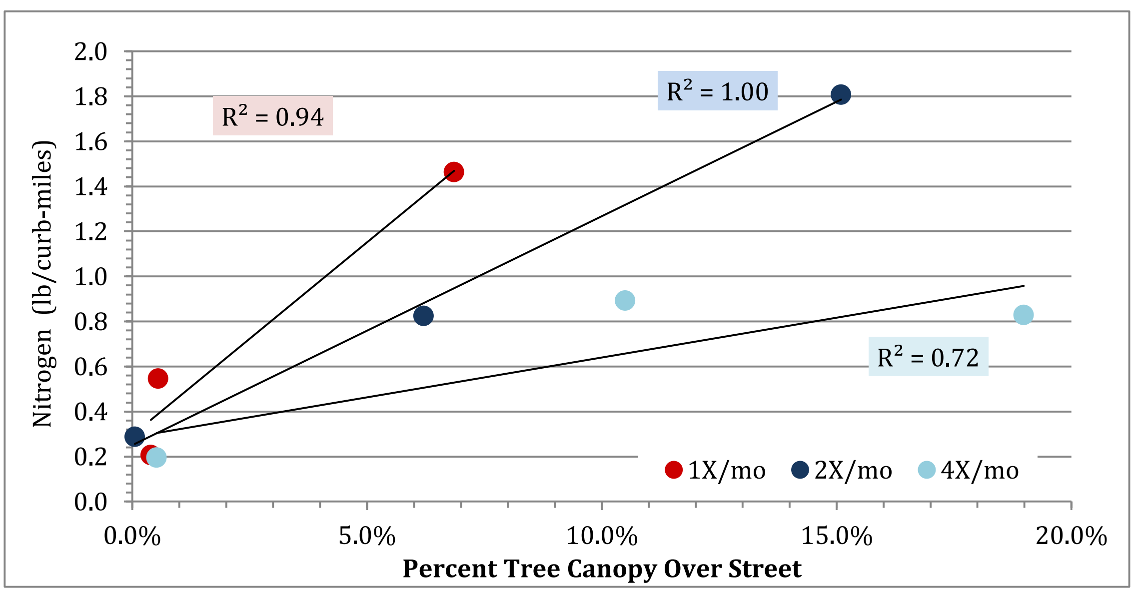


Figure 5. Average nitrogen recovered per sweep vs. tree canopy cover by sweeping frequency.

Recovery of Nutrients Associated with the Coarse and Fine Fractions.

Tree canopy affected coarse fraction mass and nutrients more strongly than it did fine fraction mass and nutrients. In simple regressions of route mean recovered loads that predict loads using both influences - canopy cover and sweeping frequency, canopy cover positively influences the phosphorus load associated with both sweeping fractions, although clearly more so for the coarse organic phosphorus (Table 5). Sweeping frequency appears to have a similar, but negative influence on both phosphorus fractions. Similar results were found for regressions on average nitrogen loads.

Table 5. Regressions for predicting average phosphorus recovered per sweep based on overhead tree canopy and sweeping frequency

Dependent Variable	β_0	β_1 (% canopy)	β_2, (sweeping frequency)	R^2	**p**
Log (Coarse P, lb/curb-mile)	-3.2	11.7	-0.29	0.86	0.0027
Log (Fine P, lb/curb-mile)	-1.8	*2.3*	-0.25	0.71	0.0239
Log (Coarse N, lb/curb-mile)	-1.1	11.0	-0.26	0.80	0.0085
Log (Fine N, lb/curb-mile)	-1.7	6.8	-0.25	0.62	0.0531

When to Sweep *(The Influence of Season on Recovered Loads)*

Influence of Season on Recovered Solids

In addition to tree canopy cover, another key factor is the month or season in which street sweeping is conducted. If sweeping for solids recovery, spring stands out as the primary season to clean streets (Figure 6). The combined recovered solids for the months of March and April made up approximately one third of the total solids recovered during the study. Application of non-skid materials (road salt and sand) plus soil and debris entrained in snow results in large residual loads of fines on streets after snow melt. Most municipalities that have the capacity to do so clean streets at least once during this time for safety and aesthetics. The influence of winter road maintenance practices can be seen in March (year 2) and April (year 1). The data indicate that sweeping should be performed early in the spring to recover large residual loads, but that a single sweep may not be sufficient to recover a majority of winter residuals.

We tested the significance of seasonal variation using paired t-tests to compare loads recovered (lb/curb-mile) in different seasons. Season-to-season comparisons of average recovered loads were made using all the loads collected during each season (all routes). Sweeping seasons were defined based on visual inspection of graphical representations of the data (as in Figure 6 - Figure 16). Sweeping seasons were defined as follows: Spring

Cleaning (Mar, Apr), Spring (May, Jun), Summer (Jul, Aug, Sep), and Fall (Oct, Nov). Winter month (Dec, Jan, Feb) could not be included due to sparse data in those months. Under this classification scheme, per sweep average dry solids loads (lb/curb-mile) differed significantly (α=0.05) in all comparisons except spring-fall and spring-summer.

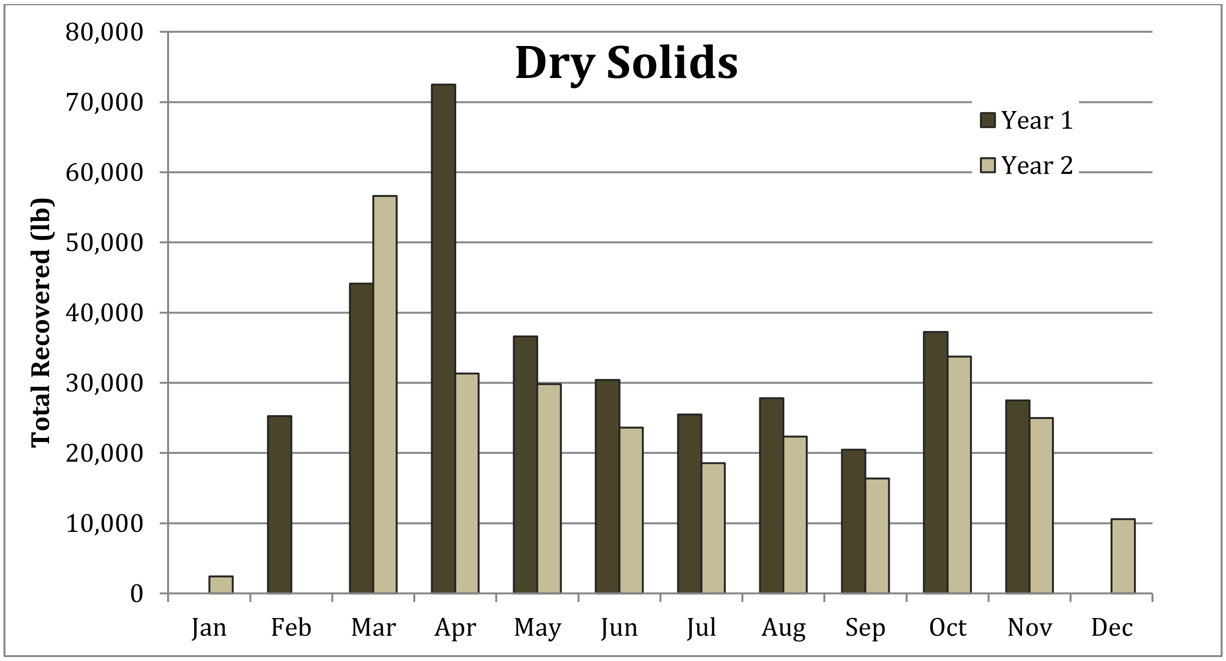


Figure 6. Total dry solids collected by month and year, all routes.

Fine sediment loads drove the seasonal pattern in total dry solids recovery in the early spring and coarse organics load drove the pattern in the fall. For fines, recovered loads were 2-4 fold greater in the spring than in the remainder of the year (Figure 7), but seasonal differences in the mean recovered load (lb/curb-mile) were significant in all comparisons except spring-summer and summer-fall. Coarse organic loads increased 3-8 fold or more during October, as the result of leaf fall (Figure 8). Seasonal differences in the mean recovered coarse organic load (lb/curb-mile) were significant in comparisons of fall with other seasons only.

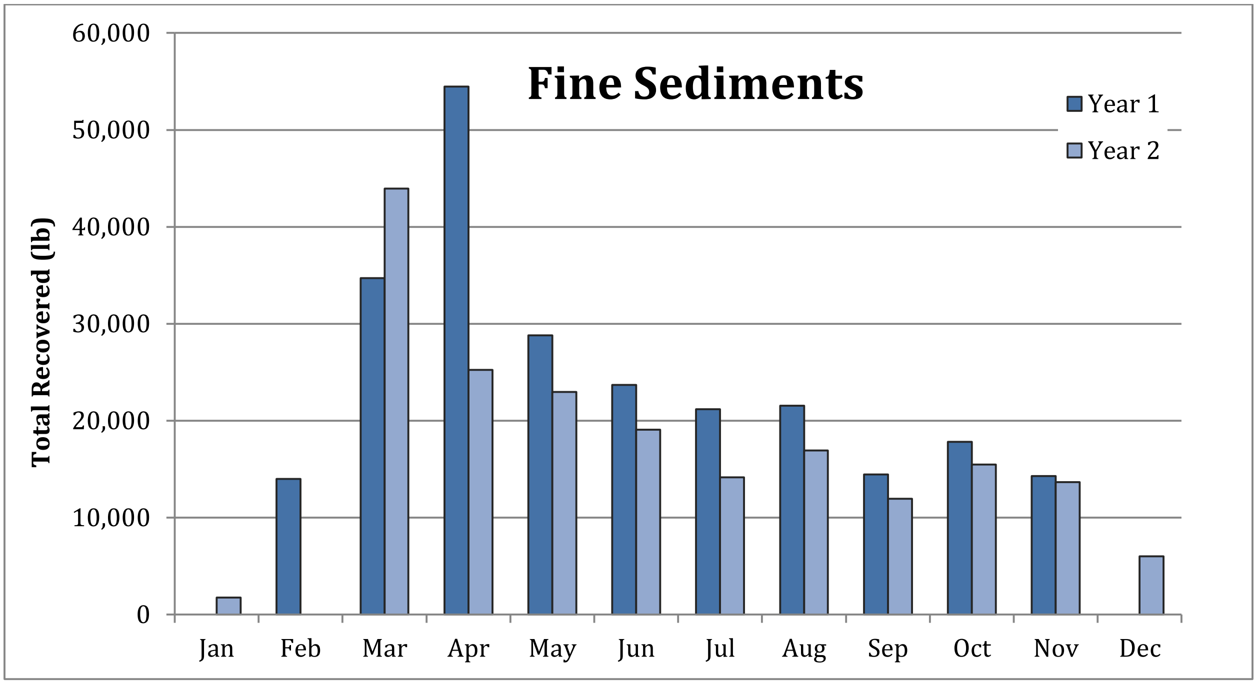


Figure 7. Total fine sediment recovered by month and year, all routes.

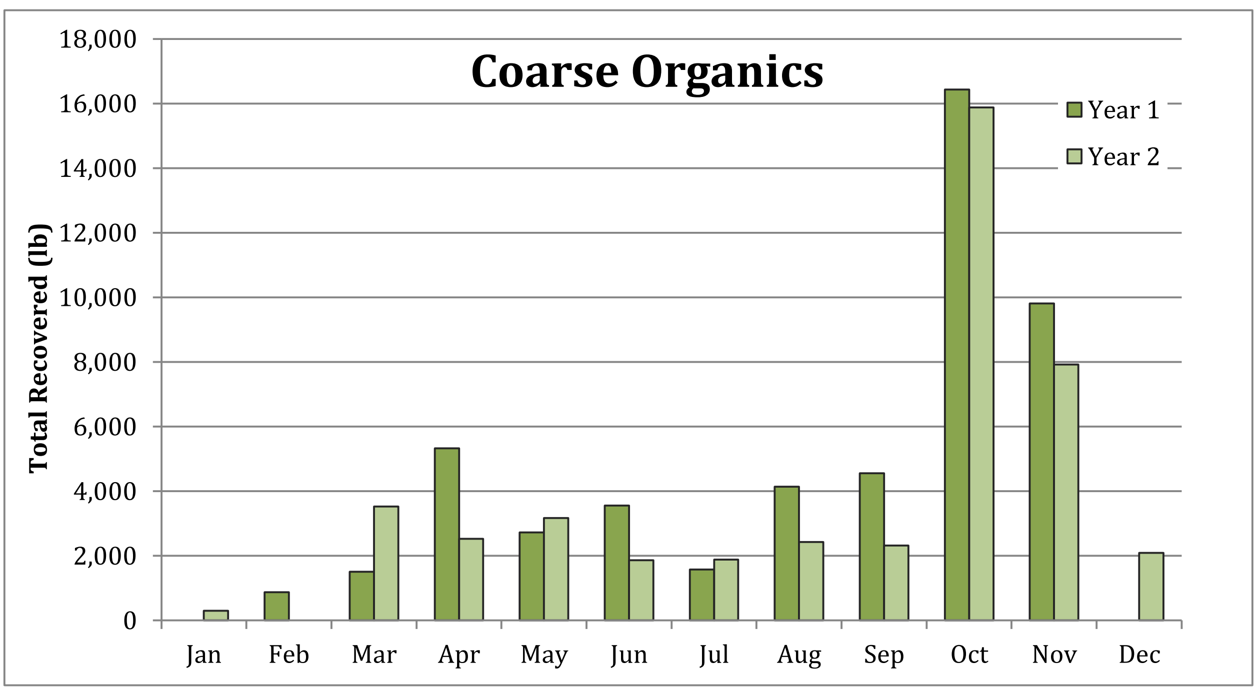


Figure 8. Total coarse organics recovered by month and year, all routes.

Influence of Season on Recovered Nutrients

If nutrient recovery is a key goal of sweeping operations, fall is the primary target season, followed by spring (Figure 9- Figure 14, phosphorus, Figure 13 - Figure 16, nitrogen). More phosphorus and nitrogen were recovered in October than any other month (Figure 9, Figure 13), but seasonal trends varied depending on which component recovered nutrients was being inspected. In the coarse organic fraction, average recovered loads (lb/curb-mile) were greatest in October and November for both phosphorus (Figure 11) and nitrogen (Figure 15) with lesser spikes in loading occurring in late spring. In the fine fraction (Figure 12), average phosphorus loads peaked in early spring during the cleaning of winter residuals, then tapered off during the summer months, and increased again with the timing of fall leaf drop.

In contrast to this, the nitrogen content of fine sediments recovered during spring cleaning was relatively low (Figure 16), and average recovered nitrogen loads increased over the late spring while recovered total solids were declining (Figure 6). The corresponding increase in average nitrogen concentrations in the fine fraction, from 2.3 ppm in March to 26.2 ppm in June, is likely due to incorporation of organic matter into the fine fraction over the spring month (*see Figure 19*).

Given the influence of tree canopy cover on nutrient loads (see 'Where to Sweep *(The Influence of Tree Canopy of Recovered Loads)*') nutrient recovery is more efficient on a per sweep basis in high canopy areas than in low canopy areas. The combined influence of season and canopy is seen in the range of values for phosphorus and nitrogen load intensity. Based on monthly average loads (lb/curb-mile), recovered phosphorus varied from a low of 0.04 lb/curb-mile in July for route L4, to a high of 0.80 lb/curb-mile in October for route H2. Monthly average nitrogen loads ranged from 0.19 lb/curb-mile in August for route L4 to 3.5 lb/curb mile October for route H2.

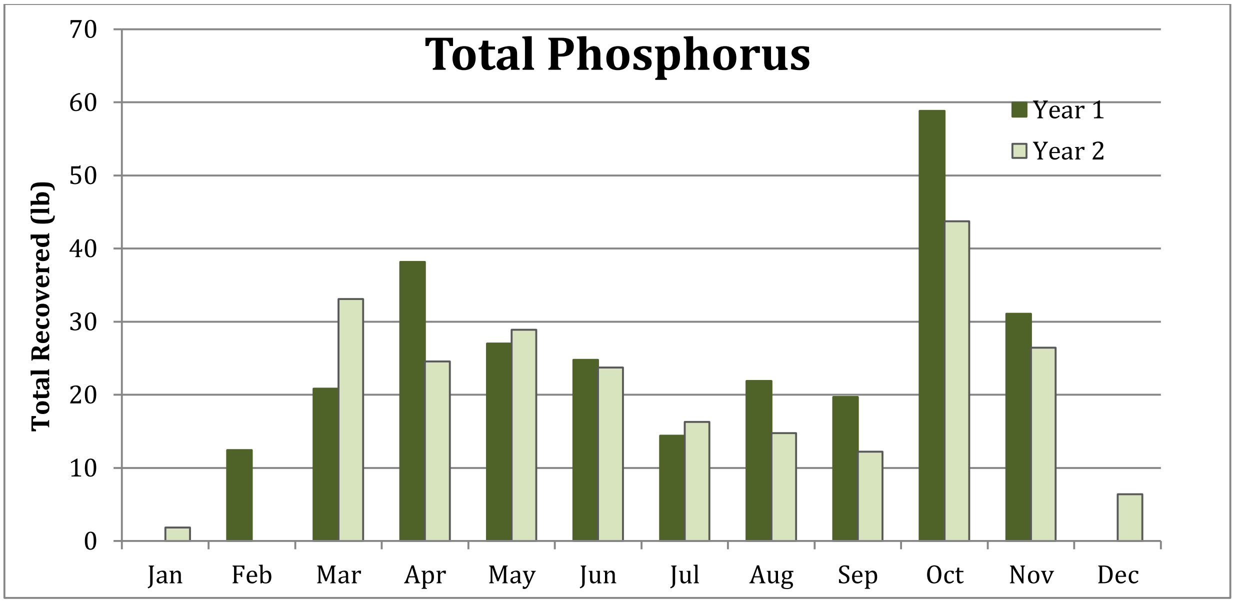


Figure 9. Total phosphorus (lb) recovered by month and year, all routes.

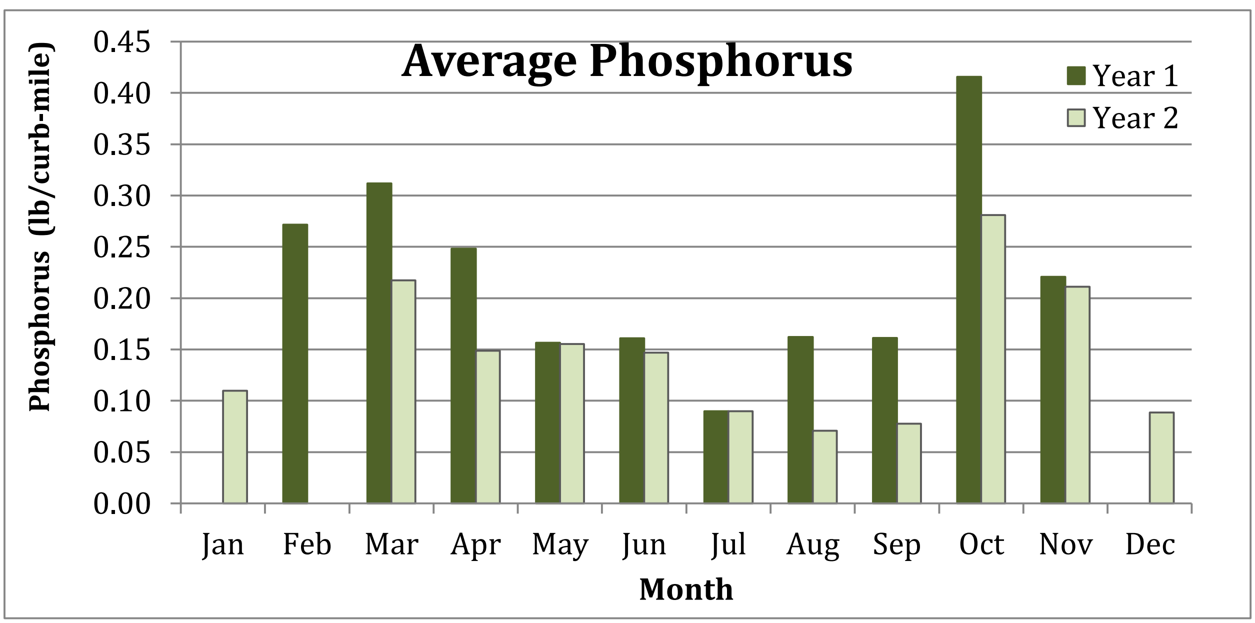


Figure 10. Phosphorus recovered (lb/curb-mile), by month and year, all routes.

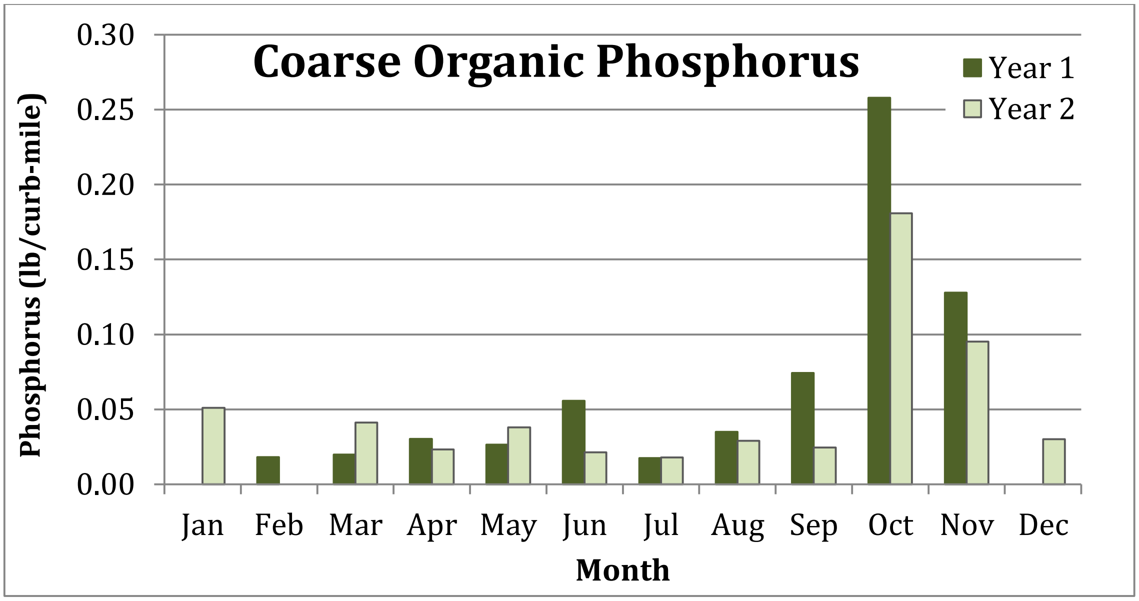


Figure 11. Phosphorus recovered in the coarse organic fraction by month and year, all routes.

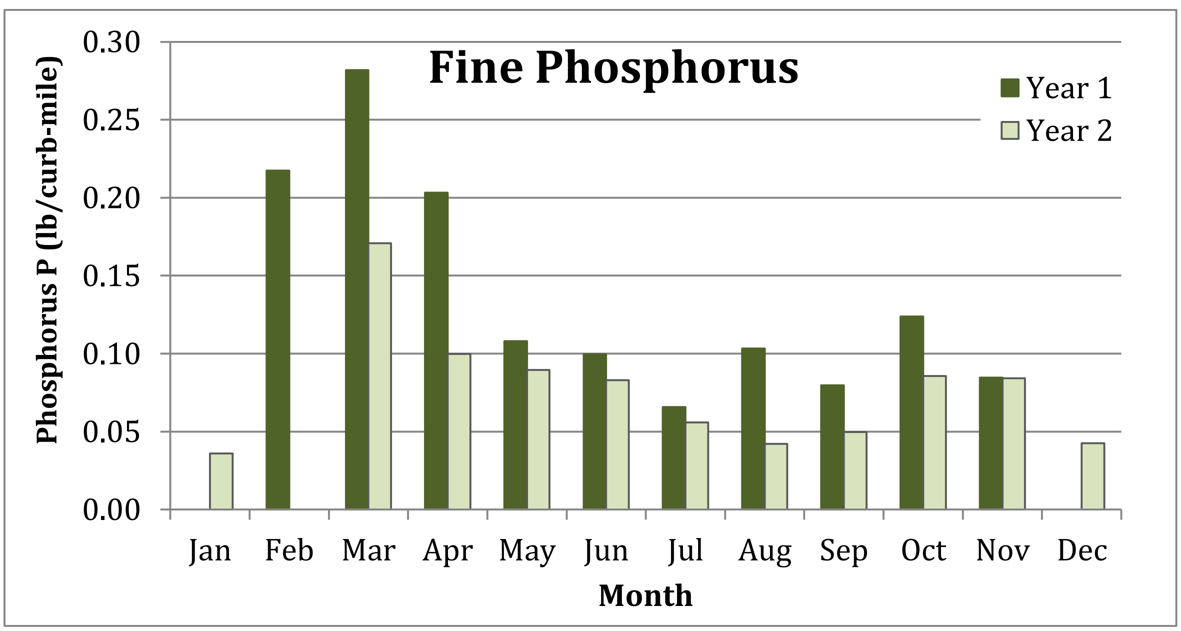


Figure 12. Phosphorus recovered in the fine fraction by month and year, all routes.

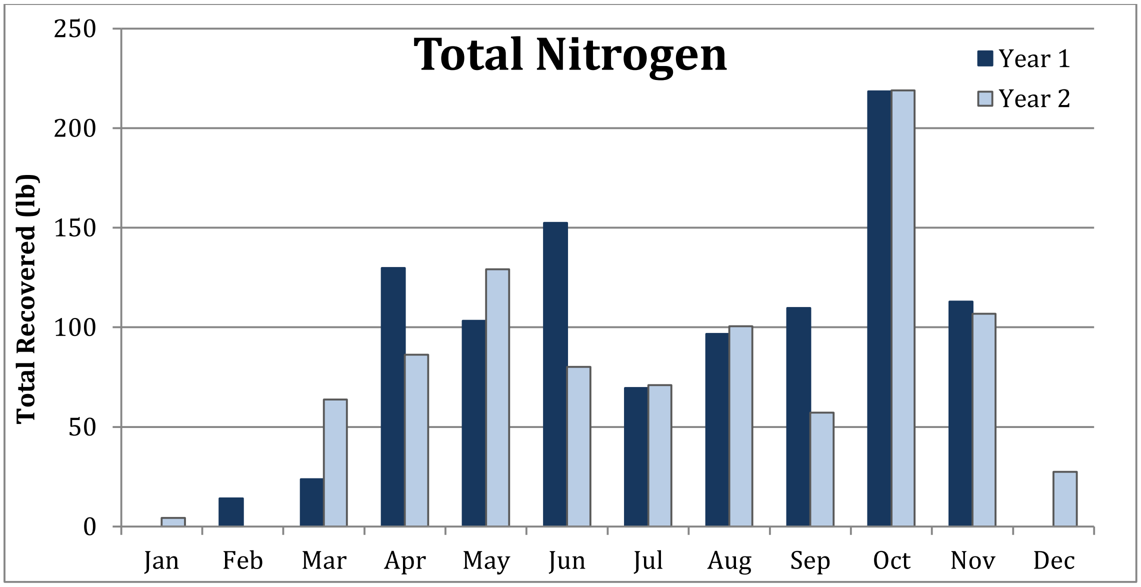


Figure 13. Total nitrogen recovered by month and year, all routes.

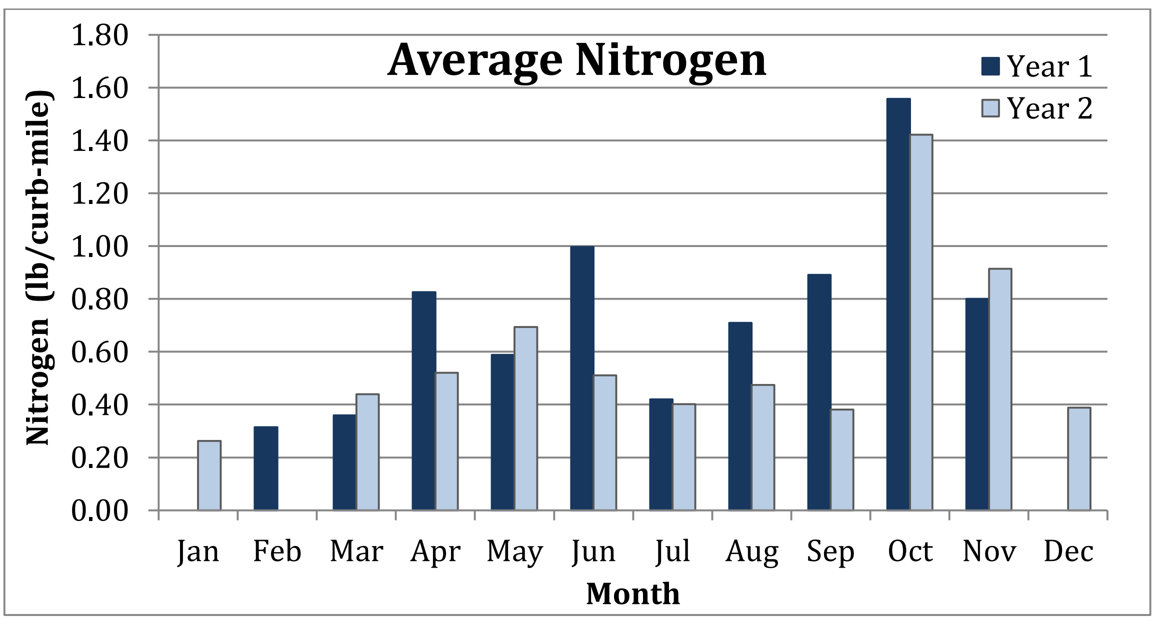


Figure 14. Nitrogen recovered by month and year, all routes.

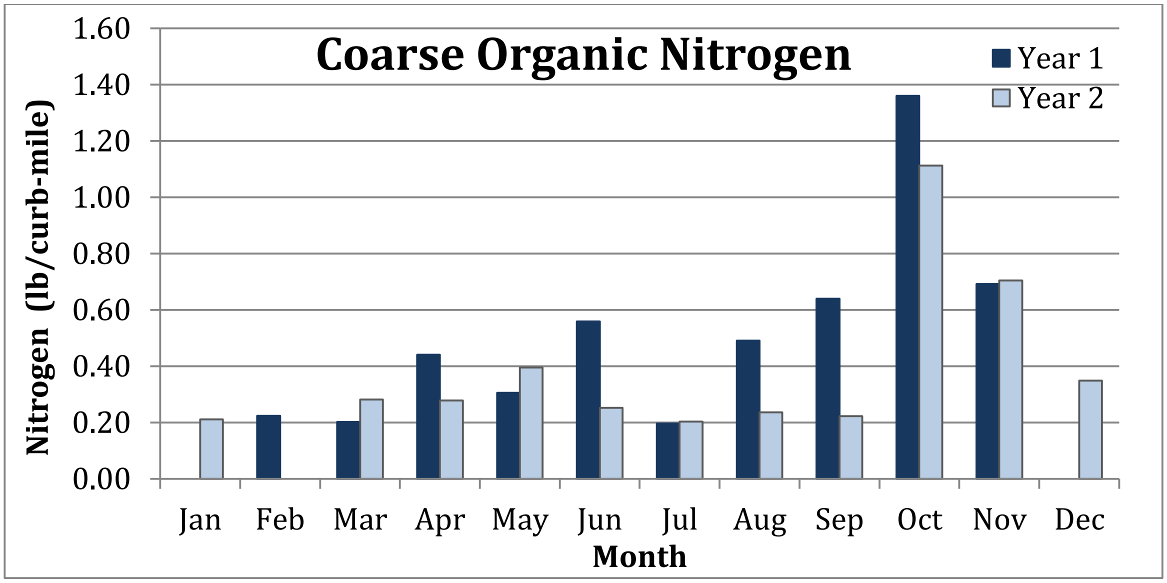


Figure 15. Nitrogen recovered in the coarse organic fraction month and year, all routes.

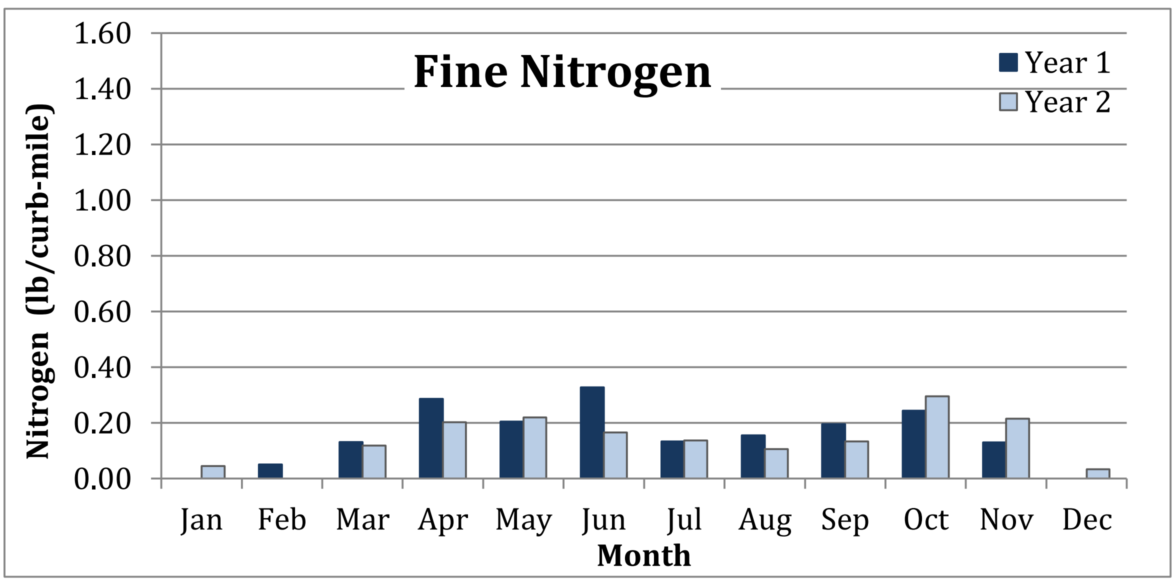


Figure 16. Nitrogen recovered in the fine fraction by month and year, all routes.

Distribution of Nutrient Loads in Sweeper Waste

The spike in nutrient loads corresponding to the timing of fall leaf drop indicates the influence of tree canopy cover on nutrient loads. But coarse organic sediments, which include material other than leaves such as flowers and grass clippings, represent a significant portion of nutrients found in sweeper waste throughout the year (Figure 17). While coarse organic loads comprise a relatively small fraction of the dry mass of removed sweepings during most months of the year, the mass fraction of phosphorus recovered as coarse organic sediment is about 2-5 times the dry mass fraction of total solids recovered as coarse organics and coarse organic sediments consistently contain the majority of recovered nitrogen loads.

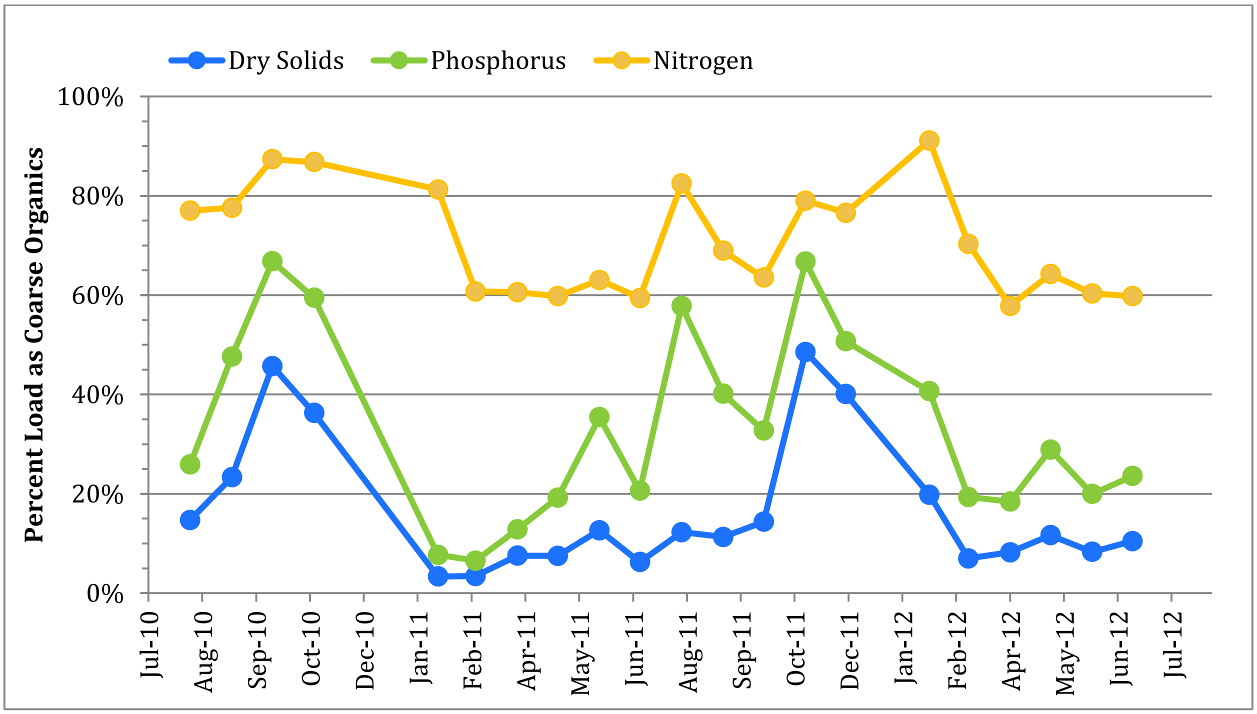


Figure 17. Average mass percent of recovered dry solid, phosphorus and nitrogen loads recovered as coarse organics by month, all study routes.

In addition to the influence of coarse organics, what can be collected on 2 mm sieves, there is also a significant amount of fine organic material derived from weathered or decomposing organic litter. We therefore expected tree canopy cover and season to have some influence on composition the fine sediment fraction as well as the overall composition of sweeper waste. In support of this, both the organic content (%OM) and the nutrient concentrations (phosphorus and nitrogen) of the fine sediment fraction increased from early to late spring, then dropped off somewhat during summer months and peaked in October (Figure 18 and Figure 19). Concentrations of these constituents were typically highest in high tree canopy areas.

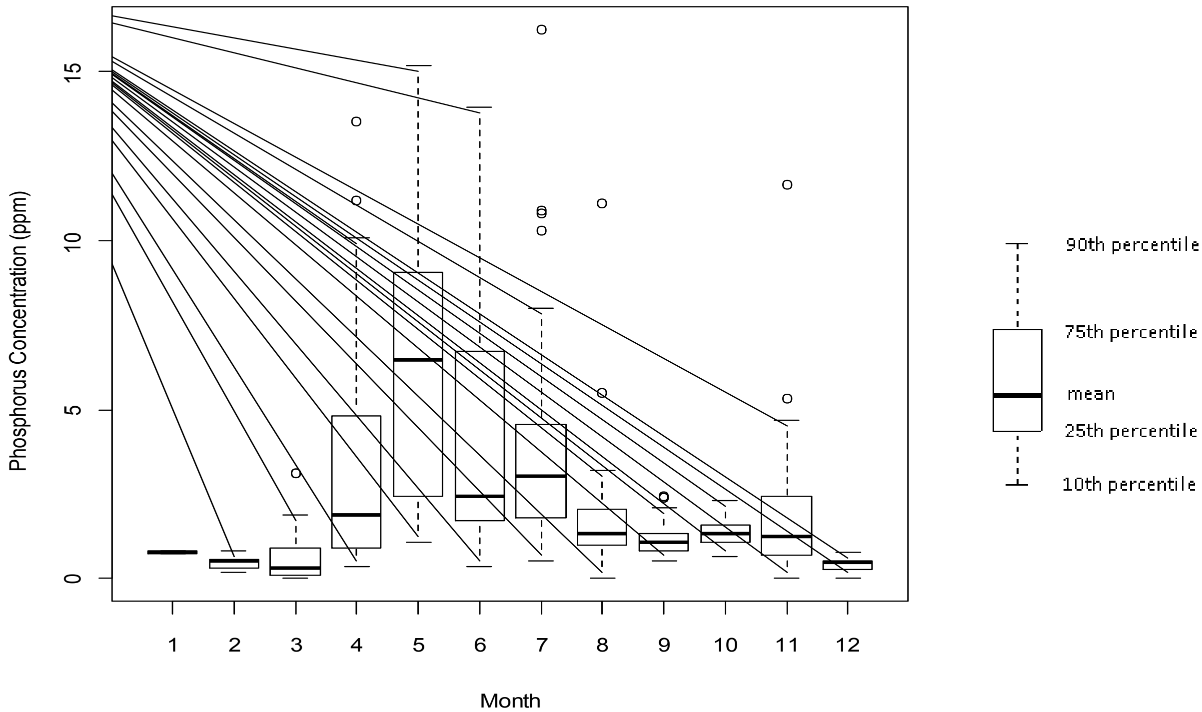


Figure 18. Phosphorus concentration in the fine fraction by month (all routes).

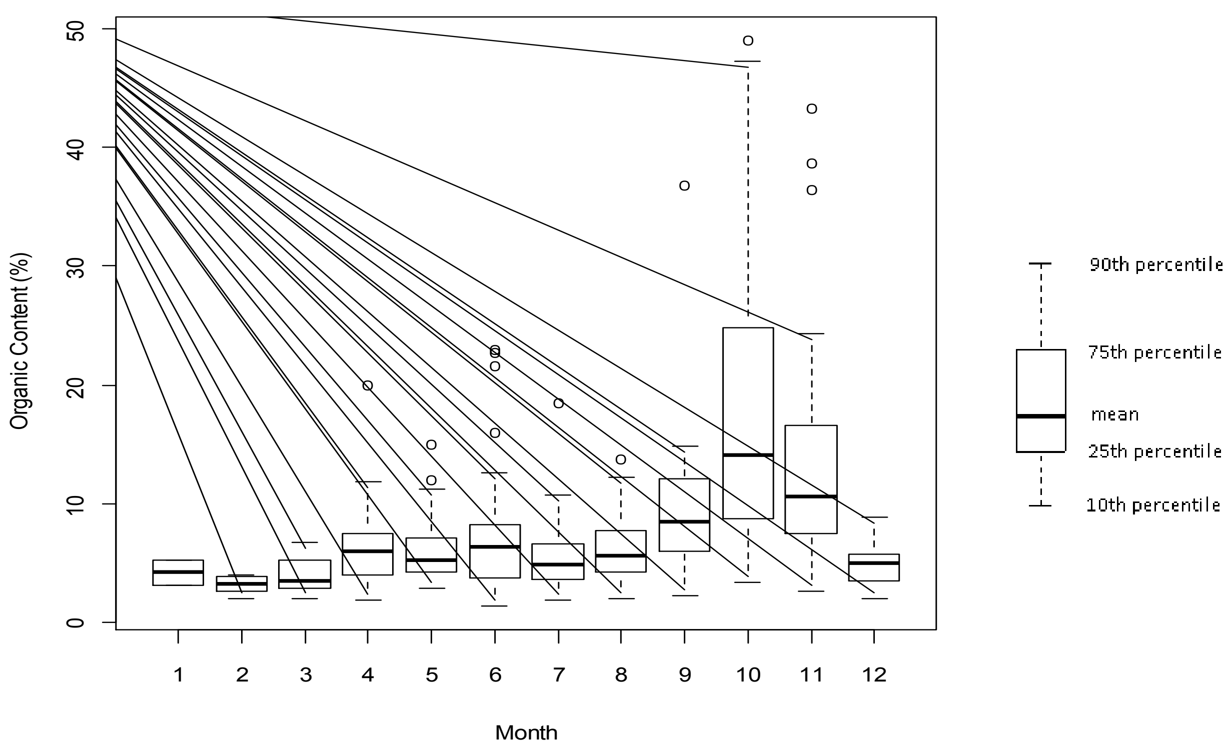


Figure 19. Percent organic content in the fine fraction by month (all routes).

Annual Variation in Solids Loads – We expected that, as long as there were no significant disturbances to the landscape or to land use patterns in the study area, variation in loading patterns from one year to the next could be approximated by a normal distribution. This is a fundamental assumption street sweeping planning calculator tool. To see if the variation in recovered loads from year 1 to year 2 fit our assumption, we used paired t-tests (α= 0.05 significance level) to compare total solids, coarse organic, fine sediment, total phosphorus, and total nitrogen loads recovered in year 1 to those recovered in year 2 for each month. Given the regular sweeping schedule followed throughout the study, the composition of these groups was fairly consistent from one year to the next (see Appendix F, Appendix G) making the comparisons reasonable. December, January, and February were not included because street sweeping was performed in only one of the two years during these months. In the majority of cases (31 of 45 comparisons), no significant difference was found in the mean recovered load intensity for each month when comparing year one to year two. Significant differences in mean recovered loads between the two years were most common for the months of March, April and August. Differences in March and April from year 1 to year 2 can be attributed to differences in winter weather and winter road maintenance. Differences in mean recovered loads in August are likely an artifact of start-up operations: streets were not swept regularly prior to the study, which began in August 2010. Overall, the analysis indicates consistency in the loading patterns from one year to the next.

Cost of Nutrient and Solids Recovery

A key question for most storm water managers considering street sweeping is cost-effectiveness. To address this question, we tracked the cost of sweeping operations throughout the study. Cost estimates included both labor and vehicle-related expenses, including maintenance and capital depreciation of the vehicle. The general formula used for estimating costs on a per-event basis is shown below. An outline of the costs estimation method is included in Appendix I. Although the cost of sweeping will vary given circumstances specific to a location or organization, the estimates given here provide a reasonable basis for cost considerations.

Cost of Sweeping Event = Operation time (hr)*$60/hr + Distance Swept (mi)*$5.25/mi

In addition to total costs, both the cost efficiency (cost per mile) and cost effectiveness (cost per pound of recovered material) of sweeping operations were tracked during the study. On the whole, cost efficiency was relatively stable, while cost effectiveness was heavily influenced by season and canopy cover.

Cost Efficiency of Sweeping

Over the course of the study, the median cost of sweeping was $21.42 per mile (standard deviation = $7.20). Costs varied somewhat from route-to–route with the highest average costs in route H1 ($29/mi) and the lowest average costs in route L4 ($20/mi). On a per mile basis, the mean cost of sweeping was not significantly influenced by the season, but the variation was greater in the early spring and fall (Figure 20). This is likely due to time and fuel use increases that are incurred when large or very wet loads must be recovered. These conditions occur more frequently in the spring and fall.

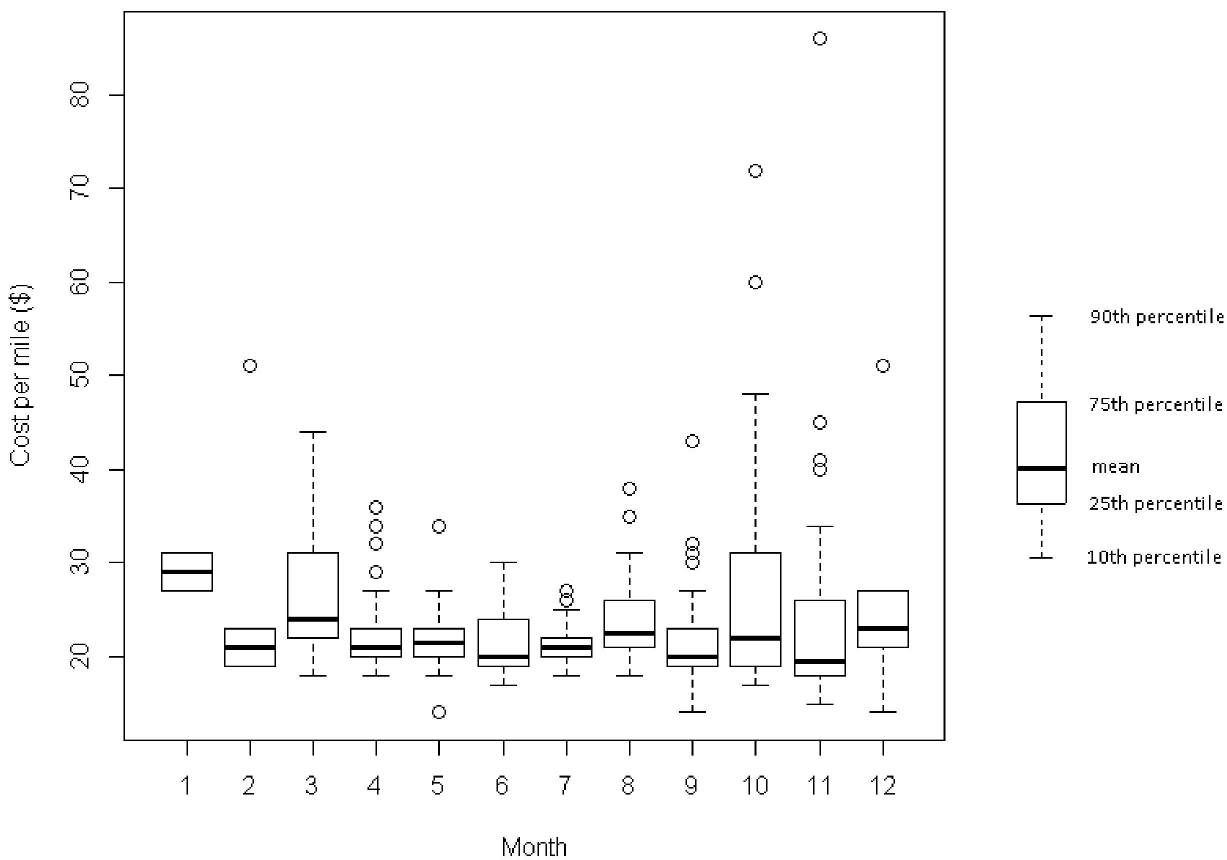


Figure 20. Costs for sweeping in $/mile (all routes) by month.

Cost Effectiveness of Sweeping

In contrast to the relatively stable cost per mile of sweeping, the cost per pound of solids or nutrient recovery varied significantly from month-to-month. The study average cost of street sweeping for phosphorus recovery was $270/lb of phosphorus recovered, however, sweeping was significantly more cost effective in the spring and fall when target loads (solids, phosphorus, or nitrogen) were more intense. Since loading intensity is also influenced by tree canopy cover and sweeping frequency, it follows that cost effectiveness would also vary from route-to-route.

The combined effects of season, tree canopy cover and sweeping frequency can be seen in Figure 21 where the average costs of phosphorus recovery for the least (L4) and most (H2) cost effective sweeping routes are shown by month. Monthly means for February in this plot represent single sweeping events for both routes. The greatest cost effectiveness for the H2 route was achieved in October (mean cost $41/lb phosphorus recovered) and average costs below $100/lb were achieved in March, April, October and November. Other than the single event in February, the greatest cost effectiveness for the L4 route was achieved in March (average cost $135/lb). The cost of phosphorus removal in October for this route, while less than the cost in the summer, was approximately 10 times the cost for the H2 route during the same month.

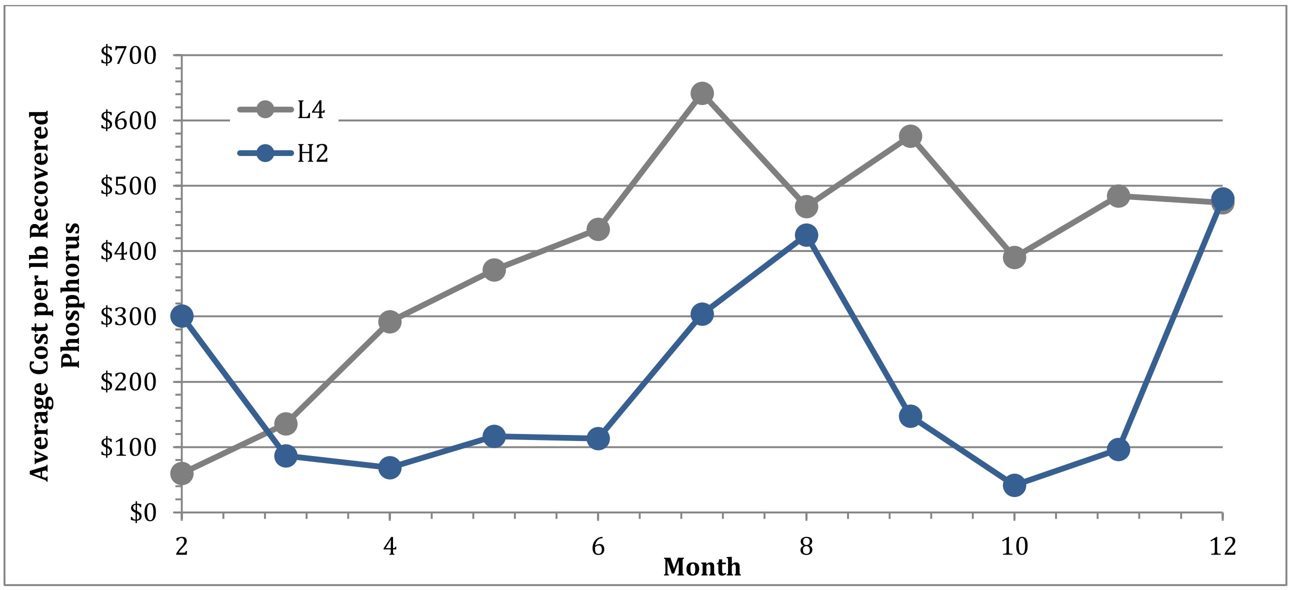


Figure 21. Monthly average cost of phosphorus recovery in $/lb for routes with the highest (L4) and lowest (H2) overall mean cost per pound.

A route-by-route comparison of the cost of phosphorus recovery during the most cost effective months of the year is given in Table 6. We expected tree canopy cover to positively influence the cost effectiveness of sweeping, and frequency to decrease the cost effectiveness. While this is somewhat the case, patterns in cost-effectiveness are less consistent than those seen for solids and nutrient loading. Differences in the March-April and October patterns of cost effectiveness are likely due to differences in the influence of coarse and fine sediments on nutrient loads as well as differences in loading rates for the two fractions during these times of the year.

Table 6. Average cost of phosphorus recovery in $/lb during months when sweeping was most cost effective.

	Low Canopy	Medium Canopy	High Canopy
		October	
1x/mo	173	112	70
2x/mo	170	93	41
4x/mo	390	77	167
		March-April	
1x/mo	89	92	99
2x/mo	249	129	73
4x/mo	231	159	236

Key Findings and Limitations of the Study

Key Findings

- Sweeping is most cost effective in the spring and fall. During these periods costs were as low $100/lb of recovered phosphorus in Prior Lake.
- Spring cleanup is an opportunity to recover large quantities of material from streets. High loading rates were seen over the much of March and April, suggesting that a single pass in the spring may not be sufficient to recover a majority of winter residuals.
- Fall sweeping represents a significant opportunity to recover nutrients from streets. This is especially true in areas of higher tree canopy cover.
- In general a significant portion of recovered nutrients (6 – 67% of the phosphorus and 58 -91% percent of the nitrogen) is found in the coarse organic fraction, a components of sweepings often overlooked in previous sweeping studies.
- Statistical analysis of recovered loads indicates that seasonal differences in solids loading are meaningful and that average recoverable loads are well predictable based on the timing, frequency of sweeping along with overhead tree canopy cover.

Limitations

Extrapolating results from this study to other cities should be done with care for several reasons. First, trees in Prior Lake are mostly deciduous, dropping their leaves in the fall. The pattern of leaf inputs to streets would be different for cities located in regions where autumn leaf fall is less pronounced, such as those in the southern U.S. Results would also not apply to residential areas where street trees are mainly conifers. Also, findings might not be accurately mapped into residential areas where the tree planting pattern is substantially different. Furthermore, the extent of over-street tree canopy cover was limited to a maximum of 19%. Results of this study likely underestimate recoverable loads for streets with far higher canopy percentages, including older neighborhoods with larger boulevard trees that sometimes have > 50% canopy cover. Lastly, it should be re-stated that all loads were recovered using a regenerative air sweeper. While other high efficiency sweepers are expected to recover street sediments with similar efficiency, results may be different if older technologies are used. In particular, recovery of fines is expected to be lower with older mechanical broom technologies (Chapter 2). These limitations apply to use of the Spreadsheet Calculator Tool described in Chapter 5.

Chapter 4. DECOMPOSITION AND LITTER LEACHING TEXT

Goals

Along with the potential for movement of leaf litter particles into storm drains via mass flow during rain and snowmelt events, we assessed the potential for movement of nutrients from leaf litter resulting from leaching and decomposition of litter in the street.

Methods

Leaf Litter Decomposition

We collected freshly leaf litter from five commonly planted street tree species: *Acer platanoides* L. (Norway maple), *Acer x fremontii* (Freeman maple), *Fraxinus pennsylvanica* Marsh. (green ash), *Quercus bicolor* Willd. (swamp white oak), and *Tilia cordata* Mill. (little leaf linden). Known amounts of freshly fallen leaf litter were enclosed in 1-mm mesh bags, constructed of fiberglass window screen.

Subsamples of fresh litter were analyzed for ash content (550°C); total carbon and nitrogen on a Costech ECS4010 element analyzer (Costech Analytical, Valencia, California, USA) at the University of Nebraska, Lincoln; total phosphorus by digestion with persulfate followed by colorimetric analysis; and for carbon fractions using an ANKOM Fiber Analyzer (Ankom Technology, Macedon, New York, USA) (cell solubles, hemicellulose+bound protein, cellulose, and lignin+other recalcitrants).

Figure 22. Installation of litterbags along a curb.

Sufficient bags were made to harvest three replicate bags of each species 15 times over the course of one year. We deployed bags alongside the concrete curb in a street gutter in the parking lot of the University of Minnesota Equine Center, Saint Paul, MN on Oct. 1, 2010 (Figure 22). This location was chosen because the parking lot is a large, but very little used, area so it has abundant linear meters of curb but is not prone to vandalism. Once per week, a car was driven over the bags to simulate car parking that would normally occur along curbs on city streets.

Three replicate bags were harvested every two weeks through December, 2010 and approximately monthly thereafter through October 1, 2011. No bags were harvested during February 2011 due to snow cover. Upon collection, we separated litter from bags, and dried (65°C), weighed, and ashed it for one hour (550°C) to determine ash-free dry mass remaining as a proportion of the initial ash-free dry mass. Harvested litter was analyzed for C, N, and P content, as above.

Leaf Litter Leaching

We also determine the amount of readily leachable nitrogen and phosphorus by placing five grams of air-dried leaf litter of each species in 500 ml of deionized water in wide-mouth high-density polyethylene bottles (5 replicates/species). Samples were shaken by hand for 10 seconds and then allowed to sit at 22°C for 24 hours when they were shaken again by hand for 10 seconds. Duplicate 30 ml subsamples of leachate were taken after 30 minutes and again 24 hours, syringe-filtered through pre-ashed GF/F filters, and analyzed for dissolved organic carbon, total dissolved nitrogen, dissolved inorganic nitrogen, soluble reactive phosphorus, and total dissolved phosphorus. Dissolved organic nitrogen and phosphorus were calculated by subtracting dissolved inorganic nitrogen and soluble reactive phosphorus from total dissolved nitrogen and phosphorus, respectively.

Results

Decomposition

Decomposition preceded rapidly in the street, suggesting that delays in street sweeping provide an opportunity for movement of nutrients, particularly phosphorus, into the storm sewer drainage network, from decomposition and subsequent runoff of soluble material. These losses would occur in addition to any particulate nutrients that might be washed into storm drains during precipitation and snowmelt events.

For all species, there was a period of rapid decomposition in the first 1.5 months in the street, when up to 22 percent of the litter decomposed (Figure 23). By the end of one year, about 80% of the litter had decomposed for all of the species except Quercus bicolor. Litter of Quercus had lost about 60% of its initial mass by this time. The slow decomposition of Quercus bicolor compared to the other species likely related to its high litter lignin concentration (Table 7).

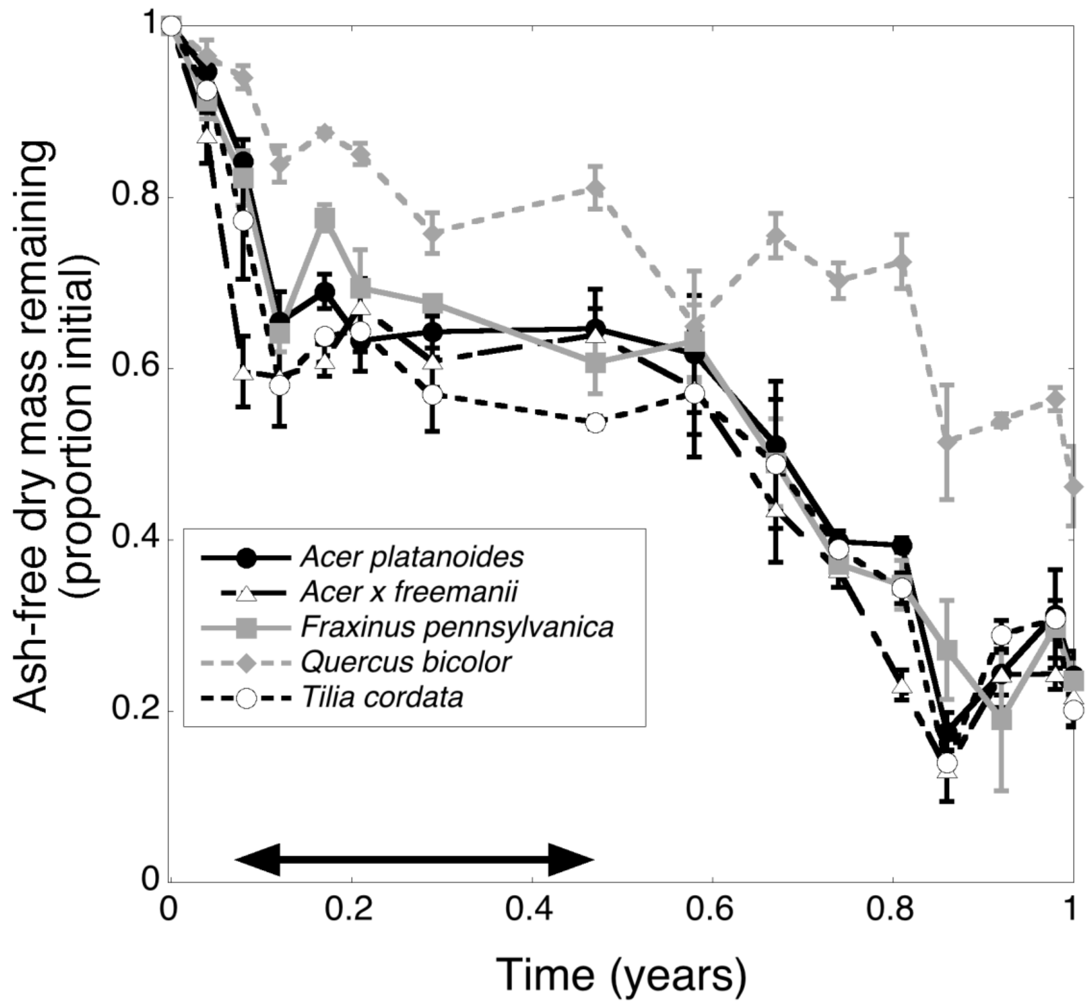


Figure 23. Decomposition of litter of five tree species decomposing in a street gutter, expressed as the proportion of the initial ash-free dry mass remaining over time. The arrow indicates the time during the year when precipitation fell as snow.

Table 7. Initial litter chemistry for five species studied. All parameters are expressed in percent of total mass. Values are means (standard errors).

Species	N	P	cell solubles	hemicellulose	cellulose	lignin
Acer platanoides	1.22 (0.01)	0.096 (0.004)	26.6 (1.8)	39.4 (1.5)	17.8 (0.3)	16.5 (0.2)
Acer x freemanii	1.57 (0.02)	0.134 (0.010)	64.3 (0.4)	14.0 (0.6)	11.2 (0.1)	10.9 (0.1)
Fraxinus pennsylvanica	0.96 (0.13)	0.162 (0.002)	50.0 (1.4)	15.5 (1.3)	23.1 (0.1)	11.8 (0.2)
Quercus bicolor	1.16 (0.13)	0.099 (0.002)	42.6 (0.2)	11.1 (0.2	22.4 (0.2)	24.3 (0.1)
Tilia cordata	1.39 (0.03)	0.162 (0.010)	38.9 (1.7)	28.4 (1.4)	18.7 (0.2)	14.4 (0.6)

If street sweeping is delayed, runoff of nutrients from decomposing litter is likely to be more substantial for phosphorus than for nitrogen. Litter retained most of its nitrogen for about 10 months, before beginning to release nitrogen (Figure 24). Phosphorus, on the other hand, was rapidly lost from litter of several species – up to 50% of the phosphorus had been lost from some species' litter after 1.5 months, and nearly all species had lost about 50% of their initial phosphorus by the end of one year (Figure 25). This "lost" phosphorus is likely available to be washed into storm drains during rainfall and snowmelt events.

These results are consistent with the large fraction of phosphorus that was leached out of leaf litter in laboratory experiments, compared to nitrogen (Figure 26). After 0.5 hours, less than 4% of the initial nitrogen was leached, whereas 9 – 26% of the initial phosphorus was leached. After 24 hours, less than 10% of initial nitrogen was leached, whereas 28 – 88% of the initial phosphorus was leached. However, because leaf litter contains more nitrogen than phosphorus (Table 7), the absolute amounts of nitrogen and phosphorus that leached from the litter were not as different from one another (Figure 27). These results indicate that leaching losses of both nitrogen and phosphorus from litter in the street could contribute to runoff of nutrients to storm drains.

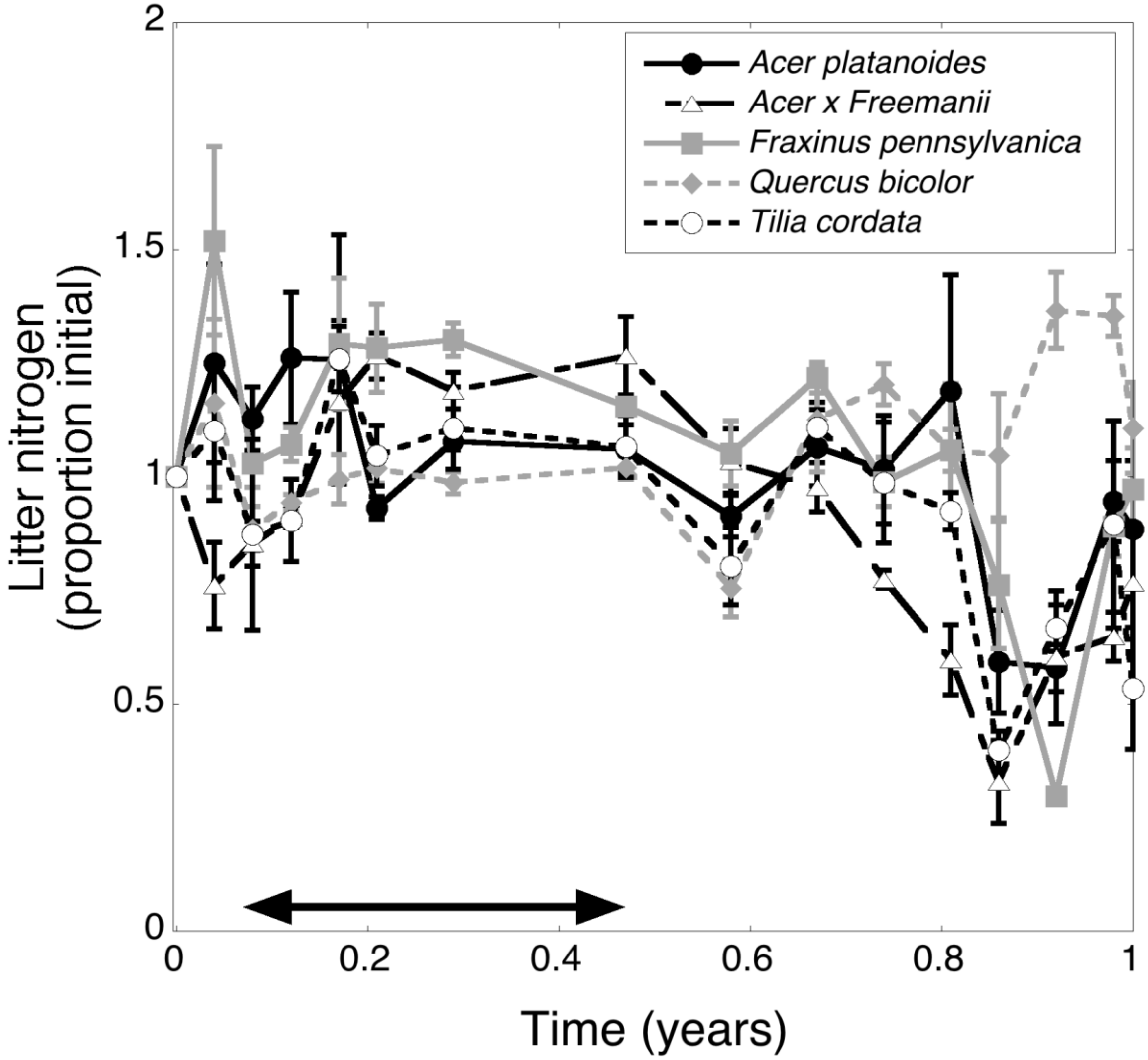


Figure 24. Nitrogen dynamics of litter of five tree species decomposing in a street gutter, expressed as the proportion of the initial nitrogen content present over time. The arrow indicates the time during the year when precipitation fell as snow. Nitrogen content can remain constant or even rise above 100% of the initial nitrogen content because decomposer microorganisms colonizing the litter can import nitrogen from their environment.

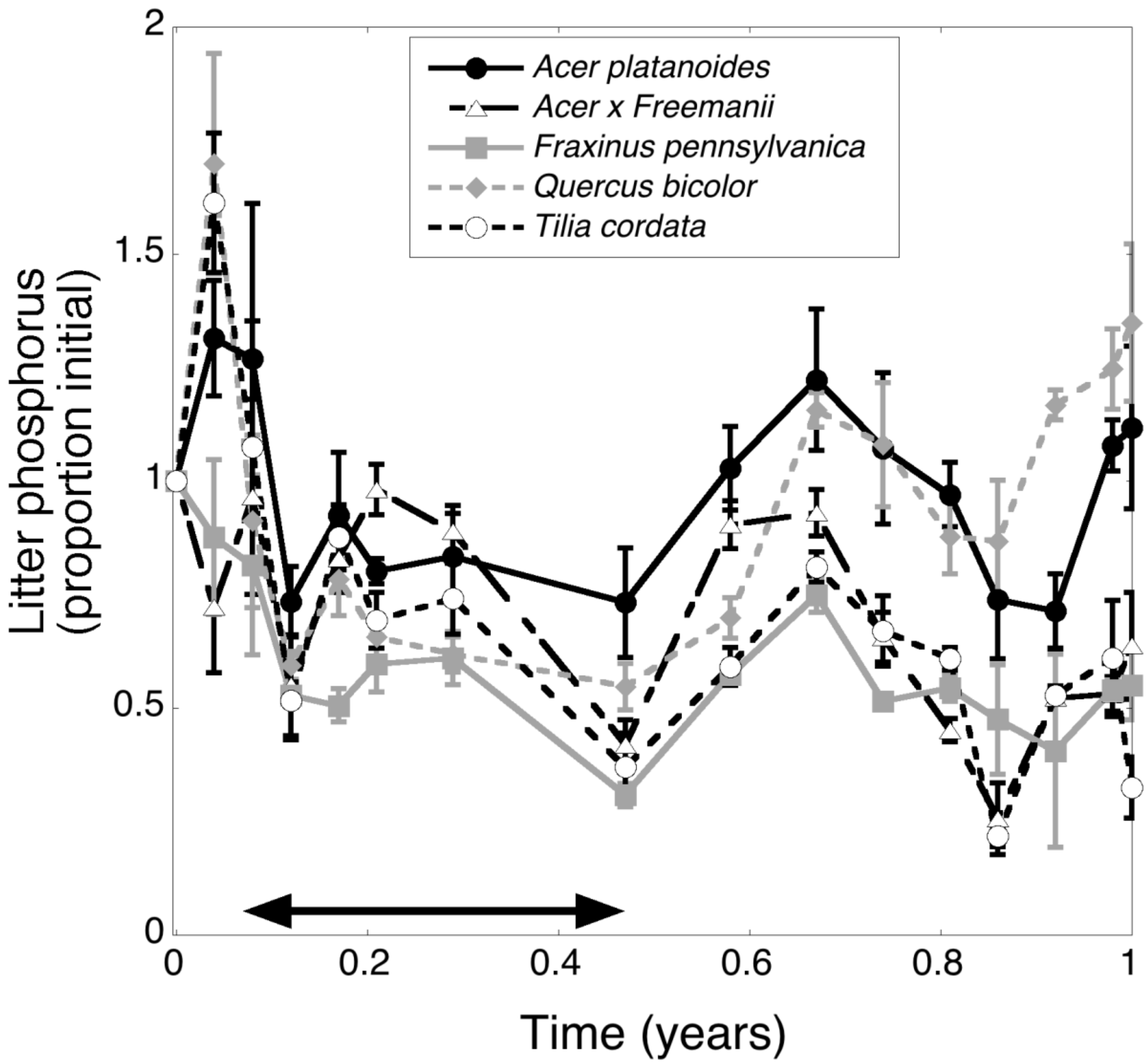


Figure 25. Phosphorus dynamics of litter of five tree species decomposing in a street gutter, expressed as the proportion of the initial phosphorus content present over time. The arrow indicates the time during the year when precipitation fell as snow. Phosphorus content can remain constant or even rise above 100% of the initial phosphorus content because decomposer microorganisms colonizing the litter can import phosphorus from their environment.

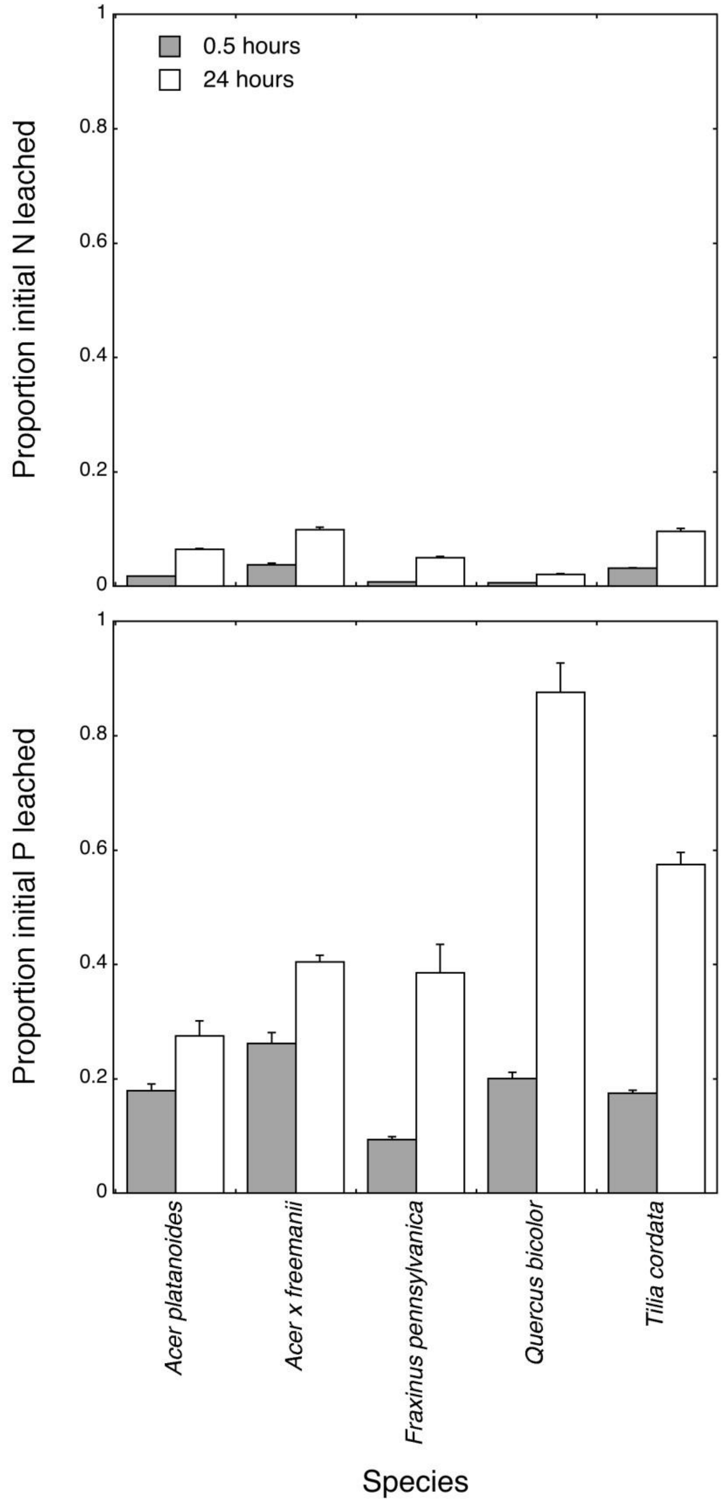


Figure 26. The proportions of the initial pools of nitrogen (top) and phosphorus (bottom) leached from litter over 0.5 and 24 hours in a laboratory experiment.

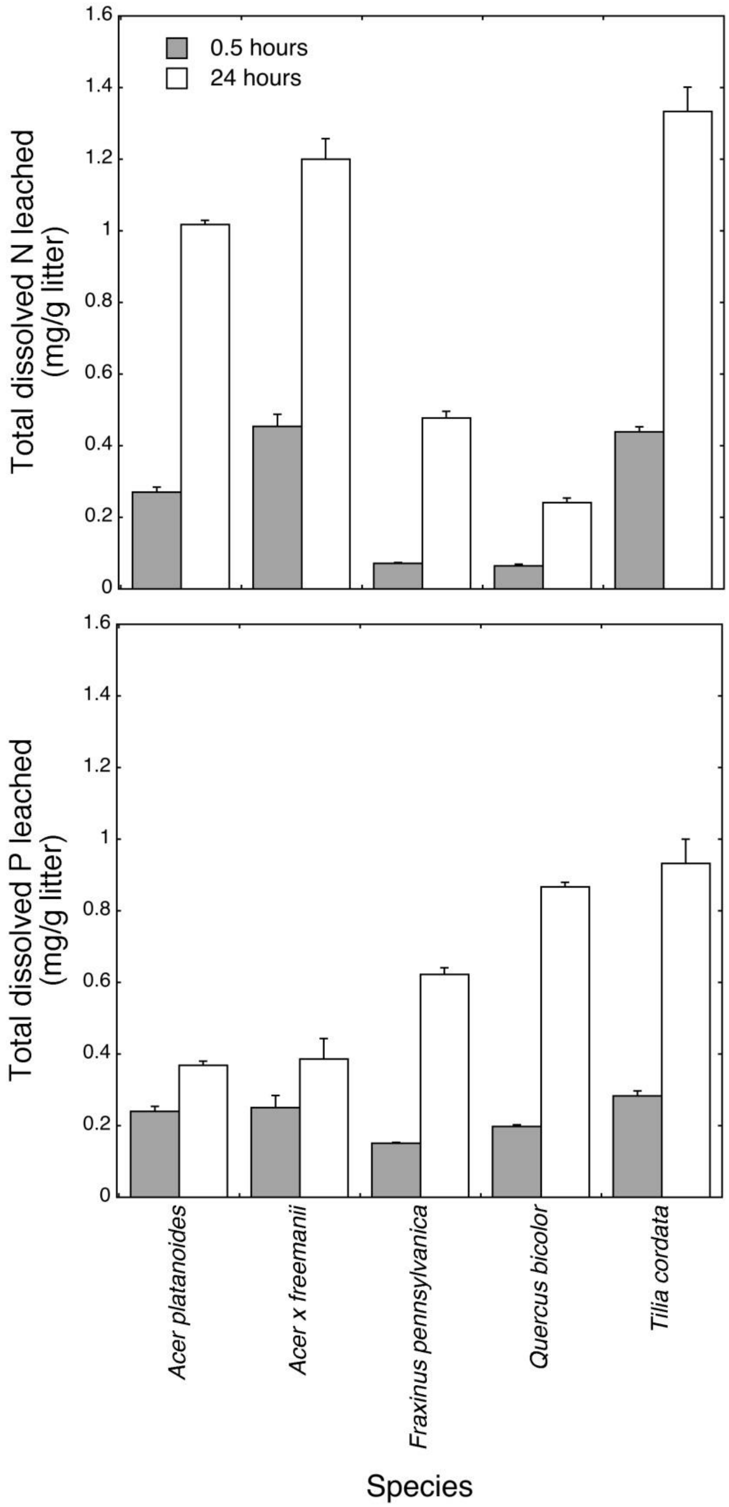


Figure 27. The total amount of dissolved nitrogen (top) and phosphorus (bottom) leached from litter over 0.5 and 24 hours in a laboratory experiment.

Chapter 5. Planning Calculator Tool for Estimating Nutrient and Solids Load Recovery through Street Sweeping

General Model for Predicting Solids and Nutrient Loads

A main goal of the study was to develop simple statistical models that could be used to predict the solids and nutrients that could be recovered through street sweeping. These models could be used for planning sweeping programs and for estimating the potential for sweeping as a water quality BMP. Our results indicate that tree canopy cover, frequency, and the timing of sweeping all influence street sediment loads. A robust model would take all three variables into account. A practical tool would be based on inputs that can be easily supplied by the user. Through regression analysis we arrived at the simple, base model shown below. This base model can be applied to any of the load types (solids or nutrients) measured in the study, and forms the basis of the planning calculator tool.

Log(Recovered Load) lb/curb-miles =
β_1 x (Month Factor) + β_2 x (Overhead Tree Canopy) + β_3 x (Sweepings per month)

This form of equation was calibrated for predictions of total solids, nitrogen, and phosphorus in our Excel-based Street Sweeping Planning Calculator Tool: Estimating Solids and Nutrient Load Recovery through Street Sweeping. To use the Calculator Tool, users specify a route, with associated over-street tree canopy cover, and then develop sweeping scenarios by altering the number of sweepings that occur during each month. This process is then repeated for other routes. The Calculator then estimates solids, nitrogen, and phosphorus removal for each route, and then for the entire swept area (all routes), with associated costs. Instructions for use of the calculator are presented in the next chapter.

Predictions were validated using a five-fold cross-validation procedure. In this procedure, the data set was randomly divided into five subsets. The model was 'trained' on 4/5th of the data and then used to predict recovered loads on the remaining 1/5th based on the month of the sweeping event, the over-street canopy cover for the particular route, and interval between sweeping events (sweeping frequency). This procedure was repeated with similar results in several trials. Results show that the model is very robust (Table 8).

Table 8. Results of five-fold cross-validation for

Load Component*	**Total Collected (lb)**	**5-fold cross validation result**	**% Error**
Dry Solids	619,422	638,302	3.0%
Fine Solids (dry wt)	435,199	443,249	1.8%
Coarse Organics (dry wt)	95,031	102,875	8.3%
Fine phosphorus	284.0	293.6	3.4%
Coarse phosphorus	166	179	7.5%
Total Phosphorus (n=385)	458	4778	4.4%
Fine Nitrogen (n=377)	505	521	3.1%
Coarse Nitrogen	1292	1,370	6.1%
Total Nitrogen (n=262)	1363	1,913	5.2%

*Sample size = 392 unless otherwise noted.

One limitation of the model is that is does not account for build-up that may occur during long intervals when sweeping is not performed (e.g., over the summer period). In such cases it is assumed that once per month sweeping frequency provides a conservative estimate of recoverable loads. Of course, predictions made using the Calculator also assume that the neighborhoods being modeled are “similar” to those in the city of Prior Lake. Some key limitations to extrapolating findings from this study to other cities were discussed in Chapter 1 and Chapter 3.

User Guide to the Planning Calculator Tool

Planning Calculator for Estimating Nutrient Removal through Street Sweeping
Quick Reference Users' Guide

Overview of Planning Calculator
The Planning Calculator for Estimating Nutrient Removal through Street Sweeping is designed to provide an estimate of the average solids and nutrient (phosphorus and nitrogen) loads that can be recovered through street sweeping based on the timing and frequency of sweeping operations and an estimate of the percent tree canopy cover over the streets to be swept. It has been calibrated to conditions in Prior Lake, MN and is recommended for use in the greater Twin Cities metropolitan Region or geographic areas with comparable climate and vegetation.

Step 1: Define Sweeping Routes

In order to use the spreadsheet calculator tool, the user must define sweeping routes. This information is entered on the "Routes" tab of the spreadsheet tool.

The following parameters must be defined for each route created:

1) Unique identification tag (Route ID)
2) Curb-miles to be swept (curb-mile = 1 mile along one side of a street)
3) The average **over-street** tree canopy cover for the entire route.

*** Denotes Required** Route ID*	Curb-miles*	Average % Canopy Cover*	Priority Rating	Unique Cost ($/curb-mile)
(any string of characters)	(each side of the street)	(route average)	(user defined)	(replaces default cost for special circumstances)
Example NW10	15	20	1	

Sweeping routes can be designed based on any number of factors (ex. street or land use type, proximity to receiving waters, stormwater management concerns). For the purpose of the planning calculator, a route represents streets for which the timing and frequency of annual sweeping operations is (nearly) identical. For example, all street for route 'A' will be swept once in March and once in the October. Streets with similar characteristics for which the timing or frequency of sweeping will vary should be represented in different routes.

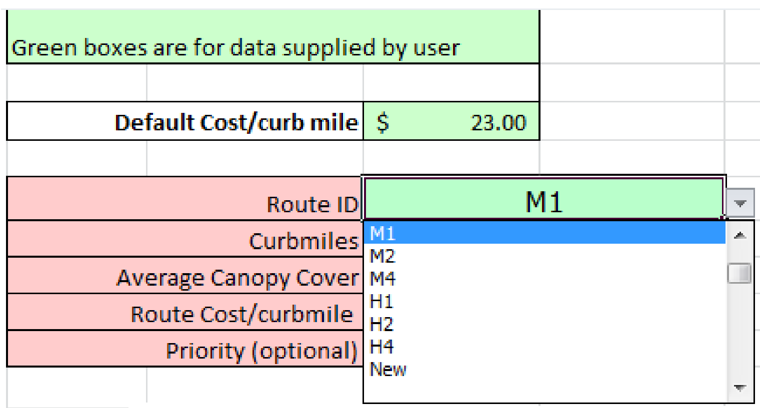
Step 2: Define Default Cost

Because the cost of sweeping operations will vary depending on sweeper type and unique overhead considerations, no default cost algorithm was built into the spreadsheet calculator tool. To include cost-estimates in planning calculations, users must supply a default cost basis in the form of the expected *cost per curb-mile of sweeping* on the "Planning" tab. Guidance on estimating the cost-per curb-mile of sweeping is provided in the spreadsheet support material. Cost estimates are not required to calculate expected recovered loads.

Green boxes are for data supplied by user	
Default Cost/curb mile	$

Step 3: Design Sweeping Operations for Individual Routes

Once routes have been entered on the "Routes" tab, they are available in a drop down menu on the "Planning" tab. Use the drop down menu to choose a route. The relevant route information will be loaded to the planning tab automatically.



Type the number of sweeping events planned in each month for the chosen route in the frequency column of the Load Prediction table. Hit "enter" to calculate the expected recovered loads and associated costs for each sweeping event. The calculator is calibrated to sweeping frequencies between 0 times per month and once weekly. Frequencies are restricted to integer values and the maximum allowable value of '5' represents the maximum number of weekly sweepings possible in a month. The calculator assumes an equal interval between sweeping operations for frequencies greater than once per month (ex. 3 times per month is calculated at a 10 day interval) and adjusts the expected load for the first sweeping event in each month to reflect sweeping intervals in the previous month.

Month	Frequency	Predicted (lb)				Predicted (lb)	
		Wet Solids	Dry Solids	Nitrogen	Phosphorus	Cost	$ Cost/lb P
January							
February							
March	1	3632	2931	1.8	1.6	$ 138.00	$ 87.45

Step 4: Create Sweeping Scenarios

When sweeping operations have been designed to satisfaction for a given route, route operations can be added to sweeping summaries to create sweeping plans. Use the “Accept Changes” button to add operations to summaries, and “Edit Routes” button to edit sweeping operations that have already been saved.

Clear Form	“Start over” command – clears route information and computations from the calculator.
Accept Changes	Adds the current computation to the route summaries.
Edit Route	Pulls information from route summaries so that routes can be edited.

Note that the user is able to change route parameters (curb-miles, percent canopy cover) on the “Planning” tab, however, any changes made to route parameters on the “Planning” tab **will not be saved** on the “Route” tab. This means that the next time the route is called, or when the route is called for editing from sweeping summaries, the parameter values will default to those supplied on the “Route” tab.

Routes parameters may be edited at any time on the “Routes” tab; however, sweeping summaries will not automatically update to reflect these changes. To update saved sweeping operations when route parameters have changed, re-load the saved route using the “Edit Route” feature and re-save the route sweeping operations using the “Accept Changes” feature. Expected loads and cost-estimates are re- calculated when route information is loaded from sweeping summaries. The effect of changing route parameters can be seen by comparing saved values with re-calculated values when routes are called for editing. Saved values are not over-written until the user accepts edits.

Step 5: Export Sweeping Scenarios

When sweeping operations for all routes have been designed to satisfaction, the sweeping plan can be exported to a new workbook using the "Save/Clear" function found on any of the summary tabs. The "Save" feature will export summary information only. If additional editing work is to be complete at a later data, the workbook can simply be saved under a new file name. The workbook is not designed to re-initialize upon opening or closing, so a simple save will protect the current work. The sweeping summaries can be reset using the "Clear" feature found on any of the summary pages. Choosing this option will reset all sweeping summaries, but will not affect route parameter information. To adjust route parameters simply edit/add/delete from the "Routes" tab.

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QUALITY ASSURANCE/QUALTIY CONTROL

Sample Processing

Field sampling – A total of 394 samples of sweeper waste were collected in Prior Lake. Vehicle operators followed a documented protocol when sampling sweeper waste. To avoid contamination of sediments, vehicle operators wore nitrile gloves and samples were stored in 1-gallon plastic freezer bags. Samples were labeled at the time of collection with the sweeping route and date of sweep and stored in a freezer at Prior Lake until collection and transported to the University of Minnesota in coolers. Due to the cost-prohibitive nature of processing, duplicate samples of sweeper waste were not taken in the field.

To insure collection of representative samples, sweeper loads were dumped before sample collection to re-mix sediments that may have stratified in the hopper. Sampling protocol required that vehicle operators visually inspect the dumped load before sample collection to estimate the portion of soil and plant debris, and to check the degree of consolidation of material from the bottom of the hopper. One handful each of sweeper material was collected from four sides of the dumped load. Samples were visually inspected after collection to insure that fractions in the sample were representative of their proportions in the dumped load. The sampling procedure was repeated if drivers determined that a sample was not representative.

Laboratory Processing – A total of 392 sweeper waste samples were processed at the University of Minnesota. Samples from two sweeping events were not processed due to ambiguous labeling. Trained laboratory staff followed documented protocols in all sweeper waste processing and standard operating procedures for laboratory safety, operation, and maintenance of equipment were followed throughout the study.

During the fractionation process, duplicate samples of about 250 mL each were taken from float separation leachate water. Leachate samples were filtered (Whatman #1, 11μm) to remove suspended particles. Quadruplicate subsamples of approximately 20 mL each were taken for TOC/TN and TP tests from each leachate sample. All samples were run along with instrument blanks (Nanopure water). Laboratory standards of KNO_3 with potassium hydrogen phthalate were prepared from standard-grade stock for TOC/TN analysis. For TP analysis, K_2PO_4 standards were prepared from standard-grade stock. Due to high nutrient concentrations in filtered leachate, samples were diluted for analysis. Final results for all leachate analysis were reported as the average value of results for each sweeper waste sample. Results were discarded and analyses redone if the coefficient of determination (R^2) for the standard curve fell below a value of 0.94.

After the fractionation and drying process, sub-samples were taken from the fine sediment fraction for chemical analysis (~15mL) and archiving (~25mL). The sub-sample taken for chemical analysis was first pulverized before further subdivision into samples for analysis of organic content, TP, and TC/TN. The coarse organic fraction was ground before sub-samples were taken for chemical analysis (~15 mL) and archiving (~25g).

Single sub-samples of ground fine (1-2g) and coarse organic (~0.5 g) sediments were ashed in clean borosilicate glass vials following the loss-on-ignition method described by Ben-Dor and Banin, (1989).

Total phosphorus was determined by colorimetric method as described in the methods section. This method was adopted for analysis of fines after more traditional methods (nitric acid digestion) proved insufficient due to high organic content in the fine fraction. Analysis was run on single sub-samples (1-4 mg) of ground, ashed fines with duplicates run every 1/10 samples, and with triplicate sub-samples for coarse organic sediments. Apple NIST 1515 Standard was used as the reference material in all TP analyses. This standard is typically used in analysis of organic matter. Due to a high organic content of the fine sediment fraction of street sweepings along with its urban, terrestrial origin, a suitable soil standard could not be identified. To insure that apple standard was an appropriate reference material for the fine, soil-like fraction, the TP content of an inorganic standard (K_2PO_4) was analyzed using the apple standard as a reference material. Strong agreement between the known and measured TP values provided assurance that organic matter was completely digested in the laboratory method and that the Apple NIST 1515 standard was an appropriate reference material for analysis of the fine sediment fraction.

Sub-samples of ground, fine and coarse organic material were shipped in waterproof containers via express delivery to the University of Nebraska Ecosystems Analysis Laboratory for TN/TOC analysis. Uncertainties for all laboratory methods are given in table A-1.

Table A-1: Uncertainty in Chemical Analysis Methods

Test	**Error (+/-)**
TOC/TN – float separation leachate	≤1%
TP - float separation leachate	≤6%
TP - soil	Standard Curve ≤ 1% Sample range ≤ 10%
TP – coarse organics	Standard Curve ≤ 1% Triplicate average ≤ 10%
TN, TC - soil	Standard Curve ≤ 5% Sample range ≤ 5%
TN, TC – coarse organics	Standard Curve ≤ 5% Sample range ≤ 5%

Swept-Miles Audit

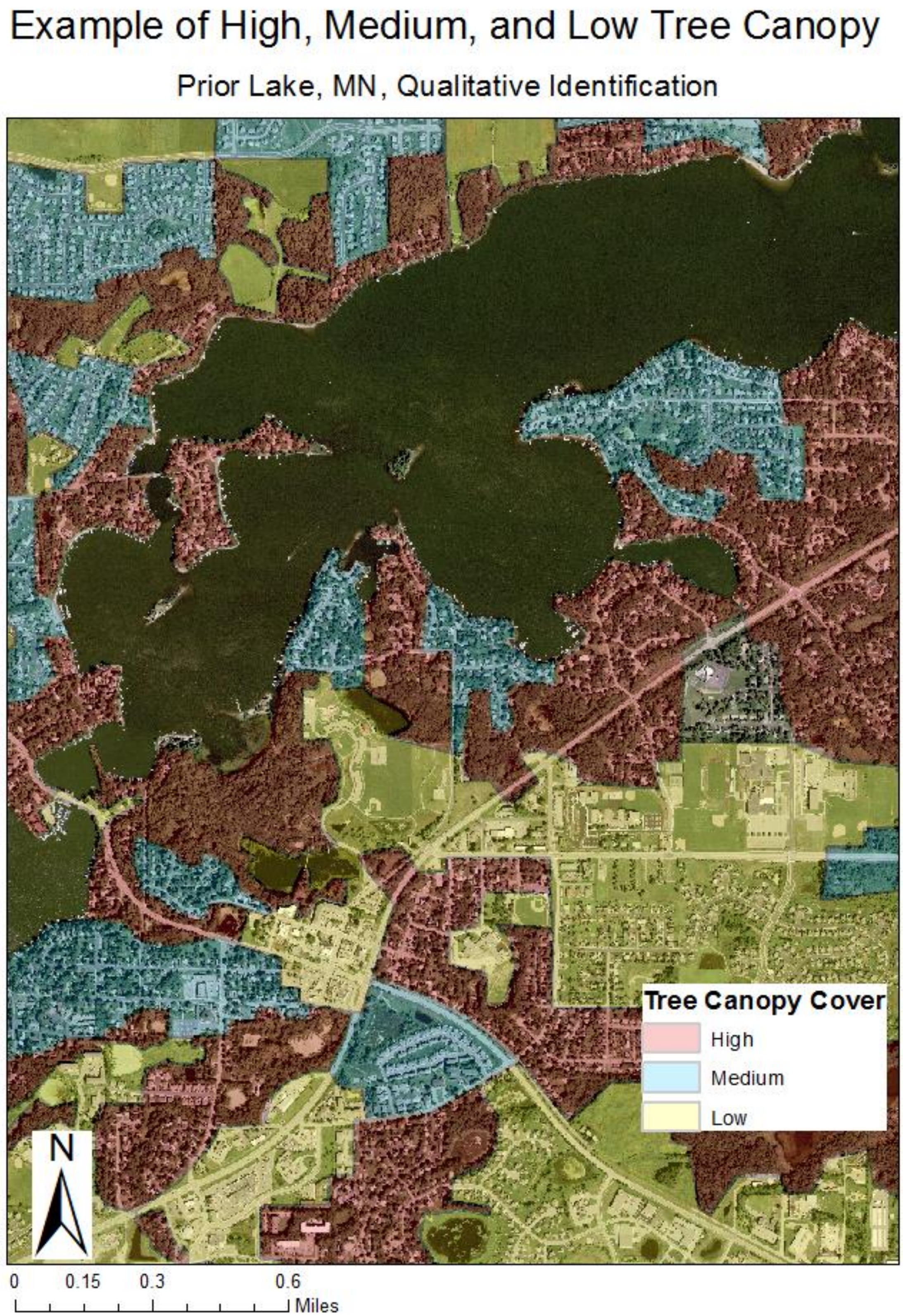
As noted earlier, sweeping patterns were altered on rare occasions when weather conditions, road maintenance or other factors interrupted sweeping or when additional passes were required to complete route cleaning. A slight oversight in operations, these alterations were not recorded by the vehicle operator. To insure that the curb-miles swept (determined through GIS analysis) accounted for these exceptions, a vehicle mileage audit was performed. It was assumed that exceptions to regular sweeping patterns could be identified through driver reports where the reported miles-swept differed significantly compared to typical reported values. Using this rationale, the GPS data recorded through PreCise Mobile Resource Management software was inspected whenever the reported miles-swept varied by more than +/- 20% compared to the median mileage reported for any route. Additionally, GPS data for a random subset of 119 sweeping events for which the reported miles-swept was within tolerance was also inspected.

When GPS data indicated additional passes made by the vehicle within the given route, no adjustment was made to the curb-miles swept. When GPS data indicated that any portion of the given route had not been swept, the curb-miles swept were adjusted downward accordingly. Since sampled sweeping events were only carried out within the nine designated study routes, the curb-miles swept were never adjusted upwards. Of the 188 sweeping events inspected, 29 mileage adjustments were required. Of the 29 mileage adjustments made, 23 were identified as outside the mileage tolerance for driver-reported swept miles. The swept-miles audit results are included in Appendix J.

Database Management

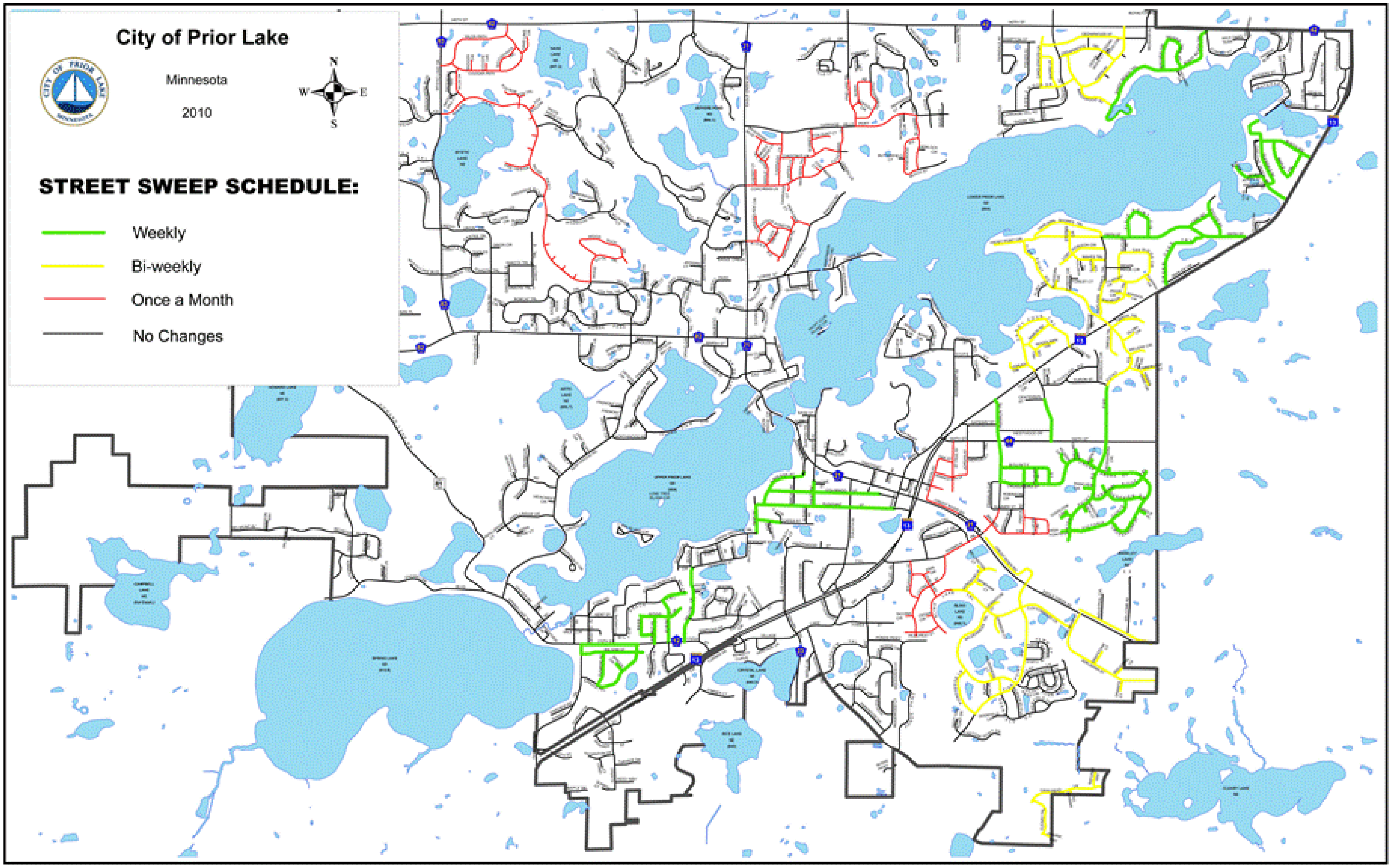
Primary field data was collected, recorded, and maintained by the City of Prior Lake, MN. Primary laboratory data was collected, recorded, and maintained in the University of Minnesota Department of Ecology, Evolution and Behavior. Field and laboratory data were merged and maintained in the University of Minnesota Department of Bioproducts and Biosystems Engineering following University data management and security protocols.

Appendix A


Example of High, Medium, and Low Tree Canopy
Prior Lake, MN, Qualitative Identification
Tree Canopy Cover
High
Medium
Low
N
0
0.15
0.3
0.6
Miles

Appendix B

Street Sweeping Study, Route Distribution, Prior Lake, MN



Appendix C

Street Sweeping Study, Sweeping Route Detail

Study Route	Total Curb-Miles	Over-street Tree Canopy Cover (%)	Tree Canopy Cover within a 20 ft buffer* (%)	Sub-Section	Sub-Section Curb-miles	Sub-Section Over-street Tree Canopy Cover (%)	Sub-Section Canopy Cover within a 20 ft buffer* (%)
H1	6.8	6.9%	22.9%	a	1.7	7.2%	21.5%
				b	2.0	6.2%	19.8%
				c	3.1	7.5%	25.6%
H2	4.6	15.1%	34.5%	a	1.9	14.8%	34.2%
				b	2.7	15.6%	34.6%
H4	8.3	19.0%	36.8%	a	2.4	25.7%	45.1%
				b	2.5	18.5%	34.5%
				c	3.4	13.3%	32.4%
M1	9.3	0.6%	9.4%	a	1.8	0.9%	9.7%
				b	4.4	0.8%	12.7%
				c	3.1	0.1%	5.0%
M2	8.1	6.2%	21.5%	a	4.2	4.2%	20.2%
				b	3.9	8.6%	22.9%
M4	8.3	10.5%	25.5%	a	1.9	2.3%	19.1%
				b	3.7	11.7%	26.0%
				c	2.7	15.0%	29.5%
L1	7.4	0.4%	3.4%	a	7.4	0.4%	3.4%
L2	8.8	0.1%	2.9%	a	7.3	0.1%	3.6%
				b	1.5	0.0%	0.2%
L4	9.5	0.5%	6.7%	a	0.4	1.4%	10.5%
				b	9.0	0.5%	6.5%

*Twenty foot buffer measured from curb lines.

Appendix D

Street Sweeping Study, Driver Report

LINE	DESCRIPTION	DATA / CALCULATION	LINE	DESCRIPTION	DATA / CALCULATION		
1	DAILY GAS USE						
A1	OPERATOR		A2	SWEEP ZONE			
B1	EQUIPMENT		B2	MATERIAL VOLUME (ENTER APROX. % OF LOAD)	Sand/Dirt/ Gravel	Leaves/ Sticks/ Grass	Sealcoat Chips
C1	DATE						
D1	START TIME		D2	GROSS WEIGHT			
E1	END TIME		E2	START ODOMETER			
F1	TOTAL TIME	Line E1 - Line D1	F2	END ODOMETER			
G1	IDLE TIME		G2	TOTAL DISTANCE	Line E2 - Line D2		
H1	SWEEP TIME	Line F1 - Line G1	H2	APX IDLE DISTANCE			
I1	SAMPLE ID	Line C1 in YYMMDD, Line A2	I2	SWEEP DISTANCE	Line F2 - Line G2		

Appendix E

Street Sweeping Study, Fuel Mass Consumed During Sweeping Operations

Fuel mass estimation method - Since the mass of fuel consumed during sweeping could not be measured with adequate precision from a fuel gage reading, the following relationship was used to account for the mass of fuel consumed when calculating the fresh weight of swept material:

Fresh Weight of Sweepings =	**Vehicle Gross Weight**	**–**	**Adjusted Vehicle Tare**
	(vehicle + sweepings + remaining fuel)		(vehicle + full fuel tank) - (estimated fuel consumed)

To determine an appropriate 'adjusted vehicle tare', we estimated the average fuel consumption rate using end of day re-fueling data. On 148 separate occasions, the fuel volume required to refill the vehicle fuel tank at the end of the day was recorded (to the nearest 1-gallon). An estimate of the fuel consumed per hour during sweeping operations was obtained using the recorded fuel volume and the total vehicle operation time recorded on the driver reports for the same day. The mean fuel consumption rate for the sweeping operations in the refueling data set was 4.75 +/-0.18 gal/hr (95% confidence, standard deviation +/- 1.08 gal/hr). As a conservative measure, we adopted the median fuel consumption rate, 4.85 gal/hr, for all sweeping operations. Using a fuel density of 6.943 lbs/gal for diesel fuel, the weight of fuel consumed was computed for each sweeping operation using the driver reported total time of vehicle operation:

Fuel Consumed (lbs) = total vehicle operation time (hr) x 4.85 gal/hr x 6.943 lbs/gal

The Tymco model 600 regenerative air street sweeper has a 50 gallon fuel tank and an empty weight, in this case, of about 17410 lb. The fresh weight of sweeping was calculated for each sweeping event using these numbers and the estimate for fuel mass consumed outlined above.

Fresh Weight = of Sweepings	**Vehicle Scale Reading**	**–**	**17760 lb**	**-**	**Fuel consumed**
	(vehicle + sweepings + remaining fuel)		(vehicle + full fuel tank)		

Uncertainty Introduced by Fuel Mass Estimate - Assuming an uncertainty of +/- 0.25 hr for the total time reported by driver for each sweeping run and an uncertainty of +/- 0.50 gal for the refill volume of fuel, the average uncertainty in the fuel mass consumed (and therefore in the fresh weight of sweepings) for sweeping operations in the refueling data set was +/- 15.1 lb (standard deviation 2.7 lb). The vehicle scale used to obtain a fresh weight of sweepings had a precision of +/- 10lb. Therefore the typical uncertainty in the fresh weight of material collected during sweeping was about +/- 25 lb. The average fresh weight of sweeping collected per sweep during the study was 2193 lb. The total uncertainty in the fresh weight of sweeping represents an error of about +/- 1% for an average sweep.

Appendix F

Street Sweeping Study, Study Route Sweeping Schedule

	Monday		Tuesday		Wednesday		Thursday	Friday
	am	pm	am	pm	am	pm		
Week 1	H4	M4	L4	H2	L2	H1		
Week 2	H4	M4	L4	M2	M1			
Week 3	H4	M4	L4	H2	L2	L1		
Week 4	H4	M4	L4	M2				

Appendix G

Sweeping Events by Month, Year, Route

Month	Year 1 Sweepings	Year 2 Sweepings
January	(none) **Total=0**	M4(1), H4(1) **Total=2**
February	L2(1), L4(1), M4(1), H1(1), H2(1), H4(1) **Total=6**	(none) **Total=0**
March	L1(1), L4(1), M1(1), M2(2), M4(4), H4(1) **Total=8**	L1(1), L2(2), L4(4), M1(1), M2(2), M4(4), H1(1), H2(1), H4(5) **Total=21**
April	L1(1), L2(2), L4(4), M1(1), M2(2), M4(4), H1(1), H2(2), H4(4) **Total=21**	L1(1), L2(2), L4(4), M1(1), M2(2), M4(5), H1(1), H2(1), H4(4) **Total=21**
May	L1(1), L2(2), L4(4), M1(1), M2(2), M4(5), H1(1), H2(2), H4(5) **Total=23**	L1(1), L2(3), L4(5), M1(1), M2(2), M4(4), H1(2), H2(3), H4(4) **Total=25**
June	L1(1), L2(2), L4(5), M1(1), M2(2), M4(3), H1(1), H2(2), H4(4) **Total=21**	L1(1), L2(2), L4(4), M1(1), M2(2), M4(4), H1(1), H2(2), H4(4) **Total=21**
July	L1(1), L2(2), L4(4), M1(1), M2(2), M4(4), H1(1), H2(2), H4(4) **Total=21**	L1(1), L2(2), L4(5), M2(3), M4(5), H1(1), H2(2), H4(4) **Total=23**
August	L2(1), L4(4), M1(1), M2(2), M4(4), H1(1), H4(4) **Total=17**	L1(1), L2(2), L4(5), M1(3), M2(3), M4(5), H1(1), H2(2), H4(5) **Total=27**
September	L1(1), L2(2), L4(3), M1(1), M2(2), M4(3), H1(1), H2(2), H4(3) **Total=17**	L1(1), L2(2), L4(4), M1(1), M2(2), M4(4), H1(1), H2(2), H4(4) **Total=21**
October	L1(2), L2(3), L4(4), M1(1), M2(1), M4(3), H1(1), H2(2), H4(4) **Total=21**	L1(2), L2(3), L4(4), M1(1), M2(1), M4(5), H1(1), H2(2), H4(5) **Total=23**
November	L1(1), L2(2), L4(3), M1(1), M2(1), M4(5), H1(1), H2(2), H4(5) **Total=21**	L1(2), L2(3), L4(4), M1(1), M2(1), M4(3), H1(1), H2(2), H4(4) **Total=21**
December	(none) **Total=0**	L4(2), M1(1), M2(1), M4(2), H2(1), H4(2) **Total=8**

Appendix H

Street Sweeping Study, Sweeping Frequency Audit

Sweeping Frequency Check – all sweeping events			
Route	**Average Sweeping Interval (days)**	**Median Sweeping Interval (days)**	**Standard Deviation (days)**
L1	29.3	28.0	4.0
L2	15.5	14.0	4.5
L4	7.7	7.0	4.2
M1	25.8	28.0	6.5
M2	14.2	14.0	4.8
M4	8.0	7.0	3.1
H1	25.8	28.0	6.5
H2	15.9	14.0	6.6
H4	8.5	7.0	7.0

Sweeping Frequency Check – April through November only			
Route	**Average Sweeping Interval (days)**	**Median Sweeping Interval (days)**	**Standard Deviation (days)**
L1	29.3	28.0	4.0
L2	15.5	14.0	4.5
L4	7.1	7.0	0.8
M1	25.8	28.0	6.5
M2	14.2	14.0	4.9
M4	7.4	7.0	1.8
H1	25.8	28.0	6.5
H2	15.8	14.0	6.7
H4	7.2	7.0	1.3

Appendix I

Street Sweeping Study Cost Estimate of Sweeping

The cost of sweeping operations in the study was found using the following relationships. Sources of labor and vehicle-related costs are shown in table I-1.

Cost of Sweeping Event = {Labor-related costs} + {Vehicle-related costs}

Cost of Sweeping Event = Sweep time(hr)*$60/hr + Curb-mile Swept (mi)*$5.25/mi

Table I-1: Source of labor-related and vehicle-related cost estimates

Labor-related Costs	
Labor	$20-40 /hr (wages + benefits+ overhead) depending on staff level. Combined staffing taken into account, total staff on scaled time basis (hours worked:hours sweeping)
Vehicle-related Costs	
Maintenance	$15,000/year average Assumes replacement of all sweeping parts once over the vehicle life span plus addition engine /systems maintenance of the vehicle.
Capital Depreciation	Capital Depreciation = (Total Cost of Vehicle + Refurbishment – Resale/Salvage)/ Vehicle Life) Assumed 8-10 year life of sweeping components Assumed 16-20 year life of vehicle
Fuel	4.8 gal/hr, brush on 1.0 gal/hr, travel and idle mode

The vehicle-related cost term of $5.25 per curb-mile swept was determined by the water resources engineer in Prior Lake using records of sweeping operations from previous years and study data. It represents the sum of vehicle-related costs given in Table I-1 scaled to "brush-on" curb-miles only. Given that vehicle mileage depends on mode of operation, vehicle-related costs would vary somewhat depending on the proportion of miles typically driven in travel and sweep modes of operation. The average cost of sweeping for different cost basis scenarios is given in table I-2. Since travel miles (brush off) will vary for different sweeping operations, estimate III may be the best general estimate of sweeping cost.

Table I-2: Estimates of cost per curb-mile of sweeping operations

Cost Basis	**Average $/mi**	**St. Dev.**
I. "Brush on" time and swept-miles only	$22	+/- $6
II. Total time (includes travel, weighing and dump time) and total miles of sweeping operation (includes travel miles to and from route and scale)	$18	+/-$3
III. Total time of operation and swept miles only.	**$23**	**+/- $7**

Appendix J

Street Sweeping Study, Miles Swept Audit

Table 9. Swept Miles Audit Results

Reported Miles Swept ≤ 80% Median Miles Swept (per route) Audit of GPS data vs. GIS route mile analysis				
Route	Date	Difference, Reported vs. Median (%)	Audit Findings	Correction (mi)
L1	5/18/11	-50	No irregularities	-
L1	8/17/11	-38	No irregularities	-
L1	6/13/12	-25	No irregularities	-
L2	9/1/10	-64	No irregularities	-
L2	10/7/10	-36	No irregularities	-
L2	5/4/11	-36	No irregularities	-
L4	10/18/10	-55	GPS data not retrievable	-
L4	9/14/10	-45	No irregularities	-
L4	11/2/10	-36	No irregularities	-
L4	8/9/11	-27	No irregularities	-
L4	12/20/11	-27	No irregularities	-
M1	11/10/10	-31	Portions of middle section not swept.	-1.5
M2	7/19/11	-33	Portions of south section not swept	-1.2
M2	8/2/11	-33	Portion of north section note swept	-3.0
M2	6/20/12	-33	South section not swept	-3.8
M2	7/3/12	-22	No irregularities	-
M2	7/31/12	-22	Portion of north section note swept.	-1.2
M4	11/28/11	-44	Middle and south sections not swept; portions of north section not swept	-4.8
M4	3/19/12	-44	Middle section not swept, portions of north and south section not swept	-4.5
M4	10/10/11	-33	South segment not swept	-1.8
M4	10/19/10	-22	No irregularities	-
M4	2/16/11	-22	No irregularities	-
M4	3/26/12	-22	South segment not swept; portions of middle section not swept.	3.6
H1	8/26/10	-25	Portions of northwest section not swept	-1.7
H1	3/7/12	-25	Portions of northwest section not swept	-1.0
H2	11/17/11	-29	No irregularities	-

Reported Miles Swept ≤ 80% Median Miles Swept (per route) Audit of GPS data vs. GIS route mile analysis				
Route	Date	Difference, Reported vs. Median (%)	Audit Findings	Correction (mi)
H2	6/12/12	-29	No irregularities	-
H4	8/8/11	-67	Portions of middle and south sections not swept	-0.8
H4	10/19/10	-44	South section not swept	-3.3
H4	10/10/11	-44	South section not swept, portions of middle section not swept	-3.5
H4	12/12/11	-44	No irregularities	-
H4	10/4/10	-33	Portions of middle section not swept	-2.8
H4	10/11/10	-33	Portions of middle section not swept	-2.0
H4	11/1/10	-33	Portions of middle section not swept	-2.1
H4	11/22/10	-22	No irregularities	-
H4	5/16/11	-22	No irregularities	-
H4	8/22/11	-22	No irregularities	-
H4	10/3/11	-22	No irregularities	-
H4	4/2/12	-22	No irregularities	-
H4	4/30/12	-22	No irregularities	-

Reported Miles Swept ≥ 80% Median Miles Swept (per route) **Audit of GPS data vs. GIS route mile analysis**				
Route	Date	Difference, Reported vs. Median (%)	Audit Findings	Correction (mi)
L1	3/21/12	+25	3rd, 4th pass apparent in some portions of route.	-
L1	10/20/10	+33	No irregularities	-
L2	6/13/12	+55	No irregularities	-
M2	3/13/12	+22	Portions of north and south sections not swept	-1.2
M2	12/13/11	+100	No irregularities	-
M4	10/4/10	+22	No irregularities	-
M4	10/11/10	+22	No irregularities	-
M4	6/6/11	+22	No irregularities	-
M4	8/8/11	+22	No irregularities	-
M4	1/9/12	+44	No irregularities	-
M4	7/16/12	+344	No irregularities	-
H1	10/7/10	+25	No irregularities	
H1	9/1/10	+38	Northwest section not swept	-2.0
H1	5/4/11	+50	No irregularities	-
H1	9/21/11	+50	No irregularities	-
H1	8/25/11	+63	No irregularities	-
H2	3/20/12	+29	No irregularities	-
H2	9/14/10	+43	No irregularities	-
H2	10/18/10	+43	GPS data not retrievable	-
H2	11/2/10	+43	No irregularities	-
H2	2/17/11	+114	No irregularities	-
H2	12/20/11	+143	No irregularities	-
H4	10/25/10	+22	North section not swept	-2.5
H4	9/12/11	+22	No irregularities	-
H4	9/13/10	+33	No irregularities	-
H4	3/12/12	+33	No irregularities	-
H4	3/5/12	+89	No irregularities	-
H4	7/16/12	+100	No irregularities	-

Reported Miles Swept within +/- 20% of Route Median Miles Swept (per route)
Random audit of GPS data vs. GIS route mile analysis

Route	Dates		Audit Findings	Corrections
L1	11/18/10	9/9/11	(none)	(none)
	3/11/11	10/5/11		
	6/15/11	4/18/12		
L2	8/25/10	8/17/11	a) Southeast section not swept b) Fishpoint Road not swept on main segment	a) -4.3 mi b) -1.5 mi
	9/16/10	9/9/11		
	10/20/10	9/21/11		
	11/18/10	10/19/11[b]		
	4/20/11	5/2/12		
	5/18/11[a]	5/16/12		
	7/13/11	5/31/12		
L4	8/17/10	7/19/11	(none)	(none)
	8/24/10	9/20/11		
	9/21/10	10/25/11		
	10/12/10	11/17/11		
	10/26/10	11/29/11		
	4/19/11	3/6/12		
	4/26/11	4/10/12		
	6/1/11	5/15/12		
	6/14/11	6/5/12		
	6/21/11	6/20/12		
M1	8/26/10	9/28/11	c) Portions of north segment not swept d) Portions of north segment not swept	c) -0.7 mi d) -0.3 mi
	9/9/10	10/26/11		
	3/11/11[c]	11/23/11		
	5/11/11	3/14/12[d]		
	8/10/11	6/6/12		
	8/31/11			
M2	8/17/10[e]	5/24/11	e) South segment not swept	e) -3.8 mi
	9/8/10	6/21/11		
	9/21/10	10/25/11		
	3/14/11	11/8/11		
	4/12/11	5/22/12		
	5/10/11	6/5/12		
M4	8/9/10	7/18/11	f) Middle and south segments not swept	f) -4.6 mi
	8/30/10	8/1/11		
	9/7/10	8/15/11		
	9/13/10	9/19/11		
	10/25/10[f]	10/24/11		
	11/1/10	11/7/11		
	11/22/10	4/2/12		
	4/18/11	4/9/12		
	5/12/11	5/21/12		
	5/23/11	6/18/12		
	5/31/11	7/9/12		
	6/13/11	7/23/12		

Reported Miles Swept within +/- 20% of Route Median Miles Swept (per route) Random audit of GPS data vs. GIS route mile analysis				
Route	**Dates**		**Audit Findings**	**Corrections**
H1	2/18/11 4/6/11 11/18/11	4/4/12 6/27/12 7/25/12	(none)	(none)
H2	4/5/11 5/3/11 6/29/11 7/12/11 9/7/11	10/4/11 11/29/11[g] 6/26/12 7/24/12	g) Portions of north section not swept	g) -2.0 mi
H4	8/9/10 8/31/10 11/8/10 3/29/11 4/4/11 5/2/11 5/9/11 7/5/11 7/11/11	7/25/11 10/17/11 10/31/11 1/9/12 4/23/12 5/7/12 6/4/12 6/25/12	(none)	(none)

MINNEHAHA CREEK WATERSHED DISTRICT
QUALITY OF WATER QUALITY OF LIFE

MEMORANDUM

To: MCWD Board of Managers

From: Eric Fieldseth

CC: Craig Dawson

Date: November 6, 2014

Re: Status update on Flowering Rush Management in Lake Minnetonka

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Purpose:

- To provide a status report on Flowering Rush as requested at the October 23, 2014 MCWD Board meeting.

Background:

- Project History: MCWD initiated a pilot program to evaluate the efficacy of hand removal on Flowering Rush in Lake Minnetonka in 2011. It was deemed successful in soft substrate, but not hard substrate. Hand removal has been ongoing annually since 2011.

- Recent Board Action/Discussion: Board approved the extension of a contract with Waterfront Restoration to perform hand removal of Flowering Rush in Lake Minnetonka on July 10, 2014. Manager Calkins recommended staff look into the use of herbicides for the rocky substrates for treatment in the 2014 season.

- Current Status: Herbicide treatment was conducted in the Maxwell Bay to Crystal Bay Channel on September 8, 2014, by PLM Lake and Land Management for a cost of $180. Hand removal just recently finished up, with Waterfront Restoration completing their final sweeps of the area on October 13th. Blue Water Science conducted the post-treatment inspection on October 13th as well, and staff is awaiting reports from both Waterfront Restoration and Blue Water Science.

- Next Steps/Board Meetings: As has been done in the past, reports on the project will be sent to the Board once staff receives them, typically by the end of the year.

Attachments: July 10, 2014 Board Meeting Minutes
If there are questions in advance of the meeting, please contact: Eric Fieldseth, 952-471-7873 or efieldseth@minnehahacreek.org

MINUTES OF THE REGULAR MEETING OF THE MINNEHAHA CREEK WATERSHED DISTRICT BOARD OF MANAGERS

July 10, 2014

CALL TO ORDER

The regular meeting of the Minnehaha Creek Watershed District Board of Managers was called to order by President Sherry White at 6:45 p.m. in the District offices, 15320 Minnetonka Boulevard, Minnetonka, Minnesota 55345

MANAGERS PRESENT

Sherry White, Brian Shekleton, Richard Miller, Jeffrey Casale, Pam Blixt, James Calkins, William Olson.

MANAGERS ABSENT

None.

OTHERS PRESENT

Jeff Spartz, Interim District Administrator; David Mandt, District Operations Manager; James Wisker, Director of Planning; Tiffany Forner, District Natural Resource Technician; Brandon Wisner, District Regulatory Technician; Bret Eidem, District Cost Share Specialist; Craig Dawson, District Aquatic Invasive Species Director; Todd Shoemaker, District Consulting Engineer; Chuck Holtman, District Counsel.

MATTERS FROM THE FLOOR

Brad Robinson, Deephaven, used a series of funnels to depict the history of increasing hydraulic demands on Minnehaha Creek with development in the upper watershed. He urged that the upper watershed be managed to maintain two feet of freeboard for snowmelt and spring rain.

APPROVAL OF AGENDA

It was moved by Manager Miller, seconded by Manager Casale, to approve the agenda with the addition of new staff introductions as item 3a. Manager Casale requested that all votes be by roll call, to which there was no opposition and which the chair accepted. ***Upon roll call vote, the motion carried, 6-0.***

NEW STAFF INTRODUCTIONS

Three new staff members introduced themselves.

Lora Pohtilla grew up in Wayzata and received a degree in Environmental Science from the University of Minnesota. She will work in Regulatory.

Jill Bjorklund grew up in Redwing. She has a degree in Biology and Water Resources from the University of Wisconsin-Stevens Point and has worked as an Aquatic Invasive Species (AIS) technician in Wisconsin. She will work in the AIS program.

Joey Handtmann has a degree in Environmental Science and Forest Resources from the University of Minnesota. He will work in Regulatory.

Manager White welcomed the new staff members on behalf of the Board.

INFORMATION ITEMS /CORRESPONDENCE

Manager White noted the items listed on the agenda. With respect to the operations and maintenance program, Manager Calkins noted that the report indicated weed whipping at one site. He offered that if landscape management is well designed, there is no need for weed whipping.

CONSENT ITEMS

Item 6.1, Approval to Extend Contract with Waterfront Restoration, was moved to item 10.1 on the regular agenda.

It was moved by Manager Miller, seconded by Manager Calkins to approve the consent agenda consisting of the June 26, 2014 minutes. Upon roll call vote, the motion carried 6-0.

REGULAR AGENDA

President's Report

Manager White noted that she attended an event on June 28 at Methodist Hospital, where Telly Mamayek had a booth. The District was identified as a partner and the event was well done.

Upcoming Meeting and Event Schedule

Manager White referenced the meeting schedule on the agenda. She advised that a special meeting will occur on July 17 concerning Mr. Evenson-Marden's personnel file review. It is expected that the meeting will be held in closed session unless Mr. Evenson-Marden requests otherwise. The Board determined that the meeting should be added to the joint committee meeting and not displace it.

Contract with Waterfront Restoration for Flowering Rush Removal, Lake Minnetonka

Manager Calkins noted that hand removal has been successful on soft substrate but not rocky substrate. He reminded the Board that the use of herbicide or other methods in rocky substrate has been discussed but he does not see reference to it in this request for board action. Mr. Dawson replied that sufficient funds exist and that staff can review the question and return with a recommendation. Manager Calkins noted that treatment would be late in the season so if the District can evaluate the issue efficiently, treatment can occur this year if appropriate.

It was moved by Manager Calkins, seconded by Manager Miller to approve proposed resolution 14-055 providing as follows:

> ***NOW, THEREFORE, BE IT RESOLVED, to authorize the District Administrator to extend the contract with Waterfront Restoration, upon approval of District counsel as to form and execution, to continue hand removal in Lake Minnetonka at multiple sites. The amount expended shall not exceed $23,000 and is contingent upon the MCWD or its contractor receiving a permit to do the work from the DNR.***

Upon roll call vote, the motion carried 6-0.

Nokomis Cost-Share Project

Mr. Eidem presented a proposed resolution authorizing funding of 50 percent of documented cost not to exceed $26,000 for stormwater best management practice (BMP) construction on up to 12 properties along an alleyway in the Nokomis neighborhood of Minneapolis. The project is being organized by Metro Blooms and is recommended for funding by the Citizens' Advisory Committee (CAC).

Manager Miller asked if pre- and post-project runoff volume measurement could be incorporated to advance the research. Manager Calkins replied that this monitoring could be provided for if the District spends the funds. Mr. Eidem said that volume capture will be determined using modeling. Mr. Wisker added that he would not recommend measurement on the scale of the proposed project but on the scale of an entire block or larger. Manager Miller said that he would not support another similar project unless there are adequate data as to expected performance. Mr. Eidem said that Metro Bloom has done prior similar projects and may have data.

Manager Casale referenced the wider-scale of urban stormwater retrofitting in Chicago and would like to know more about the cost and impact of such installations there. He further noted that a good data foundation would assist in seeking partnerships.

Mr. Eidem offered that the project benefit is increased by having a number of projects together, providing for, among other things, more effective community outreach. Manager Calkins said the proposed project fits well with projects the District historically has funded. He noted the installation would be on private property and not in the alley itself. He is assuming data exist from the Chicago work and would be applicable. He would like the District to look at implementing this type of regional project more broadly then just for alleys, on the ground that an alley is no different from a street. He supported Manager Miller's view that the District needs a better quantification of benefits and that requests for board action should speak to metrics. Manager Calkins does not believe metrics must serve to qualify projects, but believes the data are important to track the benefits of District spending and the Districts treatment of such data helps proposers develop projects.

Manager Calkins asked whether District stormwater BMP modeling is based on clean or turbid inflow. Mr. Shoemaker replied that inputs are taken from actual data so the models provide for a range of particle sizes and concentration of particles typical in runoff.

Manager Blixt recalled that the District monitored performance after completing the Cedar Lake project until Mr. Panzer said there was no further need to model because the output matched model predictions. Manager Blixt questioned is whether modeling output is sufficient if we are confident that the models are fairly accurate. Mr. Wisker replied that the modeling is well developed but there is a benefit to actual measurement for wider-scale projects to insure reliability.

Manager Miller emphasized that without data support, these are largely beautification projects. He is inclined to think that public education as to these technologies has been largely exhausted. He replied to Manager Calkins' earlier comment that alleys are different from streets by suggesting that streets are more frequently resurfaced while alleys are more suited to being disturbed for this sort of project. In addition, typically there are not subsurface utilities under alleys other than storm sewer. Mr. Wisker concluded that staff is preparing a policy discussion for this cost-share program and will return to the Board in the near future.

It was moved by Manager Calkins, seconded by Manager Blixt to advance the proposed resolution to the July 24 consent agenda.

Manager Casale said that he supports the project but before final approval would like to see the cost and benefit data from the Chicago work. ***It was moved by Manager Casale, seconded by Manager Blixt to amend the main motion to advance the proposed resolution to the July 24 discussion agenda with approval subject to Board review of the requested information. Upon roll call vote, the motion carried 5-1 (Manager Miller opposed). Upon roll call vote, the main motion carried 5-1 (Manager Miller opposed).***

<u>St. Luke Presbyterian Church Cost-Share Project</u>

Mr. Eidem presented the proposed resolution to authorize funding of 75 percent of cost for construction of two stormwater BMP's by St. Luke Presbyterian Church, not to exceed $20,062.50. Mr. Eidem said that the 75 percent cost share exceeds the program standard 50 percent but is felt justified by staff and the CAC because of attributes beyond water quality outcomes. This includes a more in-depth educational component due in part to the involvement

of two Water Stewards as well as the history of church stewardship allowing for the prospect of a larger demonstration effect and more educational opportunities.

Manager Calkins noted that this proposal does have a quantified water benefit, which is not substantial apart from 1.3-acre feet of volume reduction. He said that a comparison to the present total site volume would be appreciated. Manager White offered that phosphorous reduction is not the focus of the project. Mr. Eidem concurred that volume control is the chief beneficial outcome.

It was moved by Manager Blixt, seconded by Manager Miller to advance the proposed resolution to the July 24 discussion agenda to review the further quantification of volume reduction that Manager Calkins requested and any further quantification of other benefits stated. Upon roll call vote, the motion carried 6-0.

<u>Edina Memorandum of Understanding</u>

Mr. Wisker presented a proposed resolution authorizing execution of a memorandum of understanding (MOU) with the City of Edina for further collaboration in efforts along the Minnehaha Creek Corridor.

Mr. Wisker reported that after the 54^{th} Street project City and District staff sat down to discuss further collaboration, resulting in this nonbinding policy umbrella. He noted specific elements referenced. As to education and outreach, the City has asked if the District might fulfill certain City obligations under its National Pollution Discharge Elimination System (NPDES) permit, with a City annual financial contribution to the District. Also, the City has a graphic arts capacity that the District may be able to use cost effectively. Regarding development oversight, the MOU allows for better coordination in the context of recent teardown issues. There has been discussion about closing gaps in coordination, including a City regulatory program element that no building permits may be issued without evidence of a District permit. There is also interest in coordinating compliance monitoring. Coordination involves aligning capital planning and investments and better integrating land use and water resource management efforts.

Manager Blixt asked how specifics will be put into practice. Mr. Wisker replied that the parties would proceed by means of specific agreements or other formalized frameworks. He said that the MOU is a statement of policy makers that will serve to help foster cooperation between staffs and set expectations.

(Manager Shekleton arrived at 7:55 p.m.)

It was moved by Manager Miller, seconded by Manager Calkins to advance the proposed resolution to the July 24 consent agenda.

Manager Casale asked how many City permit applicants in 2013 did not apply to the District. Mr. Wisker replied that there were about 54 such permits and that at this time only four have not

been brought in under District review. He added that all of these sites have been inspected. Mr. Spartz advised the Board that it should expect to see more of these types of MOUs as staff implements the urban ecology approach. ***Upon roll call vote, the motion carried 7-0.***

<u>Transitional Duties of Former District Administrator</u>

Manager White noted that under Mr. Evenson-Marden's agreement direction as to his transitional activities is to come from the full Board. Accordingly, she is looking for authority to direct Mr. Evenson-Marden to undertake work activities to review his personnel file in advance of the Board's personnel review on Thursday evening and to bring any questions to Mr. Spartz by the close of business on Tuesday.

It was moved by Manager Miller, seconded by Manager Shekleton to authorize the Board President to give such direction to Mr. Evenson-Marden.

Manager Calkins asked if the close of business Tuesday affords reasonable time to Mr. Evenson-Marden and whether he should be consulted. Manager Shekleton asked counsel if Mr. Evenson-Marden has received the documents that constitute his personnel file. Mr. Holtman replied that he received them yesterday. The Board further discussed whether Mr. Evenson-Marden should be consulted as to his availability and ability to complete his work in the time indicated. ***Upon vote, the motion carried 4-2-1 (Managers Calkins, Olson opposed; Manager Blixt abstaining).***

Manager White stated that she would advise Mr. Evenson-Marden by email and would copy the Board members on her email and Mr. Evenson-Marden's response. Mr. Holtman recommended that all communications be channeled through Mr. Spartz to avoid potential Open Meeting Law issues. Manager Blixt asked whether Manager White's email to Mr. Evenson-Marden should ask for his concurrence in the reasonableness of the schedule. Manager White replied that the approved motion did not provide for that.

BOARD DISCUSSION ITEMS

<u>Stormwater Facility Maintenance</u>

Ms. Forner noted that there are a number of stormwater basins on the landscape that were constructed as far back as the 1970's. The District doesn't necessarily know where these basins are, who owns them or whether their owners know what they are. Staff has been considering a program to identify and seek rehabilitation of some of these facilities. She noted that the District schedules maintenance of its own facilities, that it presently is up to date on maintenance and that when operation and maintenance funds are not needed for District facilities, the District could prioritize geographic areas and seek out agreements with land owners to reinstate landowner maintenance responsibilities in exchange for District funding or partial funding of initial maintenance.

Manager Miller concurred in the potential value of such a program. Manager Calkins asked whether facilities would be screened for recondition or conversion to other management approaches before being abandoned. Ms. Forner said that this sort of evaluation is intended based on the principle that it is cheaper to maintain than to build facilities. Responding to Manager Blixt, Ms. Forner advised that staff intends to return in the fall with further details. Responding to Manager Blixt's question as to resource demands, Ms. Forner suggested that developing the framework would be the primary effort in that administrating actual maintenance work is fairly standard.

Manager Shekleton said he is favorably inclined toward the concept. Manager Blixt asked if the District would establish "priority areas" like under the land conservation program. Mr. Wisker said that no one else in the state is attempting to manage this "legacy infrastructure." The first policy question is whether the Board is willing to spend public dollars to rehabilitate facilities, which may be private. Manager Miller said he doesn't care if the facilities are public or private since they all treat water. He added that there are numerous assessment mechanisms and that any plan should look at options for funding.

Responding to Manager Calkins, Mr. Holtman addressed the relevance of maintenance covenants. He observed that a scrupulous approach would include identifying basin locations and reviewing property records to determine the existence of maintenance obligations recorded on the deed. However, he noted, even if such covenants exist, if they are old they may be simplistic or unclear. Accordingly, the District as a policy matter will need to determine the amount of effort that such a program would put into identifying and asserting legal obligations versus creating incentives to encourage landowners to participate. He further noted that this may be an opportunity to move BMP maintenance from private hands into the hands of cities that also have assessment and other mechanisms to fund future maintenance work.

Manager Millers and Casale concurred in carefully reviewing different program structures. Manager Casale knows of cities hoarding stormwater funds and would rather that funding comes to the District for the District to do the maintenance.

<u>Administrator's Report</u>

Mr. Spartz reported that he met with the District auditor and that the District's fiscal accountability mechanisms are in "excellent shape" given the District's size. He noted that the City of Victoria administrator and community development director both are departing. He and Manager Blixt attended a meeting regarding mosquito-borne disease. It was stated that still water in stormwater containment basins is a favorite mosquito habitat. He suggested that the District could seek to assist the Mosquito Control District.

Mr. Spartz distributed a Minneapolis Star Tribune editorial regarding infiltration and inflow into storm sewer systems. Manager Blixt would like a discussion of whether and how the District can assist the cities and Metropolitan Council Environmental Services with this issue. Manager

Casale added that the Lakeshore News contained an article this week regarding the meeting between the Metropolitan Council and the City of Mound.

Mr. Spartz distributed a letter of introduction that he is sending to cities. He also distributed a letter received from the Mayor of Medina raising the possibility of incorporating all of Medina into the District. The City is not happy with the performance of the Pioneer-Sarah Creek Watershed Management Commission. Manager Blixt asked that Mr. Spartz check with the Minnesota Board of Water and Soil Resources on the status of its performance review before the District engages itself in this matter.

Mr. Spartz noted a meeting with the Department of Agriculture regarding AIS. Mr. Dawson said that the AIS council convened by the Department of Agriculture asked the District to attend and describe its programs.

Managers Blixt and Calkins noted a letter sent by District Counsel Louis Smith to the attorney for Mr. Evenson-Marden in response to that attorney's letter asserting defamation concerns. They expressed the view that counsel should have circulated the proposed response to the Board members before sending. Mr. Holtman advised that he would pass the concern on to Mr. Smith, who would respond.

Manager Blixt referenced the issue of falling trees and other debris in the District's waterways as a result of recent weather. She noted that in the past the District has offered funds to cities to use crews to clear District waterways of debris after high water. She asked that staff review this issue and return with a recommendation. Mr. Spartz noted that Hennepin County has been declared a disaster area, which may help on these issues. Manager Blixt asked if the District has been meeting its obligation to inspect its drainage systems and address obstructions. Mr. Wisker replied that District staff is very busy inspecting, receiving communications from constituents, compiling its information and coordinating with other agencies including Hennepin County. Staff is reviewing all high water issues including falling trees and debris in channels, slope failures and others. Staff will update the Board regularly on this.

Manager Calkins asked the other managers to keep in mind that it is District policy not to clear all trees and debris but to recognize that these conditions serve habitat and other District purposes as well. He noted that the District policy is to remove navigational obstructions.

ADJOURNMENT

There being no further business, the regular meeting of the Minnehaha Creek Watershed District Board of Managers was adjourned at 8:50 p.m.

Respectfully Submitted,

Jeff Casale, Secretary

MINNEHAHA CREEK WATERSHED DISTRICT
QUALITY OF WATER QUALITY OF LIFE

MEMORANDUM

To: MCWD Board of Managers

From: Eric Fieldseth

CC: Craig Dawson

Date: November 6, 2014

Re: Status update of zebra mussels (including failures and their implications)

Purpose:

- To provide a status report on "zebra mussels (including failures and their implications)" as requested at the October 23, 2014 MCWD Board meeting.

Background:

- Staff has provided the board several status reports on the discovery and rapid response of zebra mussels in Christmas Lake, with the latest update provided on October 14^{th}. There is no further information to provide at this point.

- Discussion on the "failures and their implications" will need to be scheduled for the Operations Committee after clarification of the "issue".

- Updates on Christmas Lake have been provided on: August 17, August 21 Board Meeting, September 5, September 23 and October 14.

- Updates will continue to be provided as further information is available to share.

Attachments:
August 17 update
August 21 Board Meeting report/update
September 5 update
September 23 update
October 14 update

If there are questions in advance of the meeting, please contact: Eric Fieldseth, 952-471-7873 or efieldseth@minnehahacreek.org

MINNEHAHA CREEK WATERSHED DISTRICT
15320 Minnetonka Boulevard, Minnetonka, Minnesota 55345
952.471.0590 www.minnehahacreek.org

August 18, 2014

MCWD staff has detected the presence of zebra mussels at the public boat access to Christmas Lake in Shorewood, Minnesota.

On Saturday, August 16, MCWD staff checked the District's zebra mussel sampler that is suspended in the water below the dock at the public access, and found four zebra mussels attached to the sampler's plates. A few additional zebra mussels were found on rocks underwater and on-shore at the launch site. Based on their size, the zebra mussels were estimated to be a few months old.

On Monday, August 18, MCWD staff and staff of the Minnesota Department of Natural Resources (MN DNR) examined the site further and inspected other sites in and along the lake. MN DNR staff confirmed the presence of zebra mussels. From the staffs' inspection, the extent of zebra mussels appears to be limited to the immediate area where boats are launched into Christmas Lake.

MCWD staff checks the Christmas Lake zebra mussel sampler monthly. The last check was made in mid-July, and no zebra mussels were attached to the sampler. Additionally, water has been sampled twice in 2014 to detect the presence of veligers (zebra mussel larvae). None of the samples, including the latest one taken July 29, 2014, has contained veligers. On July 29, 2014, MCWD staff performed an extensive early detection inspection for aquatic invasive species (AIS) in Christmas Lake, which included extensive in-water and on-shore searches for zebra mussels. No zebra mussels were observed.

MCWD staff is consulting with MN DNR and the City of Shorewood about vigorous and effective rapid response to this early detection of zebra mussels. The goal will be to remove the zebra mussels from the site. It is hoped, but not certain, that the course of action will remove the zebra mussel population from Christmas Lake as quickly as possible.

An extensive watercraft inspection program for (AIS) has been provided since 2012 by a partnership of the City of Shorewood, Christmas Lake Homeowners' Association, and MCWD. These services have been provided by a private firm on a 6:00 a.m.-to-dusk schedule from spring ice-out through the end of October.

M E M O R A N D U M

TO: MCWD Board of Managers
FROM: Craig Dawson, AIS Program Director
DATE: August 21, 2014
SUBJECT: Rapid Response to Early Detection of Zebra Mussels in Christmas Lake

Zebra mussels were found on a sampler suspended in water under the dock at the Christmas Lake public access on Saturday, August 16. MCWD and Minnesota Department of Natural Resources staff confirmed the presence of zebra mussels on the sampler and on rocks in the immediate area of the public access on Monday, August 18. As no other zebra mussels were found during an extensive search of shoreline and in-water locations throughout the lake on August 18, staffs are reasonably certain that zebra mussels have not spread further from the boat launch area.

Staff had performed an extensive early detection monitoring survey throughout Christmas Lake on July 29, and no evidence of zebra mussels was present. Zebra mussels thus were introduced to the boat launch site during a 2.5-week window.

Given the early detection and the small area of infestation, MCWD staff and the DNR believe that there is a realistic chance that the zebra mussel population in Christmas Lake can be removed entirely.

<u>Proposed Response</u>: Staffs of MCWD, DNR, and the City of Shorewood met on Wednesday, August 20, and reviewed a plan of action developed by District staff. All were in agreement about its effectiveness and are recommending it to their respective decision-makers. Each agency would expedite what was within their responsibility to implement the response. MCWD would be the coordinating agency on the response.

1) Temporarily close public access and remove public dock. (City of Shorewood; already done.) Notify lake residents of closure. (City of Shorewood)
2) Install curtain barrier in the water surrounding the launch area where zebra mussels were found. This area would be 50 feet along the shore by 60 feet into the lake. (Installed by MCWD staff on August 21.)
3) Pre- and post-treatment monitoring by DNR, MCWD, and University of Minnesota for research/evaluation purposes.
4) Treat enclosed area with Zequanox; minimum eight hours contact time needed. (MCWD)
5) Dredge rock, substrate, and vegetation from the enclosed area. (DNR)**
6) Pull existing cement launch pad and replace with new launch pad. (DNR)**
7) Possible second application of Zequanox. (DNR)
8) Restore launch area by placing new, larger rock that won't wash away from propeller action. (DNR)**
9) Re-open public access; dock to remain out of water until spring 2015. (City of Shorewood)

** The DNR and Shorewood had already planned to replace the concrete ramp at the Christmas Lake access. In fact, the new concrete panels are already at the City park in front of the public access. By coincidence, much of the work for this part of the rapid response was already a planned expenditure by the DNR and Shorewood. The cost of the additional dredging will be somewhat offset by having the equipment already mobilized for the boat ramp replacement.

We believe that this response will be the first one in Minnesota to use Zequanox in open water. Zequanox has been found to result in mortality rates in the high 90s%. As it is not 100% effective, the dredging should result in removal of the relatively few zebra mussels that would remain.

DNR staff commented that ideally, the response would include *another* application of Zequanox after dredging. This second application of Zequanox could be paid by DNR.

<u>Cost estimates are very tentative</u>. Assignment of costs was discussed among agency staffs on a conceptual level and will need to be refined.

<u>City of Shorewood</u>:

Temporary closure signage	$ 200
Removal of dock	in-kind
Access improvements	? and in-kind

<u>MCWD</u>:

Water curtain	$ 1,600 - $ 2,000
Zequanox treatment	$ 5,500

<u>DNR</u>:

Dredging*	$ 15,000 - $25,000
Zequanox – second treatment	$ 5,500

*Given the length of time often in State contract processes, it may be that either MCWD or Shorewood would contract for these services and be reimbursed by the DNR.

Pre- and post-treatment monitoring would be provided in-kind by MCWD, DNR, and University of Minnesota.

The 2014 AIS Workplan includes $10,000 for rapid response activities.

Permits, etc.: Several permits will be needed in conjunction with this response.

MCWD:

- Dredging
- Removal and new installation of boat launch – Shoreland and streambank stabilization rule

We have discussed with District Counsel whether and how the District's Exception Rule may apply to these permits. Counsel believes that it is appropriate to have a permit granting exception for work to remove zebra mussels from Christmas Lake, and that the Board could delegate approval to the interim administrator.

DNR:

- Application of Zequanox

Board Approval / Direction: Under the emergency conditions for the rapid response, the Board should consider:

- Authorizing the Interim Administrator to enter, on advice and consent of counsel, either (a) agreements with the City of Shorewood or the Minnesota Department of Natural Resources providing reimbursement of documented costs not to exceed $35,000 for emergency zebra mussel removal from Christmas Lake; or, (b), in the alternative, a contract for such work along with necessary property access and use and reimbursement agreements with the City of Shorewood, Department of Natural Resources and others, at a cost not to exceed $35,000.
- Delegating to the Interim Administrator the authority to take final District action on a permit application regarding land-disturbing work to remove zebra mussels from Christmas Lake, including deciding on and granting an exception as, in his judgment and on the facts, may be necessary and supported.

We will present as many items that may be ready and require Board action at the Board's regular meeting on August 28.

2014 Christmas Lake - AIS Early Detection Monitoring Report

Minnehaha Creek Watershed District

August 21, 2014

Report By: Eric Fieldseth and Jillian Bjorklund

Background

The MCWD has been monitoring for the presence of Zebra Mussels since 2010, initially using a cinder block, but switching to a hester-dendy sampling plate by 2011. These sampler plates are suspended in the water below the public access docks at non-zebra mussel infested waters. They are checked at least monthly, often times more frequent than that. In 2014, the District took on a more rigorous, and expansive early detection monitoring program. It was modeled after a program used by the Wisconsin Department of Natural Resources and looks for AIS beyond just Zebra Mussels. This monitoring program not only serves as an early detection tool, but it also gives the District baseline information on what AIS exists in our waterbodies, and to what extent the infestation is in the waterbody. Aquatic Plant Surveys are also being done by a combination of MCWD staff and the use of consultants. The plant surveys gives us a statistical assessment of the aquatic plant community in the lake and can serve as an additional early detection tool.

Christmas Lake Early Detection Monitoring

Hennepin County

Known AIS present: Eurasian Watermilfoil, Curly Leaf Pondweed, Common Carp, (Zebra Mussels – found on 8/16/2014)

Inspection Dates:

May to July 2014 – Multiple checks of the zebra mussel sampler at various times throughout this time frame by MCWD staff as they are at or near the access. Samplers are checked at least monthly, however, they are typically checked more frequently. – **No Zebra Mussels found**

July 28, 2014 – MCWD staff performed extensive early detection monitoring for new AIS in Christmas Lake. – **No new AIS found**

August 16, 2014 – Checked zebra mussel sampler – **4 Zebra Mussels found on sampler, additional Zebra Mussels found on rocks at public access.**

August 18, 2014 – MN DNR and MCWD staff performed an extensive shoreline search to assess the extent of the zebra mussel infestation. Zebra Mussels were only found at the public access. Veliger testing was also done, and no veligers were detected.

Week of August 25, 2014 – Another shoreline assessment is planned to provide further confidence that Zebra Mussels appear to be contained to the public access. This will be done by MCWD and MN DNR staff.

Report for July 28, 2014 Early Detection Monitoring

Report and Survey Completed By: MCWD AIS Staff – Eric Fieldseth and Jillian Bjorklund

	New AIS Detected	Notes
30 Minute Snorkel at boat landing	None	Checked rocks, dock, plants, and zebra mussel sampler.
10 minute snorkel/D-net sites	None	Native mussels and snails found.
Spiny Water Flea Tow	None	
Veliger Tow	None	
Aquatic Plant Point Intercept Survey	None	Completed 8/28/2013 - University of Minnesota and Spring 2014 - Freshwater Scientific

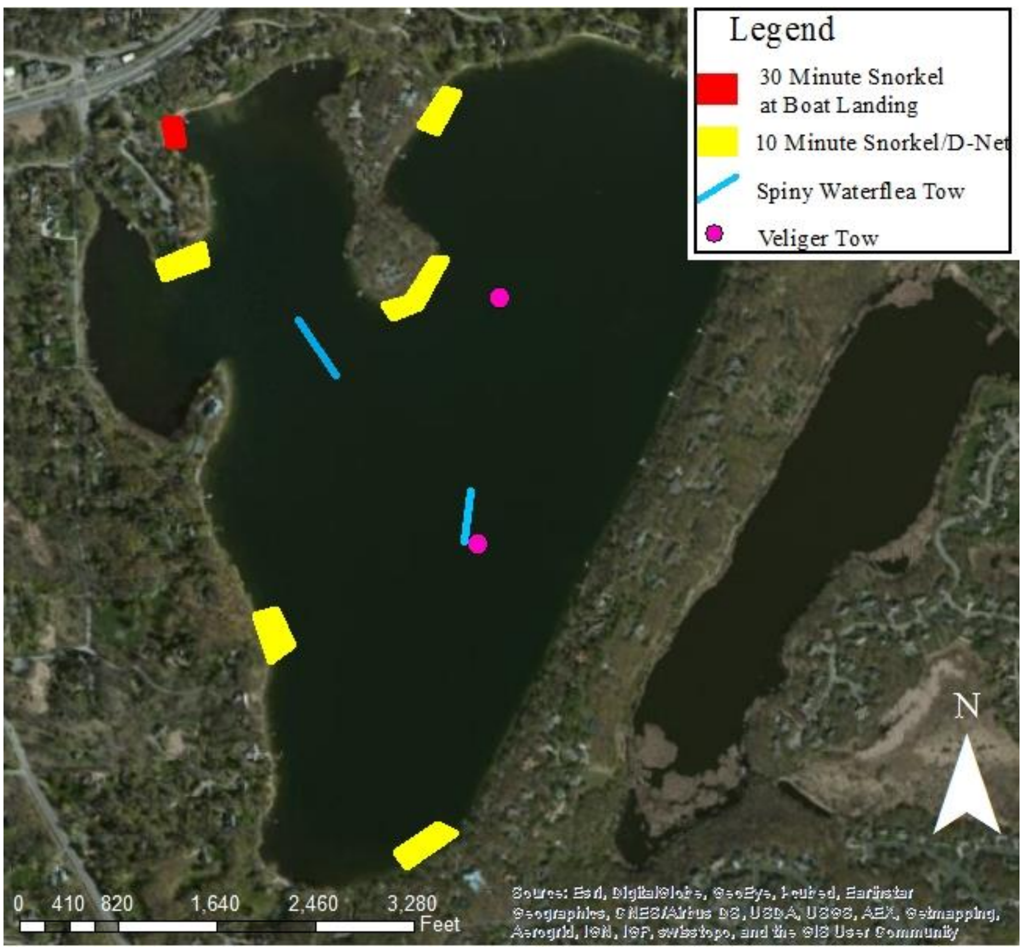
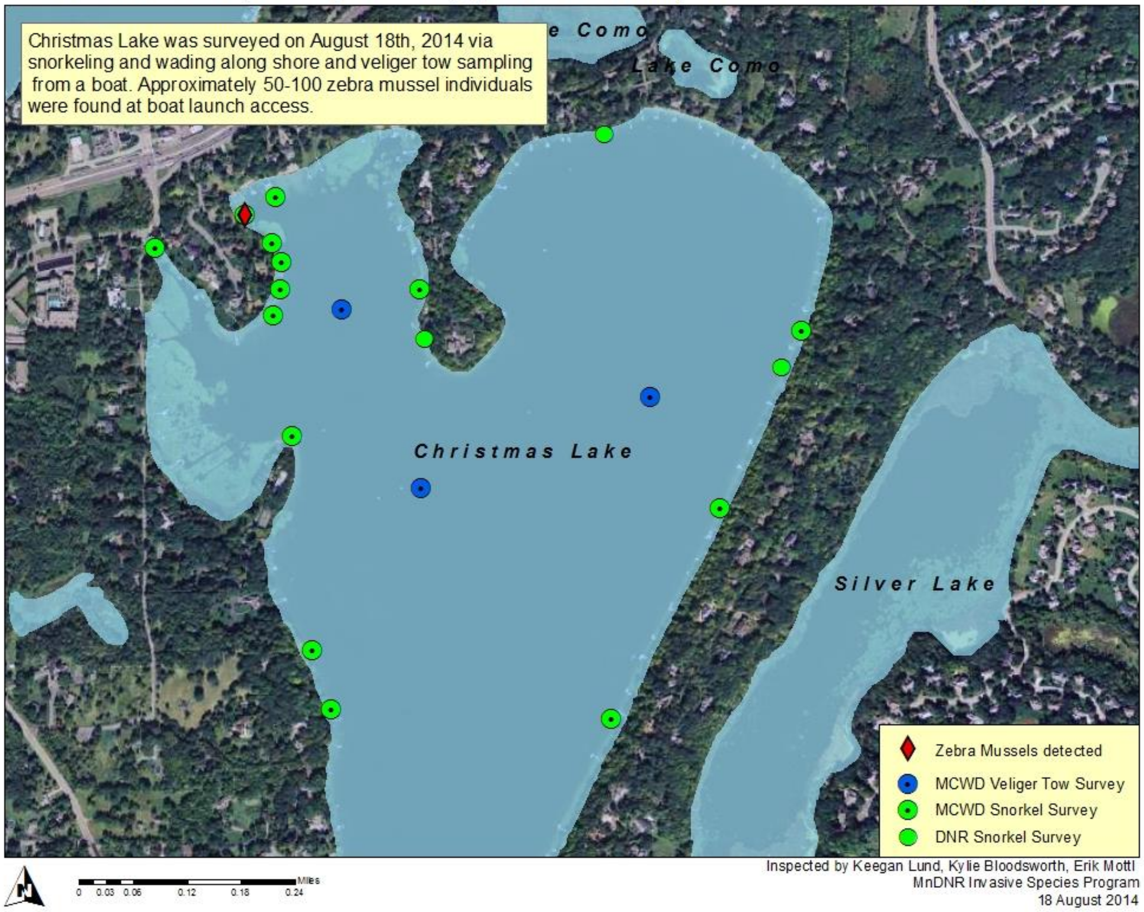


Figure 1. Early Detection Monitoring Survey of Christmas Lake completed July 28, 2014.

Zebra Mussel Assessment on August 18, 2014

Survey Completed By: MCWD AIS Staff – Eric Fieldseth and Jillian Bjorklund
MN DNR Staff – Keegan Lund, Kylie Bloodsworth, Erik Mottl

Christmas Lake, Hennepin County (DOW# 27013700) - 2014 Zebra Mussel Inspection



M E M O R A N D U M

TO: MCWD Board of Managers
Jeff Spartz, Interim District Administrator
FROM: Craig Dawson, AIS Program Director
DATE: September 5, 2014
SUBJECT: Status Report on Rapid Response to Zebra Mussel Infestation in Christmas Lake

The rapid response to the presence of zebra mussels at the public access to Christmas Lake has been aggressive and adaptive. Since the detection of zebra mussels on August 16, there has been good cooperation among the MCWD, City of Shorewood, Minnesota DNR, and Christmas Lake Homeowners Association. Initial plans have been adjusted as more information and opportunities have been shared. What follows is the status of items in the rapid response as they stand today.

Lakeshore / Neighborhood Meeting September 10: The City of Shorewood has made arrangements for a public informational meeting and discussion for Christmas Lake residents. The meeting will be held at the South Lake Minnetonka Public Safety Building, 24100-24150 Smithtown Road, Shorewood, on Wednesday, September 10, at 6:00 p.m. City, DNR, and MCWD staff will be present to update residents on the course of action and to answer questions. Steve McComas of Blue Water Science, and Megan Weber of Marrone Bio Innovations, have also been asked to be available at the meeting.

Containment Area: A water/silt curtain was installed by MCWD staff, and covers an area 50 feet along the shore and 60 feet into the water, with a maximum depth of 4.5 feet. The curtain provides a seal around the treatment area that will not only help limit zebra mussels to the area, but provide a contained area for the various treatments that are planned.

Monitoring; Extent of Infestation: MCWD staff and DNR staff, along with assistance earlier this week from the University of Minnesota and Blue Water Science, have performed extensive monitoring on both sides of the water/silt curtain, as well as throughout Christmas Lake. No zebra mussels have been observed outside of the barrier. Additionally, samples taken immediately after the barrier was installed showed no presence of veligers on either side of the barrier. Density estimates using grids in the containment area on September 3 suggest that the zebra mussel population is at least 5,000. All zebra mussels observed have been juveniles.

From the data gathered to date, it appears that the extent of zebra mussels in Christmas Lake is limited to the area that has been contained.

DNR Treatment – Zequanox® and Potash: The Minnesota DNR will be responsible for an application of Zequanox®, which will be followed a few weeks later by an application of potash (potassium chloride). Zequanox® is comprised of a dead bacterium that kills dreissenid (zebra and quagga) mussels by destroying their digestive systems. It is highly effective, with high 90s% mortality when water temperatures are above 70 degrees F. The application is planned to be made mid-morning on Monday, September 8. Aquaria have been set up in the lab at MCWD to observe how zebra mussels are faring in Christmas Lake water from both within and without the treatment area. Christmas Lake will likely be the first application of Zequanox® for a rapid response in an open-lake environment since it was approved for this use by the U.S. Environmental Protection Agency in July 2014.

As Zequanox® does not result in 100% mortality, the DNR plans to apply liquid potash a few weeks later. While potash has been used with apparent 100% mortality for dreissenid mussels and has few non-target effects, it is a compound that will remain in the area treated.
At this time, there is no plan for a second treatment of Zequanox®, as had been identified as a course of action in initial discussions.

Staff will continue to do frequent and extensive monitoring during the treatment period.

Regardless of eventual success, the combination of Zequanox® and potash treatments will provide valuable information about their effectiveness singly and together for rapid responses by others in the future.

Dredging and Boat Launch Replacement: MCWD is proposing that a shallow dredging of the area be done to remove whatever zebra mussels might remain (dead or unlikely alive), the rocks and hard surfaces that they prefer, and residual potash. This activity would be added assurance that zebra mussels have been removed.

The DNR has planned to remove the concrete planking of the existing boat launch and to replace it with new concrete ramp panels. DNR staff indicated that with high water responses challenging its work schedule this year, this work would probably have to wait until next year. It indicated a willingness to work with us for removal of the concrete planking this year and to take advantage of equipment that would be on-site to reduce the cost of dredging.

Re-opening of the Boat Launch: The standard position of the DNR is that the boat launch should be re-opened after the emergency work (which excludes the boat launch itself) has been completed. It is considering the concerns expressed by Shorewood and MCWD that this rapid response should be viewed as a scientific experiment, and consequently that the launch should be closed until ice-in. Also, it is likely that the work to be done will not be completed until late October; as a practical matter, use of the launch may not be available until ice-in nearly occurs anyway.

Christmas Lake Homeowner's Association is working with lakeshore residents to make arrangements to store boats and equipment around the lake without needing to use the Christmas Lake public access.

September 2 Meeting of DNR, MCWD, Shorewood Staffs: The staffs of the three agencies met on Tuesday, September 2, and to update each other on plans and actions, and to discuss how we would work together going forward. The meeting was productive, and all present were focused on making the rapid response successful as quickly as possible. The meeting ended with all parties understanding that plans and decisions will need to be flexible as things progress.

M E M O R A N D U M

TO: MCWD Board of Managers
FROM: Craig Dawson, AIS Program Director
DATE: September 23, 2014
SUBJECT: Progress on Rapid Response to Zebra Mussel Infestation in Christmas Lake

Staffs of the MCWD, DNR, and City of Shorewood, along with Steve McComas of Blue Water Science, met this morning to discuss progress, agency thinking, and outline next steps in the rapid response to zebra mussels in Christmas Lake. It is apparent that upcoming actions will take several weeks to complete.

Results of Zequanox application: Zequanox was applied to the 50-by-60-foot containment area on September 8. As of September 19, MCWD staff was not finding any live mussels in this area. One of the effects of Zequanox is the near-total removal of dissolved oxygen. The combination of Zequanox and the subsequent long period of time without oxygen present appears to have resulted in 100% mortality. Zebra mussels placed in aquaria in the MCWD lab were filled with Zequanox-treated water from Christmas Lake, and they also had 100% mortality after ten days. It is possible, of course, that some zebra mussels remain alive in the containment area.

Marrone Bio Innovations notes that water temperatures are falling below 70°F, and Zequanox will not be as effective, with mortality rates dropping to around 50%.

Zebra mussels found outside of containment area: A team of nine divers SCUBA-ed and snorkeled around the containment area and other nearby sites in Christmas Lake on Friday, September 19. They found around 25 zebra mussels on small submerged branches up to 50 feet out into the lake from the containment area, and near a tree by the shoreline edge of the barrier. Based on this finding, further treatment over a larger area is planned.

Diving has been an important part of the monitoring and assessment of the areal extent of zebra mussels. To date, more than 125 hours of diving has been performed.

Expansion of containment area: The containment area will be extended about 40 feet north along the shore, and an additional 100 feet into the lake, for an overall dimension of 90-by-150-feet. The maximum depth of the lake in this area is six feet. All three agencies are working to locate the additional barrier curtains needed. A tree just north of the current containment area, at which additional zebra mussels were found, will be removed after the barrier is installed.

Additional treatments under consideration: Several courses of action being pursued or evaluated.

- Potash: The preferred option is liquid potash (potassium chloride). Potash has been shown to be 100% effective and at proper doses targets only mussels—unfortunately, both invasive *and* native. DNR is meeting with the Minnesota Department of Agriculture for approval. Both, however, must get approval by the U.S. Environmental Protection Agency, and would pursue an emergency exemption to apply potash. Given this time of year, this approval process would need to be expedited, and it may be necessary to enlist the support of our Congressional delegation.

- Copper sulfate: Copper sulfate has been used in prior responses to zebra mussels, but with limited effect. It would need to be applied multiple times. It is also toxic to invertebrates and zooplankton. Copper sulfate is an available, but not preferred, approach.

- Manipulate dissolved oxygen (DO) and acidity (pH): As found with the Zequanox treatment, removing dissolved oxygen for several days affects mortality of zebra mussels. Introduction of substances that cause an oxygen demand, and perhaps the addition of carbon dioxide, may work. Zebra mussels also have a rather narrow range of tolerance for pH, and some acidification (to <5) may also be effective.

Dredging and boat launch opening: At this time, the proposed shallow dredging is being reconsidered for its effectiveness and practicability. It does not appear to be needed as earlier thought. At least some removal of sediment will happen with the removal of the concrete planking at the boat launch. Any dredging and work on the boat ramp will be done after the treatments for zebra mussels. At this point, it is difficult to estimate whether the boat launch could be re-opened before ice-in.

M E M O R A N D U M

TO: MCWD Board of Managers
Jeff Spartz, Interim District Administrator
FROM: Craig Dawson, AIS Program Director
DATE: October 14, 2014
SUBJECT: Update on Rapid Response to Zebra Mussel Infestation at Christmas Lake

Progress continues on the rapid response to the zebra mussel infestation at Christmas Lake. Some modifications have been made to the original plan. The goal remains to complete treatments and remove barriers before ice-in occurs this year.

Containment Area Expanded; New Barrier in Place: Zebra mussels were found outside the containment barrier by divers on September 19. The new area of infestation was determined to be small enough for the removal effort to continue, and new barrier curtains were ordered. The barriers arrived yesterday, and were installed today (Tuesday, October 14). The barrier extends from just south of the dock at the boat launch about 320 feet to the east and north to the shore of the small bay, and contains about three-quarters of an acre. To be on the safe side, this area is well beyond that where zebra mussels were found.

Potash Treatment: The DNR is working with the Minnesota Department of Agriculture to submit information to the U.S. Environmental Protection Agency to grant an emergency exemption to apply potash (potassium chloride). At the proper concentration, potash will kill only mussels (both native and invasive) by disrupting their respiratory systems. EPA has approved the use of potash has been used in Millbrook Quarry, near Manassas, Virginia, in 2006; and Sister Grove Creek, in Texas, in 2010. EPA has a goal of responding to emergency requests within 50 days. Given the short amount of time available until the usual time for ice-in, we may contact Minnesota members of Congress to assist in expediting EPA approval, if possible. The Washington, DC, office of the EPA will be handling the matter, rather than the regional office in Chicago.

Copper Treatments On-going: DNR and MCWD have begun the application of EarthTec QZ, a copper-based product labeled to target quagga and zebra mussels; however, it may also affect other aquatic animals. The first treatment was done on Saturday, October 4, without the new, extended barrier put in place. The product label calls for 14 days between treatments. We plan to do the next treatment on October 20, in order to coordinate with a treatment in Lake Independence. Changes in the label are being considered that would allow more frequent treatments to maintain the needed concentration (1 ppm) in the water column, and will need to be approved by the Minnesota Department of Agriculture.

In this case, doing something is preferable while awaiting approval to use potash. We can gain some data on the effects and effectiveness of the copper product both within and outside of a barrier. We are also replicating the treatments in the aquaria in the lab at MCWD offices.

Meeting with DNR Commissioner: DNR Commissioner Tom Landwehr asked to meet with staff informally at Christmas Lake boat launch last Wednesday to learn more about what MCWD is doing for AIS and what's been done at Christmas Lake. He said that he has good agency relations with the EPA and would plan to request an expedited response for the potash treatment.

Dredging No Longer under Consideration: With the containment area being larger and the approval to use potash is likely, MCWD does not plan to go forward with shallow dredging for an assurance that all zebra mussels are removed. DNR will need to arrange for removal of the boat ramp. DNR Parks & Trails wants to coordinate its work so that the removal is subordinate to the treatment schedule.

Removal of Boats, etc., at Christmas Lake: The Christmas Lake Association has set up a temporary ramp on the property of a homeowner for removal of boats and equipment for the season. The Association has reported no presence of zebra mussels as boats and docks/lifts are removed from the lake. There was a false alarm on Friday from a dock taken out of the same small bay where the public access is – the small shelled animal turned out to be a limpet, rather than a zebra mussel (whew!).