Targeted Water Reuse for Irrigation

Developing a Stormwater Reuse Irrigation Assessment Planning Tool to Reduce Reliance on Groundwater
Background

- Grant from Board of Water and Soil Resources
- Reduce reliance on groundwater through stormwater reuse
- Use stormwater for “non-essential” irrigation
  – i.e. Public parks, golf courses, semi-public open spaces
Objectives of the Assessment Methodology:

1. What locations are technically-feasible for stormwater reuse irrigation projects?
2. How do we prioritize the most promising sites?
Scale of Work

- Planning
- Concept Design
- Design
- Construction
- Operation
Overview of Process

1. Establish Planning Criteria and Apply Geospatial Data
2. Assess for Technical Feasibility Using Criteria
3. Prioritize Most Promising Feasible Projects
4. Perform Site Visits to Test Assessment Methodology
5. Lessons Learned
Planning Criteria

Technical

- Is the location near a ditch?
- What’s the site’s potential demand for irrigation?

Qualitative

- Is the site close to a high demand user?
- Is the site close to a sensitive landscape?
Overview of Process

1. Establish Planning Criteria and Apply Geospatial Data
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5. Lessons Learned
Technical Feasibility

Is there enough drainage area to support demand?

(Met Council, 2011)

Vegetated Area in Parcel

Calculate Minimum Storage Volume

Calculate required drainage area (Volume / depth)

Estimate Annual Runoff Depth

Calculate Drainage Area to Parcel

Ratio (total drainage area / required drainage area)

Technically Feasible Parcels (ratio ≥ 1)
Technical Feasibility

Is there enough potential groundwater demand?
Technically Feasible Parcels
Overview of Process

1. Establish Planning Criteria and Apply Geospatial Data
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5. Lessons Learned
Planning Criteria

**Technical**
- Is the location near a ditch?
- What’s the site’s potential demand for irrigation?

**Qualitative**
- Is the site close to a high demand user?
- Is the site close to a sensitive landscape?
Planning Criteria

Technical

• What’s the site’s potential demand for irrigation?

Qualitative

• Is the site close to a high demand user?
How do you prioritize?

Select sites that will offset the most groundwater use

- Potential Demand for Irrigation
- Demand from local high demand users
- Final calculated groundwater offset
Most Promising Potential Water Reuse Sites
SITE STATS

<table>
<thead>
<tr>
<th>Use</th>
<th>Golf Course</th>
</tr>
</thead>
<tbody>
<tr>
<td>Feasible Area for Irrigation</td>
<td>58 Acres</td>
</tr>
<tr>
<td>Permitted</td>
<td>Yes</td>
</tr>
<tr>
<td>Permitted Use</td>
<td>21.7 MGY</td>
</tr>
<tr>
<td>Volume Offset</td>
<td>21.7 MGY</td>
</tr>
</tbody>
</table>

RCWD
RICE CREEK WATERSHED DISTRICT
**SITE STATS**

<table>
<thead>
<tr>
<th>Use</th>
<th>Future Commercial</th>
</tr>
</thead>
<tbody>
<tr>
<td>Feasible Area for Irrigation</td>
<td>367 Acres</td>
</tr>
<tr>
<td>Permitted</td>
<td>No</td>
</tr>
<tr>
<td>Permitted Use</td>
<td>N/A</td>
</tr>
<tr>
<td>Volume Offset</td>
<td>137.4 MGY</td>
</tr>
</tbody>
</table>
Field Verification: Confirmed Priority
Field Verification: Confirmed Priority
Field Verification: False Priority
Field Verification: False Priority
Establish Planning Criteria and Apply Geospatial Data

Assess for Technical Feasibility Using Criteria

Prioritize Most Promising Feasible Projects

Perform Site Visits to Test Assessment Methodology

Lessons Learned
Lessons Learned

• Leverage more detailed GIS data
• Screen sites based on type of vegetation present for the pervious area
• Exclude sites with existing reuse projects by placing a simple phone call
Moving Beyond Today

• Accelerate targeting and implementation of sites for reuse irrigation projects which are:
  – Technically feasible
  – Prioritized based on intended impact
Questions?
kℓtmm$^2$kg


<table>
<thead>
<tr>
<th>Site Scale</th>
<th>Size (acre)</th>
<th>Percentage Impervious</th>
<th>Impervious Area (sq. ft.)</th>
<th>Irrigation Area (sq. ft.) (pervious area)</th>
<th>Total Storage Required (ft³)</th>
<th>Total Drainage Area Required (sq. ft.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Residential (small lot)</td>
<td>0.25</td>
<td>38%</td>
<td>4,138</td>
<td>6,752</td>
<td>9,107</td>
<td>21,857</td>
</tr>
<tr>
<td>Residential (large lot)</td>
<td>10</td>
<td>10%</td>
<td>43,560</td>
<td>392,040</td>
<td>707,119</td>
<td>1,697,085</td>
</tr>
<tr>
<td>Commercial</td>
<td>6</td>
<td>80%</td>
<td>200,088</td>
<td>52,272</td>
<td>36,720</td>
<td>92,929</td>
</tr>
<tr>
<td>Industrial</td>
<td>10</td>
<td>80%</td>
<td>346,480</td>
<td>67,120</td>
<td>64,534</td>
<td>154,882</td>
</tr>
<tr>
<td>Open Areas</td>
<td>4</td>
<td>5%</td>
<td>8,712</td>
<td>105,528</td>
<td>307,818</td>
<td>736,703</td>
</tr>
</tbody>
</table>

\[ y = 1.75x \]
\[ R^2 = 0.97 \]
## Existing Models

<table>
<thead>
<tr>
<th>Model / Tool Name</th>
<th>Project Development Phase</th>
<th>Publicly Available (Yes / No)</th>
<th>Description</th>
<th>Comment on Use (If publicly available)</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>PB (Program for Predicting Polluting Particle Passage through Pits, Puddles and Ponds)</td>
<td>Planning</td>
<td>Yes</td>
<td>Model used for predicting the generation and transport of stormwater runoff and pollutants in urban watersheds. Used to simulate the stormwater runoff and phosphorus loads generated from hypothetical development sites with varying levels of imperviousness to represent variation in typical development density.</td>
<td>Does not assess potential sites based on feasibility for water reuse projects</td>
<td>MPCA 2016</td>
</tr>
<tr>
<td>Urban Subwatershed Restoration Manual Series</td>
<td>Planning</td>
<td>Yes</td>
<td>Manual provides guidance on choosing the best locations in a subwatershed for retrofitting or improvement in a series of 12 profile sheets. The manual then presents a model to assess retrofit potential at the subwatershed level, including methods to conduct a retrofit inventory, assess candidate sites, screen for priority projects, and evaluate their expected cumulative benefits. The manual concludes by offering tips on retrofit design, permitting, construction, and maintenance considerations.</td>
<td>Does not have an associated GIS desktop analysis for use.</td>
<td>Center for Watershed Protection 2007</td>
</tr>
<tr>
<td>Stormwater Reuse Calculator</td>
<td>Concept Design</td>
<td>Yes</td>
<td>Developed to estimate the runoff volume reduction and water quality benefits of stormwater reuse using a daily time step mass balance of stormwater runoff volume and phosphorus load. Stormwater runoff volume and phosphorus load are assumed to be the same as for a non-stormwater runoff event. The model simulates the annual runoff volume and phosphorus removal as a percent of the annual watershed load, in addition to annual evaporation losses and phosphorus sedimentation over a dry, average, and wet year. Does not have an associated GIS desktop analysis for use.</td>
<td>Does not have an associated GIS desktop analysis for use.</td>
<td>EOR 2013</td>
</tr>
<tr>
<td>Minimal Impact Design (MIDS) Calculator</td>
<td>Concept Design</td>
<td>Yes</td>
<td>The MIDS BMP calculator is a tool used to determine stormwater runoff volume and pollutant reduction capabilities of various low impact development (LID) BMPs. The tool includes inputs for harvest and re-use system. Does not identify locations for potential BMP sites.</td>
<td>Does not identify locations for potential BMP sites.</td>
<td>MPCA 2016</td>
</tr>
<tr>
<td>Stormwater Rate-Efficiency-Volume (REV) curve model</td>
<td>Design</td>
<td>Yes</td>
<td>Design tool for stormwater reuse ponds that relate runoff volume to reuse rates for a selected reuse efficiency (the amount of stormwater reused as a percentage of total runoff). Model developed in Florida. Modifications are needed to apply this model to a cold climate like Minnesota.</td>
<td>Does not assess potential sites based on feasibility for water reuse projects</td>
<td>EOR 2013</td>
</tr>
<tr>
<td>Rainwater Harvesting Cistern Design Spreadsheet</td>
<td>Design</td>
<td>Yes</td>
<td>The Stormwater Design Specification for Rainwater Harvesting allows runoff reduction credits for rainwater harvesting based on the total amount of annual internal water reuse, outdoor water reuse, and tank overflow discharge. These values can be calculated using the Cistern Design Spreadsheet. Does not assess potential sites based on feasibility for water reuse projects.</td>
<td>Does not assess potential sites based on feasibility for water reuse projects</td>
<td>EOR 2013</td>
</tr>
<tr>
<td>Rainwater Harvester Computer Model</td>
<td>Design</td>
<td>Yes</td>
<td>Developed to assess the potential of residential or municipal rainfall harvesting systems. Includes cost-benefit estimates in the output. Does not assess potential sites based on feasibility for water reuse projects.</td>
<td>Does not assess potential sites based on feasibility for water reuse projects</td>
<td>EOR 2013</td>
</tr>
<tr>
<td>Stochastic and Reliability Estimation Tool (SARET)</td>
<td>Design</td>
<td>Yes</td>
<td>Model can be used to determine the efficiency of stormwater reuse systems under variable rainfall regimes. The SARET model could be used to test the reliability of a stormwater reuse pond with Minnesota historic precipitation data. Does not assess potential sites based on feasibility for water reuse projects.</td>
<td>Does not assess potential sites based on feasibility for water reuse projects</td>
<td>EOR 2013</td>
</tr>
<tr>
<td>HydCAD</td>
<td>Planning</td>
<td>No</td>
<td>Computer Aided Design tool used for modeling stormwater runoff.</td>
<td>N/A</td>
<td>Appendix D</td>
</tr>
<tr>
<td>Western Washington Hydrology Model</td>
<td>Planning</td>
<td>No</td>
<td>Model uses the EPA HSFP software program to calculate rainfall-runoff and routing computations as part of Low Impact Development design plans.</td>
<td>N/A</td>
<td>EOR 2013</td>
</tr>
<tr>
<td>Sustainable Systems Integration Model (SSIM)</td>
<td>Concept Design</td>
<td>No</td>
<td>Sustainable Systems Integrated Model (SSIM) is an integrated land planning tool that optimizes sustainable development programs in terms of project goals and provides environmental performance and cost analysis as a validation method. Used to evaluate the effects of the water conserving strategies.</td>
<td>N/A</td>
<td>WERF 2011</td>
</tr>
<tr>
<td>Source Loading and Management Model (ием SLAMM)</td>
<td>Design</td>
<td>No</td>
<td>Developed for evaluation of nonpoint pollution in urban areas, with a focus on small storm hydrology and peak period of a single storm. Used to calculate pollution functions that can be used to size storage tanks to maximize irrigation use for residential locations throughout the United States. Example of how this was accomplished for Kansas City, MO, as part of a current U.S. EPA demonstration project on green infrastructure use to reduce the magnitude and volume of combined sewer overflows.</td>
<td>N/A</td>
<td>WERF 2011</td>
</tr>
<tr>
<td>Planning Criterion</td>
<td>Criterion Purpose</td>
<td>Criterion Type</td>
<td>Geospatial Data Layer</td>
<td>Use Rules</td>
<td></td>
</tr>
<tr>
<td>-----------------------------------------------------------------------------------</td>
<td>------------------------------------------------------------------------------------</td>
<td>----------------</td>
<td>----------------------------------------</td>
<td>-----------------------------------------------------------------------------------------------------</td>
<td></td>
</tr>
<tr>
<td>Estimated Irrigation Volume</td>
<td>Assess the potential magnitude of reduced groundwater use</td>
<td>Technical</td>
<td>Runoff Depth</td>
<td>Parcels with insufficient irrigation areas are not feasible</td>
<td></td>
</tr>
<tr>
<td>Surface Water Drainage Area Size</td>
<td>Generate sufficient runoff volume to meet storage requirement of water reuse project (Appendix C)</td>
<td>Technical</td>
<td>LIDAR data</td>
<td>Parcels with insufficient drainage area size are not feasible</td>
<td></td>
</tr>
<tr>
<td>Impervious Cover in Subwatershed (%)</td>
<td>Generate sufficient runoff volume to meet storage requirement of water reuse project</td>
<td>Technical</td>
<td>NLCD 2011</td>
<td>Parcels with insufficient drainage area size are not feasible</td>
<td></td>
</tr>
<tr>
<td>Impervious Cover in Subwatershed (%)</td>
<td>Generate sufficient runoff volume to meet storage requirement of water reuse project</td>
<td>Technical</td>
<td>CERCLIS database</td>
<td>Parcels intersecting these features are not feasible</td>
<td></td>
</tr>
<tr>
<td>Presence of Known Water Quality Risk Factors</td>
<td>Evaluate probable water quality of stormwater harvested for reuse</td>
<td>Technical</td>
<td>Drinking Water Supply Management Areas</td>
<td>Parcels intersecting these features receive a lower rank for implementation</td>
<td></td>
</tr>
<tr>
<td>Groundwater Contamination Potential*</td>
<td>Depth to water table to provide sufficient zone of treatment, avoiding contamination of groundwater from stored stormwater runoff</td>
<td>Qualitative</td>
<td>Source Water Assessment Area</td>
<td>Parcels intersecting these features receive a lower rank for implementation</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Proximity upstream or downstream to sensitive landscapes features reliant on stormwater runoff as a source of water, or, within sensitive landscape features which would be disrupted by water reuse projects</td>
<td>Qualitative</td>
<td>High Water Table Sensitivity</td>
<td>Parcels intersecting these features are not feasible</td>
<td></td>
</tr>
<tr>
<td>Proximity to Sensitive Landscape Features</td>
<td>Proximity upstream or downstream to sensitive landscapes features reliant on stormwater runoff as a source of water, or, within sensitive landscape features which would be disrupted by water reuse projects</td>
<td>Qualitative</td>
<td>Wellhead Protection Area</td>
<td>Parcels intersecting these features receive a lower rank for implementation</td>
<td></td>
</tr>
<tr>
<td>Water Quality Benefit Index</td>
<td>Evaluate if site is upstream of impaired water / surface waterbody, and would therefore reduce stormwater discharge to receiving water body</td>
<td>Qualitative</td>
<td>High Drinking Water Supply Vulnerability</td>
<td>Parcels intersecting these features are not feasible</td>
<td></td>
</tr>
<tr>
<td></td>
<td>RCWD NWI Wetlands</td>
<td>Qualitative</td>
<td>RCWD NWI Wetlands</td>
<td>Parcels intersecting these features receive a lower rank for implementation</td>
<td></td>
</tr>
<tr>
<td>Potential Local Flood Damage Reduction Benefits</td>
<td>Proximity to flood prone areas to determine flood protection benefits from storage provided by water reuse projects</td>
<td>Qualitative</td>
<td>24K water features</td>
<td>Parcels intersecting these features receive a lower rank for implementation</td>
<td></td>
</tr>
<tr>
<td></td>
<td>RCWD NWI Wetlands</td>
<td>Qualitative</td>
<td>Impaired wetlands</td>
<td>Parcels intersecting these features receive a lower rank for implementation</td>
<td></td>
</tr>
<tr>
<td></td>
<td>RCWD NWI Wetlands</td>
<td>Qualitative</td>
<td>Impaired streams</td>
<td>Parcels intersecting these features receive a lower rank for implementation</td>
<td></td>
</tr>
<tr>
<td></td>
<td>surface waters</td>
<td>Qualitative</td>
<td></td>
<td>Parcels intersecting these features receive a lower rank for implementation</td>
<td></td>
</tr>
<tr>
<td>Potential for Use Conflict for Irrigated Area</td>
<td>Evaluate public access to irrigated areas: Public access is controlled in &quot;restricted&quot; areas (i.e. golf courses, highway medians) and not controlled in &quot;unrestricted&quot; areas (i.e. parks, playgrounds)</td>
<td>Qualitative</td>
<td>Wildlife Management Areas</td>
<td>Parcels intersecting these features receive a lower rank for implementation</td>
<td></td>
</tr>
<tr>
<td></td>
<td>100 year floodplain</td>
<td>Qualitative</td>
<td>Public Conservation Lands</td>
<td>Parcels intersecting these features receive a lower rank for implementation</td>
<td></td>
</tr>
<tr>
<td></td>
<td>railroad</td>
<td>Qualitative</td>
<td>High Quality Wetlands</td>
<td>Parcels intersecting these features receive a lower rank for implementation</td>
<td></td>
</tr>
<tr>
<td></td>
<td>ditches</td>
<td>Qualitative</td>
<td>MCGS sites of biodiversity significance</td>
<td>Parcels intersecting these features receive a lower rank for implementation</td>
<td></td>
</tr>
<tr>
<td></td>
<td>24K water features</td>
<td>Qualitative</td>
<td></td>
<td>Parcels intersecting these features receive a lower rank for implementation</td>
<td></td>
</tr>
<tr>
<td></td>
<td>parklands</td>
<td>Qualitative</td>
<td></td>
<td>Parcels intersecting these features receive a lower rank for implementation</td>
<td></td>
</tr>
<tr>
<td></td>
<td>surface waters</td>
<td>Qualitative</td>
<td></td>
<td>Parcels intersecting these features receive a lower rank for implementation</td>
<td></td>
</tr>
<tr>
<td>Likelihood of Treatment Needed Prior to Reuse</td>
<td>Evaluate probable quality of stormwater harvested for reuse, based on land use</td>
<td>Qualitative</td>
<td>County Parcels and MCGS land cover</td>
<td>N/A</td>
<td></td>
</tr>
<tr>
<td>Proximity to Existing High Volume Groundwater Use</td>
<td>Target high-volume users that are technically feasible for supporting water reuse projects</td>
<td>Qualitative</td>
<td>SWUDS database</td>
<td>Parcels intersecting these features receive a higher rank for implementation</td>
<td></td>
</tr>
<tr>
<td>Planning Criterion</td>
<td>Response Count</td>
<td>Relative Weight (0-1)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-----------------------------------------------------------------------------------</td>
<td>----------------</td>
<td>-----------------------</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Estimated Irrigation Volume (demand for irrigation)</td>
<td>9</td>
<td>0.60</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Availability and amount of publicly owned land / open spaces</td>
<td>8</td>
<td>0.53</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Locations and volumes of existing storage systems</td>
<td>7</td>
<td>0.47</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Soil Hydraulic Conductivity (soil type and infiltration rate)</td>
<td>5</td>
<td>0.33</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Surface Water Drainage Area Size</td>
<td>5</td>
<td>0.33</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Groundwater Contamination Potential (distance to groundwater)</td>
<td>2</td>
<td>0.13</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Impervious Cover in Subwatershed (%)</td>
<td>2</td>
<td>0.13</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Water Quality Benefit Index (Distance from reuse site to impaired waters / surface waters)</td>
<td>1</td>
<td>0.07</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Potential Local Flood Damage Reduction Benefits</td>
<td>0</td>
<td>0.00</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
# Most Promising Sites for Reuse

<table>
<thead>
<tr>
<th>Rank</th>
<th>Site</th>
<th>Pervious Area (acres)</th>
<th>Offset Volume of Water (gallons/year)</th>
<th>If High-Volume User...</th>
<th>Volume Offset (gallons/year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Oneka Ridge Golf Course</td>
<td>150</td>
<td>21,700,000</td>
<td></td>
<td>21,700,000</td>
</tr>
<tr>
<td>2</td>
<td>Midland Hills Country Club</td>
<td>144</td>
<td>53,805,000</td>
<td></td>
<td>18,820,800</td>
</tr>
<tr>
<td>3</td>
<td>U of Mn Les Bolstad Golf Course</td>
<td>133</td>
<td>17,611,200</td>
<td></td>
<td>17,611,200</td>
</tr>
<tr>
<td>4</td>
<td>White Bear Yacht Club</td>
<td>219</td>
<td>20,081,700</td>
<td></td>
<td>8,341,670</td>
</tr>
<tr>
<td>5</td>
<td>Land O Lakes Inc.</td>
<td>27</td>
<td>10,016,900</td>
<td></td>
<td>8,335,800</td>
</tr>
<tr>
<td>6</td>
<td>New Brighton - Brightwood Hills Golf</td>
<td>26</td>
<td>9,642,100</td>
<td></td>
<td>6,962,500</td>
</tr>
<tr>
<td>7</td>
<td>Running Aces</td>
<td>154</td>
<td>21,610,500</td>
<td></td>
<td>6,202,300</td>
</tr>
<tr>
<td>8</td>
<td>Bethel University</td>
<td>118</td>
<td>44,042,600</td>
<td></td>
<td>2,495,830</td>
</tr>
<tr>
<td>9</td>
<td>Medtronic Inc.</td>
<td>65</td>
<td>24,369,800</td>
<td></td>
<td>1,583,330</td>
</tr>
<tr>
<td>10</td>
<td>Arden Hills Army Training Site (AHATS)</td>
<td>1258</td>
<td>139,695,000</td>
<td></td>
<td>0</td>
</tr>
<tr>
<td>11</td>
<td>Rice Creek Commons</td>
<td>367</td>
<td>137,431,000</td>
<td></td>
<td>0</td>
</tr>
</tbody>
</table>
Estimated Irrigation Volume
Surface Water Drainage Area Size
Impervious Cover in Subwatershed (% (For use in absence of runoff depths))
Presence of Known Water Quality Risk Factors

Groundwater Contamination Potential
Proximity to Sensitive Landscape Features
Water Quality Benefit Index
Potential Local Flood Damage Reduction Benefits
Potential for Use Conflict for Irrigated Area
Likelihood of Treatment Needed Prior to Reuse
Proximity to Existing High Volume Groundwater Use
Feasible parcels ranked by area available for irrigation
Feasible parcels ranked by high demand water users
Water Resources Conference

Cottageville Park: Integrating Land Use and Water Resources Planning

Renae Clark, Minnehaha Creek Watershed District
Chris Meehan, Wenck Associates
Planning Approach

1. Develop a common understanding of natural resource issues and drivers
2. Understand local priorities by assessing partner agencies’ existing plans and policies
3. Integrate natural resource goals with local plans and policies
4. Develop a strategic implementation and investment framework
Partnership Model: Understanding mutual interests to achieve clean water and thriving communities

- Focused understanding of public and private partner goals
- Remain flexible, opportunistic and streamline regulation
- Value added partner
- District is more successful when working across disciplines to achieve broad goals.
- Great public ROI
Call for Integration

- 2007 *Evaluation Report on Watershed Management* (Legislative Auditor)
- 2009 *Land and Water Policy Project* (MEI)
- 2011 *Water Governance Study* (Hennepin County/Humphrey School)
- 2013 *Water Regulation and Governance* (MPCA)
- 2016 APA
Highest Pollutant Loading to Lake Hiawatha

Figure 1-2. Minnehaha Creek total phosphorus cumulative load longitudinal profile (Drainage Area)
Minnehaha Creek Greenway: Partnership, Focus and Flexibility
Cottageville Park
Integrated Planning for Partnerships

- Not everyone cares about your issue as much as you do
- Step outside comfort zone and understand other people’s objectives and constraints
- Plan projects with equal attention to issues outside primary discipline
- Breeds holistic projects, spanning multiple systems, creating layered benefit
- It takes longer than you think it should – Be patient
- Keep the vision in mind and focus on shared goals
Creating Sustainable Communities Through Collaborative Planning

- 450 acres stormwater management
- 50 acres newly accessible green space
- 1.5 miles restored urban stream
- 2 miles new trail network connecting 600 housing units to transit
- 4.6 million of partner investment
SWLRT Regulatory Complexity

Earth Evans
2016 WR Conference
Oct 18, 2016

Brady Busselman, Sambatek; Charlie Howley, HTPO
Today’s Topics

• Project Overview
• Project Schedule
• Environmental Regulatory Agencies
  ▪ Federal
  ▪ State
  ▪ Local
• Environmental Regulatory Coordination
Project Overview
Southwest LRT

- 14.5 miles new track
- 32 bridges
- 2 LRT tunnels
- Over 7 lineal miles of retaining walls
- 15 new stations
  - 1 deferred station
- 34,000 average weekday rides in 2040
Project Status
Project Readiness: Milestones Completed

- Environmental reviews complete
  - Final Environmental Impact Statement: May 2016
  - Record of Decision: July 2016
  - FEIS Determination of Adequacy: Aug 2016
- Funding commitments for 100% ($928.8M) of the local share complete Aug 2016
- Application for Entry into Engineering for FTA New Starts Program Aug 2016
- 90% design plans complete
- 90% cost estimate complete
Milestones Look Ahead:

<table>
<thead>
<tr>
<th>Milestone</th>
<th>Rev. 10.0 Submitted 8/19/16</th>
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<tbody>
<tr>
<td>FTA Approves Entry into Engineering</td>
<td>Nov 2016</td>
</tr>
<tr>
<td>Complete 100% Design Package for Civil</td>
<td>Dec 2016</td>
</tr>
<tr>
<td>Submit FFGA Application</td>
<td>Early 2017</td>
</tr>
<tr>
<td>Complete 100% Design Package for Systems</td>
<td>March 2017</td>
</tr>
<tr>
<td>Complete 100% Design Package for OMF</td>
<td>May 2017</td>
</tr>
<tr>
<td>FTA Approves FFGA</td>
<td>July 2017</td>
</tr>
<tr>
<td>Heavy Construction</td>
<td>2017-2020</td>
</tr>
<tr>
<td>Revenue Service</td>
<td>2021</td>
</tr>
</tbody>
</table>
Environmental Regulatory Agencies
Federal and State
Federal Approvals

- **FEIS**  
  Published 5/13/16

- **ROD**  
  Signed by FTA 7/15/16;  
  All NEPA requirements met

- **DEIS**  
  Published 10/11/2012

- **SDEIS**  
  Published 5/22/15
Local / Stakeholders
Local / Watershed
Environmental Regulatory Coordination
Environmental Regulatory Coordination

What makes this project unique?

• Size: 14.5 miles of track
• Numerous Stakeholders
• Overlapping Requirements
• Public and Private Scrutiny
• Fully Developed Urban Environment
• Contamination
Size

- Linear Corridor – used linear BMPs adjacent to track where feasible

Example: Ditch checks

Track Typical Cross Section
Extensive Coordination with Stakeholders

- Weekly meetings with municipal staff starting in 2013
- Technical Evaluation Panel meetings monthly starting in 2013
- Plan submittals to Municipalities at 30%, 60%, 90%, 95%, 100%
- Ongoing meetings and formal submittals to Watersheds at 60%, 95%, and 100%. Presentations to Boards at 60%
- Public Outreach Staff from Metro Transit
Urban Environment

• Oversized corridor BMPs
  ▪ Retrofit water quality for densely impervious corridor where feasible
  ▪ Routed public ROW impervious to proposed BMPs
  ▪ Length of linear corridor was an advantage
  ▪ Flexibility to meet standards within Watershed or City boundary versus by waterbody

Source: Empire WWTP Infiltration Basin

Proposed Infiltration Basin

Source: Empire WWTP Infiltration Basin
Contamination

- Challenge
  - Groundwater and Soil contamination for half of the project corridor
Contamination

- MULTIPLE BMP TYPES TO ADDRESS CONTAMINATION
  - Meet water quality requirement with ponds and bioretention
  - Store roof runoff in a collection tank and use for train washing
  - Rainwater collection tank size restricted by frequency of train washing (not feasible to use larger tank and reuse all the water)
  - Meeting B3 rate control and water quality requirements
  - Reconstructing existing non-functioning wetland outlet
  - Net reduction in impervious surfaces
Regulatory Compliance

- Determination of Adequacy under MEPA on August 10, 2016
- CWA Section 404 Permit in progress and 401 certification issued
- DNR waived jurisdiction
- Eden Prairie and Minnetonka WCA Notice of Decision
- Watershed District and City permits in process; approvals expected in Nov-Dec
More Information

Online:
www.SWLRT.org

Email:
SWLRT@metrotransit.org

Twitter:
www.twitter.com/southwestlrt
Project Design Team

• Civil Design, Utilities, Construction Admin, and Project Management – HTPO

• Landscape Architecture and Historic Review - Damon Farber Landscape Architects

• Stormwater Management, Lighting, Traffic Signal – SRF Consulting Group, Inc.
University Team

• Capital Planning and Project Management (CPPM)
• Landcare
• Parking and Transportation Services
• Engineering and Utilities
Project Need

• Street deterioration, localized flooding, limited storm sewer capacity

• Need for traffic redesign to meet University priorities for pedestrians, bikes, and vehicles
  – Non-functioning intersection with temporary signal

• Planned extension of chilled water lines through corridor

• 53 Ash trees in corridor selected for removal and replaced with diverse species mix
Stormwater Management Goals

• University’s ‘Guiding Principles’
  – Treat stormwater close to where it falls; reduce downstream impacts; recharge groundwater through infiltration where possible

• B3 Requirements
  – Post development site runoff must be controlled to match the runoff rates for native soil and vegetation conditions for the 2-year and 10-year, 24-hour design storms
  – Prohibit discharge from the site for 1.1 inches of runoff for all new/redeveloped impervious surfaces
  – Provide treatment systems to remove 80% of post-development TSS and 60% of post-development TP
Stormwater Management Goals

• Project Goals
  – Reduce runoff rate for 2-year and 10-year, 24-hour design storms, ensure no capacity issues at connection to Minneapolis system
  – Retain 1.1 inches of runoff from the new/redeveloped impervious
  – Retain 0.5 inches of runoff from the impervious area if infiltration is infeasible
  – Remove 80% of TSS and 60% of TP
Existing Drainage

Drainage divide at Pleasant and Pillsbury

• North system discharges to Minneapolis storm sewer

• South system discharges to University storm tunnel

• Existing storm sewer in southern area is located in an area that is not to be disturbed and has capacity issues
Proposed Drainage

ADDITIONAL 2+ ACRES OF DRAINAGE AREA TO NORTH TO AVOID CROSSING EXISTING UTILITIES

TREE REMOVAL DUE TO DISEASE = OPPORTUNITY TO PROVIDE GREEN INFRASTRUCTURE BMPS
Center Median BMP

- CONNECTION TO MINNEAPOLIS STORM SEWER SYSTEM
- WEIR STRUCTURE HOLDS BACK STORMWATER
Center Median BMP

- Stormwater runoff from street to center median tree trench and bioretention basin.
- Stormwater uptake by trees and plants.
- Stormwater infiltration.
- Stormwater distributed through solid wall and perforated pipe.
- Bioretention soil.
- Electrical concrete duct bank to remain.
- Lift for removal tree trench.

Dimensions and materials specified include:
- 24" perforated PVC pipe drain.
- 18" solid wall PVC.
Tree Trenches/Permeable Paver Boulevard
Tree Trenches/Permeable Paver Boulevard

**Diagram Description**
- **Tree Trenches/Permeable Paver Boulevard**
- **Stormwater Uptake by Trees and Plants**
- **Stormwater Infiltration**
- **Diagram Elements**:
  - Boulevard Tree
  - Center Tree in Grate
  - Curb
  - 4" Tree Grate
  - 2" No.8 Bedding Sand
  - Non-Woven Geotextile Fabric
  - Existing Concrete Sidewalk
  - Aggregate Base
  - See Typical Sections
  - Stormwater Runoff from Street to Tree Trench
  - Dipped Street
  - 12" Solid PVC Pipe Drain
  - 12" Perforated PVC Pipe Drain
  - In-Situ Soil
  - Structural Soil
  - Coarse Filter Aggregate
  - Geotextile
  - Concrete Sidewalk
## Results - Rate Control

### North Section

<table>
<thead>
<tr>
<th></th>
<th>Existing Conditions</th>
<th>Proposed Conditions</th>
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<tbody>
<tr>
<td>2-year, 24-hour Peak Discharge Rate</td>
<td>6.0</td>
<td>1.3</td>
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<td>10-year, 24-hour Peak Discharge Rate</td>
<td>9.8</td>
<td>6.6</td>
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<tr>
<td>100-year, 24-hour Peak Discharge Rate</td>
<td>15.4</td>
<td>15.2</td>
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### South Section

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<tr>
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<th>Existing Conditions</th>
<th>Proposed Conditions</th>
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<tbody>
<tr>
<td>2-year, 24-hour Peak Discharge Rate</td>
<td>6.2</td>
<td>3.0</td>
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<tr>
<td>10-year, 24-hour Peak Discharge Rate</td>
<td>7.8</td>
<td>7.1</td>
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<tr>
<td>100-year, 24-hour Peak Discharge Rate</td>
<td>9.5</td>
<td>10.6</td>
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## Results – Water Quality & Volume Control

### North Drainage Area

<p>| | |</p>
<table>
<thead>
<tr>
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<tbody>
<tr>
<td>Volume Goal (1.1” over impervious area)</td>
<td>5,300 cubic feet</td>
</tr>
<tr>
<td>Volume Required (0.5” over impervious area)</td>
<td>2,400 cubic feet</td>
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<tr>
<td>Volume Provided</td>
<td>8,900 cubic feet</td>
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<tr>
<td>Percent TSS Removed</td>
<td>100%</td>
</tr>
<tr>
<td>Percent TP Removed</td>
<td>100%</td>
</tr>
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### South Drainage Area

<p>| | |</p>
<table>
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<tr>
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<tbody>
<tr>
<td>Volume Goal (1.1” over impervious area)</td>
<td>2,000 cubic feet</td>
</tr>
<tr>
<td>Volume Required (0.5” over impervious area)</td>
<td>900 cubic feet</td>
</tr>
<tr>
<td>Volume Provided</td>
<td>1,200 cubic feet</td>
</tr>
<tr>
<td>Percent TSS Removed</td>
<td>79%</td>
</tr>
<tr>
<td>Percent TP Removed</td>
<td>79%</td>
</tr>
</tbody>
</table>
Changes During Construction

- Lowered Gas Line for Storm Sewer
- Eliminate CB 4, Reuse Structure for 2A
- Grade Curved Radius to Drain 10-05 S
- Raised Entire Line .5 w/ Same Grade to Go Over Chilled Water Piping
- Raised Entire Line .5 w/ Same Grade to Go Over Chilled Water Piping
- Eliminate Pipes
- CB 2A
  - RIM: 839.45
  - INV. IN: 834.19 (SW)
  - INV. IN: 836.60 (S)
  - INV. OUT: 835.84
  - N: 168138.30
  - E: 538151.00
- CB 14
  - INV. IN: 834.19 (SW)
- 75-15 RCP @ 120% Tee main Karl
- 75-15 RCP @ 120% Tee main Karl
- Structure B moved 10' and Cap
- Lay Out 7' & Cap
- Set MH 17 Two Feet Lower to Go Under Electric Duct Bank (INV 830.6)
Construction
Construction
Building an Urban Stormwater Treatment Testbed

St. Anthony Regional Stormwater Treatment & Research System

Marcy Bean, Mississippi Watershed Management Organization

Bill Alms, WSB Engineering

October 18, 2016
St. Anthony Regional Treatment & Research System

- Project Overview
- Partnerships
- Design + Construction
- Research
Figure 1: Annual Mass of TSS Removed at Specific Design Flow Rate

- Additional TSS Removal Efficiency:
  - 4%
  - 8%
  - 53%

- Additional Cost Per lb of TSS:
  - $56/lb
  - $9.10/lb
  - $2.40/lb
  - $0.19/lb

*Assumed 80% Treatment Efficiency at Design flow Rate
Figure 1: Annual Mass of TP Removed at Specific Design Flow Rate

- Additional TP Removal Efficiency:
  - 3.0%
  - 5.2%
  - 5.4%
  - 41.3%

- Additional Cost Per lb of TP:
  - $49,700/lb
  - $8,164/lb
  - $2,120/lb
  - $152/lb

*Assumed 30% Treatment Efficiency at Design flow Rate
Particulate Phosphorus Only
**ST. ANTHONY REGIONAL TREATMENT**

**A. Aluminum Swirl Chamber**
“Primary Treatment” in a chamber designed to swirl water to separate out total suspended solids (TSS), dropping them to the bottom of the chamber. The solids can be vacuumed out of the tank as part of standard City maintenance.

**B. Distribution Well**
If the system is full, the water will flow out after 90% of the TSS has been removed.

Some of the water will enter the last two chambers that contain “filter media” that the MWMO will monitor to see how effective they are at removing dissolved pollutants. These chambers can be modified to allow the MWMO to study other methods of treatment.

**C. Iron Sand Filter (Trial)**
Iron helps removed dissolved pollutants from water, particularly phosphorus. Iron is mixed with sand, which acts as secondary treatment to test removal of the dissolved pollutants.

**D. StormFilter System® (Trial)**
StormFilter is a proprietary system that consists of cartridges filled with filter media customized to the pollutant you’re trying to remove from the water. As of 2015, the MWMO will be targeting dissolved phosphorus.

---

**MWMO Stormwater Monitoring Locations**

Project completed in collaboration with:
City of Saint Anthony Village, City of Minneapolis,
WSB Associates
CONSTRUCTION
SECONDARY TREATMENT - IESF

Underdrain Rock

Conveyor

Iron Enhanced Sand
SECONDARY TREATMENT – MEDIA FILTER

Cartridge Chamber  Storm Filter®  Phosphosorb®
~ 1” Rainfall
10/7/2016

SWIRL CHAMBER INLET
Water level
Samples collected

DISTRIBUTION WELL
Water level
Pump 1 on/off: 0=off; -1=on
Questions?

Marcy Bean  
Capital Projects & Stewardship Specialist  
mbean@mwmo.org

Bill Alms  
Water Resources Project Engineer  
BALms@wsbeng.com
Irrigate, Infiltrate, Automate;
Upper Villa Park Stormwater Project

MN Water Resources Conference, 2016
St. Paul, MN

Forrest J. Kelley, PE
Capitol Region Watershed District
Overview

• Background
• The Water Resources
• The Problem
• The Project
• Challenges
• Next Steps
Capitol Region Watershed District

- 41 Square Miles (25,965 acres)
- Portions of 5 Cities
- 5 Lakes (Como, McCarrons, Big Crosby, Little Crosby, Loeb)
- Numerous wetlands
- 42% Impervious surfaces
All of CRWD Drains to Mississippi River
The Water Resources – Lake McCarrons

- 81-acre recreational lake - swimming beach, boating, and fishing
- Deep lake classification 57-ft max depth
- Primarily residential land use within the fully developed 1,044-acre drainage area.
The Water Resources – Villa Park Wetlands

• Villa Park Wetland System Constructed in 2004
• Series of weirs created pools and wetland cells
• Slow water and enhance sedimentation
• Drains 753 acres to Lake McCarrons
The Problem

- McCarrons has historically good water quality, but trending downward
- Villa Park Wetland System undersized for its drainage area
- Determined to be a source of Total Phosphorus to Lake McCarrons
McCarrons – TP Concentrations (ug/l)

- Hypolimnetic Average TP
- Epilimnetic Average TP
- Deep Lake TP Standard (40 ug/L)
Previous Analysis recommended:

- Upstream volume reduction
- 45 pound annual TP removal goal
The Project

- CRWD received $275K MPCA grant to identify, design, and construct volume reduction BMPs
- Five BMP options ranging from $300K to $1.5M
- Prioritized by effectiveness and land ownership
The Project

- Underground infiltration system below City of Roseville Park.
- Divert runoff from 250 acres of drainage in 36 inch pipe beneath existing softball field.
- Assumed 80,000 cf of storage could remove 45 pounds at cost of $810K
Stand Alone, Option C- B-Dale Club, Underground BMP:

Phosphorus Removed: 45.4 lbs/yr (54%)
Probable Construction Cost: $810,000
$/lb removal: $17,832/lb P removed

In Series, Option D- Victoria Street BMP and Option C- B-Dale Club, Underground BMP:

Phosphorus Removed: 47.5 lbs/yr
Probable Construction Cost: $1,100,000
$/lb removal: $23,158/lb P removed
Concept Refinement

- Additional $360K grant for storm water reuse
- No MHs allowed in outfield
- Balance size and location with cost and paving
- Soils
Stormwater Reuse

- Additional grant funds provided to add stormwater harvest and reuse
- Reuse feasibility study conducted for water balance and cistern sizing
- 13,000 cf StormTrap cistern provides 2-weeks of irrigation
- Optimized Real Time Controls (OptiRTC) system determined to remove additional 5-lbs TP/yr
OptiRTC

- Cloud based technology to actively manage stormwater retention
- Level sensors in the cistern and infiltration system
- CMP and concrete vault connected by 10” DIP with actuated butterfly valve
- Opti logic analyzes the NOAA forecasted precipitation and drains the cistern into the CMP in advance of a rain event
Final Layout

- 575 feet of 10 ft CMP (60,000 cf)
- 13,000 cf precast modular segmental cistern
- The Preserver pretreatment baffle
- OptiRTC valve
- Pump and filter to reuse stormwater for irrigation
• Tight construction window due to softball schedule and community events Nov 2, 2015
  Start-Dec 31 substantial completion
• Irrigation, pump installation and OptiRTC commissioning in Spring 2016
• Constrained construction limits, active parking lot with private business and parkgoers
• Field usable for April 20 softball season opener
Exfiltration Sampling Wells

- Three custom built pan-lysimeters
- Abstract samples beneath infiltration pipes
- Determine effectiveness of native soils
Screen and Well
Collection Barrels
Standpipes and Pea Gravel
Variable speed pump
300 micron filter
Backflush capabilities
Low level municipal source
OptiRTC
Monitoring

• Automated Isco sampler, level, velocity
• Measure TP, TSS, metals, bacteria, Chloride, etc.
• Calculate flow upstream and downstream of diversion
• Exfiltration wells at 1.5, 3, and 7 feet below CMP
• Similar constituents
Preliminary Results

Total Stormwater: May-August
1,706,825 ft³

- 1.3M cf volume reduction
- 24 lbs TP
- 4,900 lbs TSS
Challenges

• Field Schedule – temporary ag-lime in outfield
Challenges

- Clay soils encountered – Wells raised
- 6 inches removed in east corner of infiltration bottom
Calibration and alignment of ultrasonic sensors – pressure transducer
Challenges

• Cistern drained in 5 days
• Likely pipe boot seals
• Contractor vac’ed and cleaned cistern
• Completed internal joint sealant
Next Steps

- Refine Exfiltration monitoring
- Determine need for small weir in diversion
- Vac pre-treatment manhole
- Restore outfield turf and irrigation
- Monitor
Partners

MN Clean Water Fund (BWSR)
Minnesota Pollution Control Agency
Capitol Region Watershed District
City of Roseville
B-Dale Club
SRF Consulting Group, Inc.
New Look Contracting, Inc.
Questions

Forrest Kelley, PE, Capitol Region Watershed District
forrest@capitolregionwd.org
https://webapp.senserasystems.com/C1/view-device.html?bs=409129

https://portal.onopti.com/dashboard/951/
Tree Trench and Permeable Pavers in the Edison High School Parking Lot

Minnesota Water Resources Conference
October 18, 2016
Agenda

1. Project Background and Partners
2. BMP Design and Construction
3. Education and Outreach
4. Stormwater Research and Monitoring
Project Background & Partners
Phase I (Completed 2013)
BMP Design & Construction
• Tree trench
• Permeable pavers
• Rain garden
• Infiltration Curb

BMP DESIGN & CONSTRUCTION
TREE TRENCH DESIGN

- Street tree plantings as specified. See plan for tree locations.
- Modified planting soil as specified.
- Concrete wheel stop typ. See sheet C3.02.
- 3.5" thick bituminous parking lot paving. See specification.
- 6.5" Class V agg. compact to 100% standard Proctor density.
- Towards 22nd Avenue.
- 8" perf. PVC drain pipe.
- 2"-4" rock borrow aggregate approx. 2'-6" depth, in lower storage level, as specified.
- Undisturbed or uncompacted subgrade.
- Continuous concrete wheel stops. See sheet C3.02.
- Filter fabric, as specified. Incidental.
- Rock mulch borrow (granite aggregate), 4"-6" in diameter, as specified.
- Note: Coordinate planting of trees within aggregate soils with General and Landscape contractor to determine the most efficient means of planting.
- 8" perf. PVC dist. pipe.
- Approx. 10'-0".
COMPLETED TREE TRENCH
PAVER AND INFILTRATION CURB CONSTRUCTION
COMPLETED PAVERS AND INFILTRATION CURB
RAIN GARDEN CONSTRUCTION
Phase II (Completed 2016)
STORMWATER REUSE SCHEMATIC
Green Elements

- Engineered soil amendments for football Field
- Filtration planting beds on plaza
- Underground storage/stormwater reuse for irrigation of football field and practice field
- Community gardens/greenhouse
- Future stormwater reuse in toilets/urinals
- Future solar canopy and electric car charging
UNDERGROUND STORAGE CONSTRUCTION
Education & Outreach
ART
Using art as a way to fold our work into the goals of the local arts community.

DEMONSTRATION
Working with teachers to find ways to bring our work into their classrooms.

INTERPRETATION
Using plain language & infographics to communicate our message.
**Tree Trench**

A tree trench holds water after it rains, providing water for the trees to use and helping to filter out pollutants. This reduces the amount of stormwater and pollution that goes into the stormdrains.

**Permeable Pavers**

Permeable pavers allow water to pass through the surface and soak into the ground. Diverting water from the stormdrain and into the ground allows plants and soil to filter out pollutants, which keeps our rivers and lakes healthy!

1. Stormwater flows into the tree trench, where it is absorbed and filtered by trees, or soaks into the ground.
2. If the tree trench gets full, excess water flows into an overflow pipe and goes into the stormdrain to prevent flooding.
3. Stormwater flows to and between the pavers.
The tank is 65% full. This can water the field for 9 days.

These 72,498 gallons could fill 10.3 school buses.
Stormwater Monitoring
INFLOW
Capturing the runoff into the trench

OUTFLOW
Monitoring flow and pollutants coming out

MONITORING
• Rainfall
• Runoff volume
• TP loading
• TSS loading

INFLOW
Monitoring flow and pollutants going in
RESULTS (SO FAR) ……..

Precipitation (inches)

0.5 1.0 1.5 2.0 2.5 3.0

1/1/15 7/1/15 1/1/16 7/1/16

IT’S WORKING
Summary and Lessons Learned

1. Engage the community
2. Look to the future
3. Follow up
Sustainable Stormwater Management
Ford site: A 21st Century Community

Key Principles:
- Mix of Uses & Activity
- Housing Variety
- Jobs & Tax Base
- Energy & Sustainability
  Regional, national, and global model for sustainable planning, design, and day-to-day living that protects our air, water and natural resources for future generations
- Transportation Choice
- Parks & Amenities
• Ford Plant closed in 2011
• 135 acre site, industrial, mostly impervious
• Located above the Mississippi River bluffs and connected to Hidden Falls Regional Park
• Drains to Hidden Falls Creek and Mississippi River
Assembly plant closure in 2011

Excellence is never granted to man (woman) but as the reward of labor

Pre-demolition
(Ford Motor Company Archives)

Post-demolition
(fall 2015)
(Pioneer Press: Scott Takushi)
Hidden Falls and Hidden Falls Creek today

degraded stream quality, bank erosion, costly scour protection
How could managing rainwater as a vital resource within the urban landscape — instead of a neglected waste stream— factor into future planning?
A comparative analysis was performed using 5 broad assessment themes.
Project scope: Compare two stormwater management alternatives

Baseline
Stormwater management under ground
- Conventional approach, managed separately
- Meets runoff from each parcel current standards (city, watershed, state)
- Fewer amenities but greater developable acreage

Centralized
Stormwater management above ground
- Runoff from entire site managed in centralized green corridor, recreating Hidden Falls Headwaters feature
- Enhanced stormwater management goals
Two alternatives

**Baseline:** Conventional stormwater management

**Hidden Falls Headwaters** (Centralized): stormwater treated in green infrastructure corridor

Underground features meet Saint Paul and District stormwater regulations

Above ground features exceed Saint Paul and District stormwater regulations
Note: Limited public access from Ford site to Hidden Falls Park due to poor trail connection.
Re-created Hidden Falls Headwaters
Enhanced public spaces along green spine
2.4 acre retention pond
Improved recreation trail connection
4.8 acres bioretention
35 acres residential watershed area treated
Hidden Falls
3.5 cfs 2-year peak
129 cfs 100-year peak

2.4 Acres Pond
4.8 Acres Biofiltration
3.5 Acres Green Space
10.7 Acres Study Area Extent

MISSISSIPPI RIVER
The Hidden Falls Headwaters alternative restores natural hydrology

**Recent peak flow 233 cfs**
(2-year event)

**Peak flow 175 cfs**
(2-year event)

**Peak flow 3.5 cfs**
(2-year event)

### Storm Event Maximum Discharge (cfs)

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<th></th>
<th>2 Year</th>
<th>10 Year</th>
<th>100 year</th>
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<tbody>
<tr>
<td>Pre-settlement (past)</td>
<td>4</td>
<td>31</td>
<td>161</td>
</tr>
<tr>
<td>Ford assembly plant in operation (recent past)</td>
<td>233</td>
<td>401</td>
<td>792</td>
</tr>
<tr>
<td>Baseline (future)</td>
<td>175</td>
<td>268</td>
<td>362</td>
</tr>
<tr>
<td>Hidden Falls Headwaters (future)</td>
<td>4</td>
<td>31</td>
<td>129</td>
</tr>
</tbody>
</table>
Baseline vs. Hidden Falls Headwaters: Estimated Costs

Construction costs similar in order of magnitude

**Above Ground**

**Below Ground**

Approximately 80% of costs for underground stormwater management

- **Hidden Falls Creek**
  - **Biofiltration**
  - **Trunk Storm Sewer**
  - Underground Stormwater Systems on Individual Parcels

- **Hidden Falls Creek**
  - **Biofiltration and Pond**
  - Public Space
  - Hardscape and Walls
  - **Trunk Storm Sewer**

Majority of costs are for surface green infrastructure, walls, hardscape features

**Estimated O&M costs could be double those of Baseline alternative**

**Operation & Maintenance**

Baseline: $100–200,000/Year

Hidden Falls: $200–400,000/Year
Baseline vs. Hidden Falls Headwaters:

25 Year AutoCASE Model

**Benefits**

Baseline (+$6.3 million) 0.4 benefit-to-cost ratio

Hidden Falls Headwaters (+18.9 million) 0.9 benefit-to-cost ratio

**Construction Costs**

- Baseline: $16.5 Million
- Hidden Falls Headwaters: $21.2 Million

**Other Costs**

- Baseline: $6.3 Million
- Hidden Falls Headwaters: $18.9 Million

**Benefits, as calculated by AutoCASE®**

- Air Pollution Reduction
- Water Resource Value
- Recreation
- Flood Risk Reduction and Stormwater

**Construction and operation and maintenance costs**
Baseline: conventional stormwater management

Hidden Falls Headwaters (Centralized): stormwater treated in green infrastructure corridor

+ Green infrastructure ecosystem services
+ Enhanced public spaces and recreation
+ More resource awareness, users & uses
+ Connection to Hidden Falls Park
+ Restoration of Hidden Falls Creek

Benefit-to-Cost Ratio

0.4 to 0.9

2x
A comparative analysis was performed using 5 broad assessment themes.

Baseline vs. Hidden Falls Headwaters

- Stormwater Management
- Restoration
- Life Cycle Costs, Impacts
- Sustainability, SROI
- Community Benefits
Baseline vs. Hidden Falls Headwaters: life cycle assessment (LCA)

**Estimated Embodied Energy Footprint (kWH)**
- Baseline: 24,100,000 kWh
- Hidden Falls Headwaters: 16,300,000 kWh

**Estimated Greenhouse Gas Footprint kg CO2e**
- Baseline: 6,200,000 kg CO2e
- Hidden Falls Headwaters: 4,200,000 kg CO2e

**Estimated Water Footprint (ft³)**
- Baseline: 15,400,000 ft³
- Hidden Falls Headwaters: 13,200,000 ft³
Key takeaways: life cycle assessment (LCA)

The Hidden Falls Headwaters alternative resulted in a lower footprint for three key sustainability indicators:

- Estimated embodied energy footprint: 32% Reduction
- Estimated greenhouse gas footprint: 32% Reduction
- Estimated water footprint: 14% Reduction
Key takeaway: Sustainability indicators

Hidden Falls Headwaters Alt. outperformed on 17 indicators. This alternative was conceptualized with the sustainability indicators in mind.

Baseline Alt. outperformed on 1 indicator.

Big-picture metrics of success as envisioned by the City: 18 sustainability indicators.
Baseline vs. Hidden Falls Headwaters: Findings

The Hidden Falls Headwaters alternative best supports sustainable redevelopment and the protection of water resources.

- Doubles the overall benefit-to-cost ratio over 25 years
- Reduces unit cost to manage stormwater by 40%
- Better on 17 of 18 sustainability indicators
- Nearly 75% more effective in protecting Hidden Falls downstream
- More successful in mitigating urban heat island effects and reducing air impacts
- Reduces energy and materials necessary by 32%
Baseline vs. Hidden Falls Headwaters: Tradeoffs

- 6 acres of 135-acre site required for green infrastructure
- Runoff from adjacent neighborhood(s) will need to be routed to the Hidden Falls Headwaters
- Green infrastructure demands greater operation and maintenance expense
- Additional policy support required because Hidden Falls Headwaters reflects above-standard conditions
Recommendations

- Use *centralized* Hidden Falls Headwaters approach to stormwater infrastructure
- Achieve pre-settlement discharge rates
- Cost-benefit ratio for stormwater design should not be less than 0.9
Implementation Road map

- Concept refinement
- Conceptual design development
- Zoning master plan

- Preliminary/schematic design development
- Detailed design & construction documents
- Construction
Thank you! Questions?

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Iron-Enhanced Check Dams for Capturing Phosphorus in Runoff

Poornima Natarajan
John S. Gulliver
University of Minnesota

Barbara Loida, Nick Olson, David Bauer,
James Michael, Scot Way
Minnesota Department of Transportation

Kristine Giga and Ryan Johnson
City of Roseville
Roadside Swales/Drainage Ditches

- Convey, infiltrate stormwater runoff
- Filter out solids and associated pollutants
- Dissolved pollutant capture – low; by volume reduction

**Dissolved phosphorus**
- ~45% total P load in runoff
  
  (Maestre and Pitt 2005; Kayhanian et al. 2012)
- Bioavailable
- Treatment with engineered media
  - Not accounted for in typical design of swales

---


Iron-Enhanced Sand Filtration (IESF) for Stormwater Treatment

- Sand filter containing iron filings/shavings
  - Specifically for dissolved phosphorus capture

- Laboratory research and modeling (Erickson et al. 2006, 2012)
  - In media w/ 5% iron (by wt), 4.8 mg P retained/g Fe

- Current Application: Pond-perimeter filter trenches
  - Vertical flow filtration

Iron-Enhanced Check Dam

- Incorporate iron-enhanced sand filter as an “insert” in a check dam

Applications/Advantages:
- Relatively inexpensive
- Installation in limited right-of-way, poor drainage soils

“Cleaner” runoff
Objectives and Tasks

Design, install, and assess iron-enhanced check dams for dissolved phosphorus capture in swales

• Design development
  – Laboratory tests
  – Full-scale design

• Construction
  – MnDOT and City of Roseville Swales

• Performance Assessment
  – Field monitoring and field testing
    • Season 1 (2015)
Design Development

• Laboratory prototype
  – Flume tests
    • C-33 sand-iron filings media
    • Steel wool media
  • Re-design w/ coarser sand-iron media
    – Sand ($D_{50} = 1.18$ mm)
    – Column tests (92.5% Sand - 7.5% Iron)
      • $K_{sat} = 0.046$ cm/s (79 in/hr)
    – Two designs for MnDOT and City of Roseville swales


Design #1: Stillwater Check Dam

- **Filter insert**
  - Depth = 0.38 m (15 in.)
  - Height = 0.61 m (24 in.)

Stillwater, Washington County, MN

**Not drawn to scale**
Performance Assessment: Field Monitoring

- **Sand-iron filter insert performance**
  - Storm events (Summer 2015)
  - Water levels, filter outflow (*Dupuit’s equation*)
  - Composite WQ Samples
    - Soluble reactive phosphorus (SRP)
  - P mass removed in treated volume
# 2015 Field Monitoring Results

## Stillwater Check Dam

*Phosphate = Soluble Reactive Phosphorus  
EMC = Event Mean Concentration*

<table>
<thead>
<tr>
<th>Date</th>
<th>Rainfall Depth (in)</th>
<th>Phosphate EMC in (µg/L)</th>
<th>Phosphate EMC out (µg/L)</th>
<th>Date</th>
<th>Rainfall Depth (in)</th>
<th>Phosphate EMC in (µg/L)</th>
<th>Phosphate EMC out (µg/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>5/03/15</td>
<td>0.45</td>
<td>666</td>
<td>352</td>
<td>6/13/15</td>
<td>0.70</td>
<td>168</td>
<td>98</td>
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<tr>
<td>5/10/15</td>
<td>0.36</td>
<td>885</td>
<td>504</td>
<td>6/17/15</td>
<td>1.00</td>
<td>114</td>
<td>74</td>
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<td>5/14/15</td>
<td>0.45</td>
<td>627</td>
<td>401</td>
<td>6/22/15</td>
<td>0.49</td>
<td>128</td>
<td>81</td>
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<td>5/17/15</td>
<td>0.40</td>
<td>561</td>
<td>302</td>
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<td>5/24/15</td>
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<td>6/03/15</td>
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<td>179</td>
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<td>6/11/15</td>
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<td>457</td>
<td>328</td>
<td>8/22/15</td>
<td>1.62</td>
<td>184</td>
<td>200</td>
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</tbody>
</table>
Volume Exceedance and Phosphate Mass Reduction

Stillwater Iron-Enhanced Check Dam Insert

2015 Cumulative Phosphate Mass Reduction = 42%
Design #2: City of Roseville Check Dam

Check dam site

Twin Lakes Pkwy

1.8 m L x 0.15 m W x 0.38 m H
Field Testing

- Water truck (~7600 L capacity)
- Phosphorus added to water
- ~2.5-hr tests
- Filter outflow @ 10-min (catch and weigh method)
- Grab water samples @10- or 20-min for [SRP]
- Water input rate, upstream head at check dam also monitored
  - Infiltration loss
- 3 tests in Summer 2015
Field Testing: Test #1 Results

Date              Test Scenario         Volume Input (m³/m²)*  Phosphate Cin (mean)  Phosphate Cout (mean)  Phosphate Massin  Total Mass Removal
Test #2 8/7/15    High head, high P input 0.25                320 µg/L              240 µg/L              0.936 g         26.7%
Test #3 8/14/15   Low head, high P input 0.22               330 µg/L              190 µg/L              0.464 g         42.2%

Upstream head at check dam = ~0.15 m (6 in)
Upstream swale basin area = 38 m²

Total Phosphate Mass Reduction = 49.7%
Iron-Enhanced Check Dam Inserts

- Reduce phosphate in runoff
  - 30 to 50% mass reduction
- In-series installation for greater P reduction
- Long-term performance and maintenance needs yet to be investigated
Challenges, Lessons, Guidelines

- Design and construction feasibility, weather delays
- Proper sealing (and width) to prevent leakage, flow bypass
- Alternate design with multiple filter socks
  - Site conditions, future maintenance, cost
  - Filter frame enclosure
- Quality of iron filings
Acknowledgements

Project Sponsors and Partners
• Minnesota Pollution Control Agency (US EPA 319 Grant)
• MN Department of Transportation
• City of Roseville
• Local Road Research Board

Project Support
• Prof. Peter Weiss, Valparaiso University
• St. Anthony Falls Laboratory (D. Christopher, C. Ellis, B. Erickson, A. Ketchmark)
• Undergraduate research assistants (D. Liddell, A. Poovey, T. Olsen, J. Pham)

Contact Information: Poornima Natarajan
pnataraj@umn.edu
Pump and Treat Iron Enhanced Stormwater Treatment

October 18, 2016

Karen Kill, BCWD Administrator
Ryan Fleming, EOR
Collaboration

• Brown’s Creek Watershed District
• City of Stillwater (also WCA LGU)
• MN DNR Waters
• Saint Anthony Falls Lab
• Neighborhood Residents
Site Selection - Location
System Components - Pump Harvest Pond
System Components - Lift Station Control Cabinet
System Components - Pump Upgrades

- Inline Magnetic Flow Meter
  - Accuracy within 1%
  - Reduced Monitoring Staff Time
- Automatic Pump Speed Controlled by Water Level
  - Scalable to Reduce Bypass During Higher Flow Events
- Remote Monitoring & Control via Web Interface
  - Reduced Staff Time for Routine Checks, Trigger Point Adjustment, Response to Pump Faults, Downloading of Data
Remote Operation
System Components - Pretreatment
System Components – Sand Filter

- **H₂O**: Water containing phosphorus and other pollutants is pumped into the filter from a nearby stream during rain events.
- **Fe**: The Iron-Enhanced Sand Filter contains iron filings that attract and remove phosphorus from the stream water.

- **IRON-ENHANCED SAND FILTER**
  - 6" WASHED SAND
  - 18" IRON-ENHANCED SAND
  - RUBBER LINER
  - DRAIN TILE PIPE

Clean water leaving the filter re-enters the stream and flows down to Lake McKusick.
System Components - Sand Filter
System Components – Sand Filter
Monitoring & Sampling

- Rainfall (2014-2016) ~ 107 inches
- 23 Sample Events:
  - Ave. Phosphorus IN 0.248 mg/L
  - Ave. Phosphorus OUT 0.033 mg/L
  - Range of influent concentration (0.06 to 0.390 mg/L)
  - 80-90% Consistent Removal
  - Phosphorus Removed ~ 55 Pounds (18 months of pump operation)

October 2014 samples at inlet and outlet
Project Costs

- Engineering & Construction = $298,462 (CWF Grant = $158,800)
- 2016 Upgrades = $13,473
- O&M, Electric, Remote Monitoring Subscription = $21,600/Yr
- Filter Media Replacement = $50,000 (10-18 Years)
- 25 Year Lifecycle ~ $650 - $950/lb of Phosphorus
Operation & Maintenance

• Activities
  • Annual Commission/Decommission
  • Routine Observation
  • Vegetation
  • Filter Surface Maintenance
  • Remote Monitoring
  • Harvest Pond Clean Out
  • Filter Media Replacement
Project Challenges

- Catchment Drainage Characterization
- Limited Pre-Project Monitoring
- Harvest Pond Sizing & Pump trigger sensitivity
- Sediment Loading to Harvest Pond
- Contractor Understanding of Project
- Unique Operating Criteria
- Shallow Groundwater
- Neighborhood Understanding of Project
- Heavy Spring 2014 Rainfall

2014 Spring Rainfall 12+ Inches
Questions?
Thank You
Multiple Benefits of Privately Shared Stormwater Systems:

From Conceptual Design to Construction

Water Resources Conference, October 18, 2016
INTRODUCTION:
TOWERSIDE DISTRICT STORMWATER

• Towerside Innovation District and the stormwater project site

• Planning and design process
TOWERSIDE INNOVATION DISTRICT LOCATION

Towerside, the MSP Innovation District (370 acres)

District Stormwater (9 acres)

Metro Transit Green Line LRT
TOWERSIDE DISTRICT STORMWATER PROJECT SITE

<table>
<thead>
<tr>
<th>Parcel Number</th>
<th>Owners</th>
</tr>
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<tbody>
<tr>
<td>1</td>
<td>Harlem Irving Companies</td>
</tr>
<tr>
<td>2</td>
<td>The Cornerstone Group</td>
</tr>
<tr>
<td>3</td>
<td>Aeon</td>
</tr>
<tr>
<td>4</td>
<td>Green Fourth Properties, LLC</td>
</tr>
</tbody>
</table>
TOWERSIDE DISTRICT STORMWATER PROJECT SITE
Planning Initiative

Shared Stacked Green Infrastructure

- Shared treatment systems
- Stacked land use
Integrated systems thinking:

- Box culvert conveyance pipes double as sidewalks or bench seating
- Walls of underground parking for water storage
- Water storage areas for District Energy heating and cooling
- Basin of the treatment area is park infrastructure
TOWERSIDE DISTRICT STORMWATER
2012–2013

Planning Initiative

Legend

- Planning Milestones
- Contract-Related Deadlines
- Capital Project Milestones

Green 4th Street Technical Study
Prospect North Partnership is Formed
Green Line Corridor Transit Centered Development Study
Planning Initiative

Gallons of Rain and Snowmelt Available Annually

• 4 million gallons generated on the 9 acre site
**TOWERSIDE DISTRICT STORMWATER**
**2014–2015**

**Planning Initiative**

- **2014**
  - District Stormwater Feasibility Study Begins
- **2015**
  - Landowner Easement Agreements Start
  - District Stormwater 30% Design Development Begins

**Legend**
- Planning Milestones
- Contract-Related Deadlines
- Capital Project Milestones
District Stormwater System

- Tributary area: 8–9 acres of brownfields redevelopment
- Four primary components:
  1. **Conveyance** from parcels to treatment
  2. **Treatment** to City of Minneapolis standard
  3. **Underground storage** sized for 1.1” off impervious (MIDS)
  4. **Reuse** system for irrigation and future industrial use
1. Conveyance

2. Treatment (filtration basins)

3. Underground Storage

4. Reuse System
Conveyance

1,600 lineal feet of pipe conveys stormwater from four parcels to district stormwater system.

Treatment Biofiltration

Two basins capture and treat runoff from 8–9 acres, cleaning to city standard.

Creation of a stormwater park.
STORMWATER COMPONENTS

Underground Storage

StormTrap system holds 207,000 gallons of filtered water for use by future development.

Reuse System

Reuse system delivers stormwater back to parcels for irrigation and possible industrial use. System online 2017.
Landowner Costs: ~$430,000
Planning, Design, Legal, and Engineering Services; Construction: Treatment and 50% Conveyance

MWMO Costs: ~$1,045,000
Planning, Design, Legal, and Engineering Services; Construction: Storage, Reuse and 50% Conveyance

TOTAL: ~$1,475,000

- Landowners pay all O&M
- MWMO manages system and O&M for five years, then transfers to landowners
District Management of Water

Estimated **15% cost savings** by managing stormwater in a district system.

Stormwater Feature as a Park

The biofiltration cell designed to act as a public **Stormwater Park**.
**District Management of Water**

Estimated **15% cost savings** by managing stormwater in a district system.

**Stormwater Feature as a Park**

The biofiltration cell designed to act as a public **Stormwater Park**.
District Management of Water

Estimated 15% cost savings by managing stormwater in a district system.

Stormwater Feature as a Park

The biofiltration cell designed to act as a public Stormwater Park.
• Scale is critical, regional treatment saves money (15%).

• Implementing stormwater on brownfields is challenging, but can be accomplished. Grants help.

• Legal surveys to ID easements and property boundaries/disputes should be performed early on.

• Patience is critical when working with so many stakeholders. Stakeholders are critical to implement district systems.
• District systems to manage stormwater on larger scale for lower cost.

• Public/private partnerships to develop new and innovative approaches to manage urban stormwater.

• Collaboration among multiple landowners to turn brownfields into Privately Owned Public Spaces (POPS), i.e. stormwater park.

• Residential and industrial stormwater reuse to attract water-dependent economic growth.
Thanks!

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URBAN SCHOOL RETROFITS: SENDING STORMWATER TO DETENTION

2016 MINNESOTA WATER RESOURCE CONFERENCE

NATE ZWONITZER
WATER RESOURCE PROJECT MANAGER
Urban School Retrofits

• Four case studies
• Design innovations
• Lessons learned
CASE STUDY 1: HARAMBEE ELEMENTARY

ROSEVILLE AREA SCHOOLS
Harambee Elementary

- 5 rain gardens
- 1.36 acres treated
- 85% reduction in Volume, TSS, and TP
- $100,000 for design and construction
- $88,000 covered by grants
Parking Lot Island Expansion
Parking Lot Island Expansion

Harambee Elementary
CASE STUDY 2:

TWIN CITIES GERMAN IMMERSION SCHOOL (TCGIS)

K-8 CHARTER SCHOOL, SAINT PAUL
TCGIS
TCGIS

- Enhanced underground treatment
- 4 Rain Gardens
- Porous Pave permeable play surfaces
- 3 Educational Signs
TCGIS

- 1.3 acres treated
- 90% reduction in Vol, TSS, and TP
- $190,000 for design and construction
- ~$50,000 covered by grants
Twin Cities German Immersion School
Porous Pave
PUTTING DOWN ROOTS

Rain gardens help reduce pollution in Como Lake. Here’s how:

It starts when polluted rainwater flows from streets into storm drains. Polluted rainwater usually drains directly to the lake. But not here. Curb openings let water flow into the garden’s layers of mulch and soil. Plant roots guide water deeper to seep slowly into the ground. The roots absorb pollution and take up some of the water to nourish the plants.

Why?

Polluted rainwater carries dirt, oil and trash into Como Lake when it flows from streets into storm drains. Rain gardens, stormwater planters and rock trenches on the side streets were built to clean polluted rainwater before it reaches lakes and rivers.
CASE STUDY 3:

GREAT RIVER SCHOOL

1-12 GRADE CHARTER MONTESSORI SCHOOL
SAINT PAUL
Great River School

- New Play Surface
- Underground Membrane Filtration
- Rainwater Harvesting for Irrigation
New Play Surface:

- Converted 0.17 acres of parking to turf
- Pavement left in place as cap
- Drain tile provides drainage for stability/filtration
Jellyfish Filter:

- Treats all parking areas onsite (0.5 ac.)
- Easy maintenance
- Removals
  - 99% Trash/Debris
  - 90% TSS
  - 60% TP
Rainwater Harvesting:

- 4,500 gallon cistern
- 7,700 SF of roof
- WISY Prefiltration, UV disinfection
- 45,000 gallons saved per year (70% of demand)
New Play Surface:
• Treats all parking areas onsite (ac.)
• Easy maintenance
• Removals
• 99% Trash/Debris
• 90% TSS
• 60% TP
Existing Conditions
Central High School

- 2.5 acres treated
- >90% reduction in Vol, TSS, and TP
- ~$500,000 for design and construction
- >$430,000 covered by grants
Pipe Gallery

Central High School
Central High School

CAPITOL REGION WATERSHED DISTRICT
Tree Trenches & Permeable Pavers

Central High School

CAPITOL REGION WATERSHED DISTRICT
Tree Trenches & Permeable Pavers

Central High School

CAPITOL REGION WATERSHED DISTRICT
Tree Trenches & Permeable Pavers

Central High School
Tree Trenches & Permeable Pavers

Central High School
Educational Signage

WHAT’S BENEATH YOUR FEET?

Underground rock trenches at Central High School help reduce pollution in the Mississippi River. Here’s how —

Polluted stormwater runoff from Central used to flow from rooftops, parking lots and sidewalks to storm drains and then the Mississippi River. The school installed underground pipes with thousands of holes (perforated) and buried them in rock-filled trenches. The rock trench can store 49,400 gallons of stormwater runoff from around campus where it can seep through the holes into the surrounding rock and soil instead of flowing to the river untreated.

Why?

Did you know that when it rains or snow melts, water carries trash, dirt, oil, pet waste, grass and leaves to the Mississippi River? Water that flows over hard surfaces is called runoff. Projects like this one at Central are essential to capture, clean and reduce runoff before it reaches nearby lakes and rivers. Saint Paul Public Schools completed this project in partnership with Capitol Region Watershed District.
Curriculum Integration

Central High School

BMP characteristics

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<thead>
<tr>
<th>Permeable Pavers</th>
<th>DA 3</th>
<th>DA 3B</th>
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<tr>
<td>Surface Area</td>
<td>1,196 ft²</td>
<td>449 ft²</td>
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<tr>
<td>Pavers - Height/Void Space</td>
<td>4 inches, 15% voids</td>
<td>4 inches, 15% voids</td>
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<tr>
<td>Pea Gravel - Height/Void Space</td>
<td>2 inches, 40% voids</td>
<td>2 inches, 40% voids</td>
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<tr>
<td>Quarry Stone (diameter ½ - 1 in) - Height/Void Space</td>
<td>4 inches, 40% voids</td>
<td>4 inches, 40% voids</td>
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<tr>
<td>Quarry Stone (diameter 1 ½ - 3 in) - Height/Void Space</td>
<td>24 inches, 40% voids</td>
<td>6 inches, 40% voids</td>
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<tr>
<td>Infiltration Rate of Subsoils</td>
<td>0.3 in/hr</td>
<td>0.3 in/hr</td>
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</table>

Tree Trenches - can be treated as permeable pavement, installed the same as pavers in drainage area 3, for the sake of hydrologic calculations

<table>
<thead>
<tr>
<th>Tree Trench #1</th>
<th>Tree Trench #2</th>
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<tbody>
<tr>
<td>Tree Box Surface Area</td>
<td>228 ft²</td>
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Lessons Learned

• Involve the right people EARLY
  – District office, school admin, teachers, parent committees
  – facilities management

• Consider education opportunities
  – New students every year
  – Sign locations, monitoring, BMP design

• Work with site constraints
  – School operations, facility maintenance, space, foot traffic

• Plan on securing grants/fundraising
Questions?

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