
ASCE – EWRI World Congress | June 7th, 2018
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Iron-Enhanced Sand Filters – 10,000 ft Overview

What IESFs Are

- Filtration BMP: Sand filter + Fe
- Oxidized Fe removes dissolved constituents, e.g., phosphate
- Primary IESF treatment mechanisms: filtration & sorption

Why we care: Many stakeholders, including MPCA

- MPCA: Mission & activities
  - Monitor environmental quality,
  - Provide technical & financial assistance
  - Enforce environmental regulations
- General Reasons: TMDLs, stormwater regs, water & stormwater mgmt
- Because we should!
IESF History - Stormwater

- **1980s**: WA - Lab tests for treating dissolved phosphorus in stormwater
- **1990s**: Lakemont Washington Filtration Facility¹
- **2009**: Maplewood Mall, MN: Barr Engineering for Ramsey Washington Metro Watershed District²
- **UMN/SAFL**: Completed several lab & field studies, advises, greatly helped expand IESF use³,⁴
- **Recent: Design & Implementation Developments**
  - Successes & Failures
  - Growing Numbers

- **MN Guidance**
  - MN Stormwater Manual (MPCA)
  - MIDS Calculator (MPCA)

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¹ King County, 1999
² City of Minneapolis, 2015
³ Erickson et al., 2012
⁴ Erickson et al., 2015
IESFs – MN Background (Recent History)

Minnesota Stormwater Manual

Design criteria for iron enhanced sand filter

Golden Lake Iron-Enhanced Sand Filter

The Rice Creek Watershed District (RCWD) partnered with the Anoka Conservation District (ACD) and the City of Blaine to install a new iron-enhanced sand filter (IESF) to treat polluted rainwater before it reaches Golden Lake. The IESF was awarded a Clean Water Fund grant from the Clean Water Fund, Legacy Amendment, and local matching funds provided by the RCWD and $24,440 from the City of Blaine. Construction will take place in August 2015.

Golden Lake is an impounded lake within a fully developed area of the Twin Cities, surrounded by residential land use and a local point of a city park. The IESF will achieve 90% of the phosphorus reduction required for Golden Lake to meet clean water quality standards, as identified in the TMDL study. In addition, the IESF was the most cost-effective project identified in the Golden Lake Subwatershed Stormwater Retrofit Analysis.

This project provides a highly cost-effective TMDL for reducing the negative impacts of stormwater runoff on water quality within Golden Lake, one of two strategies identified in the approved TMDL that will have the most impact. Collaboration among the Anoka Conservation District, the City of Blaine, and the Rice Creek Watershed District reflects the regional assistance and importance of this project.

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Case Studies

Monitoring and Maintenance of Phosphate Adsorbing Filters

Andrew J. Erickson; Peter T. Weiss, M.ASCE; and John S. Gulliver, F.ASCE

Abstract

Field installations of two iron-enhanced sand filters (IESFs), designed to remove phosphate and particulates from stormwater runoff, were monitored and maintained for 1–3 years. One application, a traditional IESF in an agricultural watershed, retained over 64% of the influent phosphate load, whereas the second, a
Iron Content\(^1\)

- **5-8% Fe (w/w)** of Fe-sand mixture (Erickson et al., 2012)
  - Assumes high surface area, ~90% elemental Fe filings
  - Lifespan & performance affected by variable Fe composition

Hydraulics\(^1\)

- **Clogging** = greatest O&M challenge
  - Poor drainage -> fouling or Fe release
- **2’-6’ head** often recommended
- Filter should **draw down** within 48h of storm completion
  - This is typical MN guidance, esp. important for IESFs
- **Minimize tailwater** to allow dryout
- **Underdrain** should be present, vent to atmosphere, be above ds high-water level

\(^1\) MN Stormwater Manual, 2017
IESFs - Design Tidbits

Vegetation

- IESFs mainly effect filtration & sorption, not volume reduction
  - Vegetation isn’t necessary, may impair function

Iron Depletion

- Potential signs that P binding capacity is depleted:\(^1,^2\)
  - Outflow TP consistently > 60-70 ppb
  - TP:Fe ratios in media > 5 mg P/ 1g Fe
    - During lifespan, several forms of P, other constituents will bind to Fe
    - Thus, TP:Fe analysis only yields approximate P binding capacity.

^1 Erickson et al., 2007
^2 Erickson et al., 2012
IESFs – Pros of High-Functioning Systems

**Good:**

- Removal of colloidal & dissolved contaminants
- Pollutant removal rates
- Retrofit for ponds, other BMPs
- For nutrient impairments
- Alternative when infiltration is infeasible
IESFs – Current Gaps & Limitations

Considerations:

- Relatively unexplored tech, limited P performance history or research
- May be most suited to urban areas, moderate sediment loads
- Lifespan limited by clogging, Fe loss, maintenance cycles
- Vegetative buildup/decomposition may reduce DO -> affect Fe -> fouling
- Head needed for treatment, drawdown
- Tailwater constraints may restrict siting
- Bed material will require disposal when depleted
- Limited water quantity control
Stormwater credits are tools for:

- Local authorities interested in incentivizing natural preservation, reducing urban runoff pollution
- Complying with permits, including antidegradation
- Meeting MIDS performance goal
- Meeting or complying with WQ objectives, including TMDL wasteload allocations (WLAs)

<table>
<thead>
<tr>
<th>BMP</th>
<th>TSS</th>
<th>TP</th>
<th>PP</th>
<th>DP</th>
<th>TN</th>
<th>Metals</th>
<th>Bact.</th>
<th>Hydrocarbons</th>
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<tbody>
<tr>
<td>Pond</td>
<td>85</td>
<td>50</td>
<td>91</td>
<td>0</td>
<td>30</td>
<td>70</td>
<td>60</td>
<td>80</td>
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<tr>
<td>Sand filter</td>
<td>85</td>
<td>50</td>
<td>91</td>
<td>0</td>
<td>35</td>
<td>50</td>
<td>80</td>
<td>80</td>
</tr>
<tr>
<td>IESF</td>
<td>85</td>
<td>77</td>
<td>91</td>
<td>60</td>
<td>35</td>
<td>50</td>
<td>80</td>
<td>80</td>
</tr>
<tr>
<td>Pond+IESF (est)</td>
<td>98</td>
<td>~85</td>
<td>99</td>
<td>60</td>
<td>55</td>
<td>85</td>
<td>92</td>
<td>96</td>
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</tbody>
</table>

1. MPCA-recommended IESF credits
IESFs - Crediting Approaches – MIDS Calculator

**BMP Properties: 1 - Sand filter**

<table>
<thead>
<tr>
<th>Watershed</th>
<th>BMP Summary</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Particulate P load from upstream BMPs: 0 lbs</td>
</tr>
<tr>
<td></td>
<td>Particulate P load reduction: 1.34 lbs</td>
</tr>
<tr>
<td></td>
<td>Particulate P load outflow: 0.24 lbs</td>
</tr>
<tr>
<td></td>
<td>Total percent annual Particulate P reduction: 85 %</td>
</tr>
</tbody>
</table>

**BMP Properties: Iron Enhanced Media**

**Summary Information:**
- Impervious area not routed to a BMP: 0 acres
- Pervious area not routed to a BMP: 0 acres
- Performance goal requirement: 5590 ft³
- Performance goal reduction achieved: ft³
- Percent TP reduction achieved: 74 %
IESFs: Research & Monitoring Background

- Promising DP performance in lab (>80%)\(^1\)
- Varying results in field\(^2\) & local experiences
- Desire among MN regulators & practitioners
  - Get ahead of potential issues
  - Understand successes and failures
  - Optimize designs
  - Support implementation

\(^{1}\) Erickson et al., 2012
\(^{2}\) Erickson et al., 2015
IESFs: MPCA Research & Monitoring, 2015-Present

- **Goal**: Collect multi-year field data from multiple IESFs to assess overall performance & influences
  - **Engage in partnerships** to ensure applicability, gain value

- **Design**
  - Field Monitoring of Existing IESFs
  - Hydrology
  - Chemistry – TP/DP, others as feasible, CECs

- **Local Partners & Projects**
  - City of Minneapolis, Mpls Board of Parks & Rec – 3 sites
  - Ramsey Washington Metro Watershed District – 2-ish sites
  - City of Prior Lake – 3 sites
  - Capitol Region Watershed District (CEC project) – 2 sites
## Projects Status To Date

<table>
<thead>
<tr>
<th>IESF Studies</th>
<th>Minneapolis</th>
<th>RWMWD</th>
<th>Prior Lake</th>
<th>CRWD – special study</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Sampling Status</strong></td>
<td>Complete</td>
<td>June 2018</td>
<td>June 2018 <em>(data not reported here)</em></td>
<td>Complete</td>
</tr>
<tr>
<td><strong>Sampling Period</strong></td>
<td>2015-2016</td>
<td>2016-Present</td>
<td>2017-Present</td>
<td>2016</td>
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<tr>
<td><strong># of IESFs</strong></td>
<td>2</td>
<td>2*</td>
<td>2, + 1 control</td>
<td>2</td>
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<tr>
<td><strong># of Sampling points</strong></td>
<td>4</td>
<td>7</td>
<td>8</td>
<td>4</td>
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<td><strong># of Events (approx.)</strong></td>
<td>50</td>
<td>40</td>
<td>20</td>
<td>6</td>
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<tr>
<td><strong># of Samples</strong></td>
<td>345</td>
<td>150</td>
<td>300 (est.)</td>
<td>40</td>
</tr>
<tr>
<td><strong>Analytes of Interest</strong></td>
<td>TP, DP, Fe, TSS</td>
<td>TP, DP, metals, Cl, TSS</td>
<td>TP, DP, metals, TSS</td>
<td>400 CECs, 50 bioassays, etc.</td>
</tr>
<tr>
<td><strong>IESF Notes</strong></td>
<td>In-line w/small res. storm sewer</td>
<td>Parking lot</td>
<td>3 stormwater ponds, 2 w/IESF bench filters</td>
<td>2 ponds with IESF bench filters</td>
</tr>
<tr>
<td><strong>Study notes</strong></td>
<td>All projects include watershed land use assessments, IESF details, precip, flow/level monitoring – In progress</td>
<td></td>
<td></td>
<td></td>
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</tbody>
</table>
## Preliminary Chemistry Results Analysis

<table>
<thead>
<tr>
<th># of Discrete Location-Events</th>
<th>TSS</th>
<th>TP</th>
<th>Ortho-PO$_4$</th>
<th>TDP</th>
<th>TKN</th>
<th>NO$_3$ N</th>
<th>Cl</th>
<th>Fe Diss.</th>
<th>Pb Diss.</th>
<th>Zn Tot.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>mg/L</td>
<td>ug/L</td>
<td>ug/L</td>
<td>mg/L</td>
<td>mg/L</td>
<td>mg/L</td>
<td>mg/L</td>
<td>ug/L</td>
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<td>ug/L</td>
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<tr>
<td>135</td>
<td>212</td>
<td>164</td>
<td>214</td>
<td>44</td>
<td>42</td>
<td>58</td>
<td>119</td>
<td>34</td>
<td>34</td>
<td></td>
</tr>
<tr>
<td>Detection Freq. (%)</td>
<td>100</td>
<td>100</td>
<td>72</td>
<td>82</td>
<td>93</td>
<td>66</td>
<td>98</td>
<td>53</td>
<td>76</td>
<td></td>
</tr>
<tr>
<td>Median Conc.</td>
<td>14</td>
<td>180</td>
<td>42</td>
<td>110</td>
<td>&lt;RL</td>
<td>0.27</td>
<td>1.3</td>
<td>414</td>
<td>0.56</td>
<td>12</td>
</tr>
<tr>
<td>Max. Conc.</td>
<td>1300</td>
<td>3400</td>
<td>1000</td>
<td>1400</td>
<td>5.7</td>
<td>1.4</td>
<td>310</td>
<td>8300</td>
<td>3.2</td>
<td>85</td>
</tr>
</tbody>
</table>

**Notes:** Not all sites represented; Mass loading analysis is ongoing.
Phosphorus and TSS – IESF Inlets vs. Outlets

Non-Parametric Mixed Linear Effect Model:
• Significant differences in IESF inlet vs. IESF outlet concentrations of TP, OP, TSS
• Respective p-values: <0.001, 0.010)

TDP Notes:
• QA questions for some TDP data
• Currently, TDP results not directly comparable to OP & TP as fewer TDP samples were analyzed

General Stats Notes:
• These are preliminary results
• Further analysis to focus on watershed & BMP factors, hydrology, mass loads
# Preliminary Chemistry Results Analysis

<table>
<thead>
<tr>
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<th>TSS (mg/L)</th>
<th>TP (ug/L)</th>
<th>Ortho-PO₄ (ug/L)</th>
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<th>TKN (mg/L)</th>
<th>NO₃ (mg/L)</th>
<th>Cl (mg/L)</th>
<th>Fe Diss. (ug/L)</th>
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<tr>
<td><strong># Discrete Events</strong></td>
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<td>1.3</td>
<td>414</td>
<td>0.56</td>
<td>12</td>
</tr>
<tr>
<td><strong>Median - Inlets</strong></td>
<td>45</td>
<td>230</td>
<td>69</td>
<td>110</td>
<td>&lt;RL</td>
<td>0.16</td>
<td>1.2</td>
<td>720</td>
<td>0.29</td>
<td>33</td>
</tr>
<tr>
<td><strong>Median - Outlets</strong></td>
<td>3.0</td>
<td>140</td>
<td>29</td>
<td>120</td>
<td>&lt;RL</td>
<td>0.28</td>
<td>1.4</td>
<td>210</td>
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<td>3.6</td>
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<td><strong>Max. Conc.</strong></td>
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<td>3400</td>
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<td>5.7</td>
<td>1.4</td>
<td>310</td>
<td>8300</td>
<td>3.2</td>
<td>85</td>
</tr>
</tbody>
</table>
IESFs: Why Should We Care?

- Many urban waters are nutrient-impaired
- Can be hard to meet TMDL nutrient wasteload allocations for stormwater without removing dissolved P
- We need a good toolbox. This includes:
  - Understanding various influences on performance & longevity
    - Configurations, media composition, other amendments
    - Biogeochemistry – macro and micro
    - Contributing drainage
    - Best practices for routine and non-routine maintenance
CECs that were detected in >25% of stormwater samples
<table>
<thead>
<tr>
<th>Concentration (mg/L)</th>
<th>Concentration (ng/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td></td>
</tr>
<tr>
<td>20</td>
<td></td>
</tr>
</tbody>
</table>

### Stats:

- IESF-Out < IESF-In

### Codes:

- #: IESF-Out < Pipe but not IESF-In
Next Steps

- **Journal articles in review for CECs and daphnia/fathead minnow bioassays**
  - *Water Research* (CECs) & *Environmental Science & Technology* (bioassays)
  - RNA-omics & *in vitro* bioassay manuscript in development

- **IESF dataset completion & analysis**
  - Hydrology & watershed parameters
  - Multivariate analysis
  - Characterize IESF performance in terms of loads, concentrations, and their influences
  - Include additional available IESF monitoring data from other MN sites
  - Develop MPCA report, MN Stormwater Manual content, research article
  - Update MPCA guidance

- **And onward & upward..**
Acknowledgements

- **IESF Project Partners**
  - City of Minneapolis & Minneapolis Board of Parks & Recreation
  - Ramsey Washington Metropolitan Watershed District
  - City of Prior Lake
  - Capitol Region Watershed District & City of St. Paul
  - St. Cloud State University
  - USGS – Mounds View office
  - University of St. Thomas
  - MPCA & MPCA staff partners

- **State of Minnesota: Clean Water, Land, and Legacy Fund**

- **Local funding sources through project partners**

- **Many others**
Selected References

- **County, K., 1998.** Lake Sammamish Water Quality Management Project, Final Report. *King County Department of Natural Resources, Seattle, WA.*


Questions?

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