Treating Industrial Stormwater: Evaluation of Unit Operations and Treatment Trains

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High-Level Overview of Industrial Stormwater Permits

- Under CWA, effluent limits must be established to meet state-determined water quality standards.
  - State water quality standards include designated uses, which identify the uses or goals of each water body or segment (such as aquatic life, water supply, and recreation), and numeric or narrative criteria that will protect or restore the designated use.
- Technology-based effluent limits (TBELs) are applied through nationally developed effluent limitation guidelines (ELGs) and based on best applicable technology.
- Water-quality-based effluent limits (WQBELs) are established to meet the designated use objectives of individual receiving waters, and are often based on ambient water quality criteria.

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Study Description

- Three types of treatment technologies:
  - Sedimentation systems (proprietary hydrodynamic separators, dry detention ponds, sedimentation tanks)
  - Media filtration systems
  - Coagulation-flocculation system
- Sources of Data: multiple research projects on industrial sites and BMP Database studies on industrial sites.

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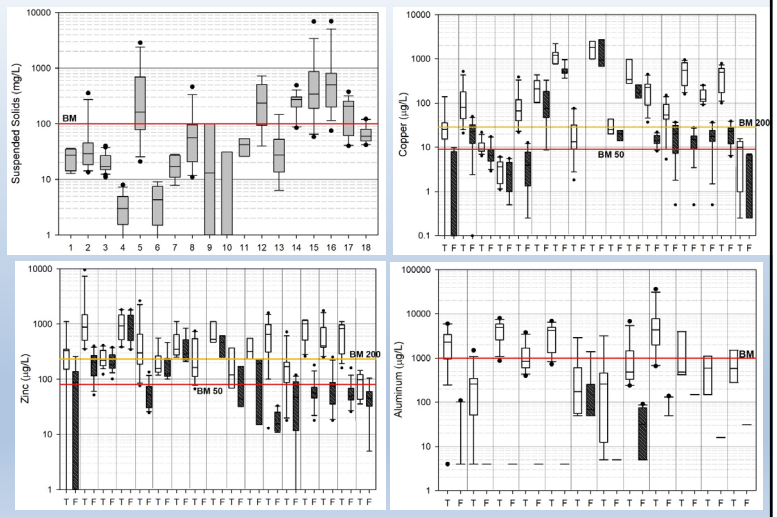
INFLUENTS COMPARED TO BENCHMARK VALUES



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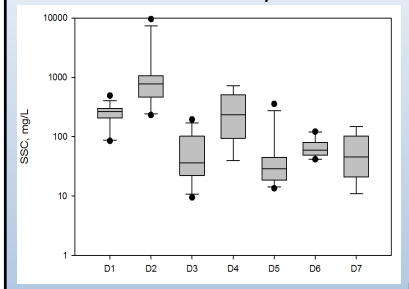
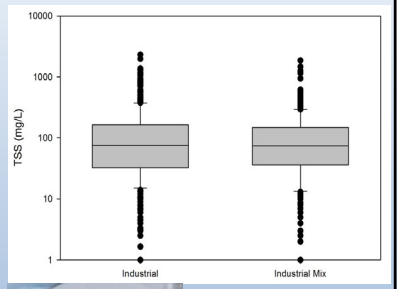
Influent Characterization

This Study



National Stormwater Quality Database



- TSS (NSQD) = 60 – 100% of SSC depending on PSD in runoff
- This study – 3 concentration categories (median concentrations):
  - High = 900 mg/L
  - Medium = 300 – 500 mg/L
  - Low = 50 – 100 mg/L (NSQD MEDIAN)

Filter pad from dirtiest site runoff – High SSC concentration.

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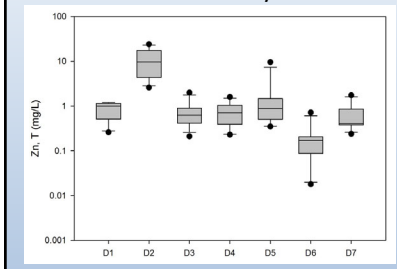
Influent Characterization

This Study



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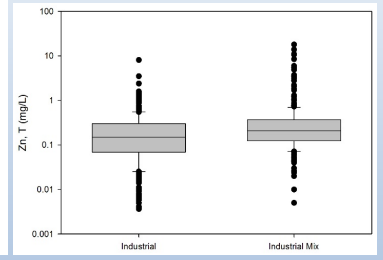

- For many metals, the study sites had total metals' concentrations (aluminum, lead, copper, iron, zinc) that were generally 2 – 10 times higher than the NSQD median concentrations. Filtered concentrations were approximately the same as the NSQD industrial filtered concentrations.
- For most sites, the median site concentration equaled the 90th percentile concentration in NSQD for zinc (similar for other metals).

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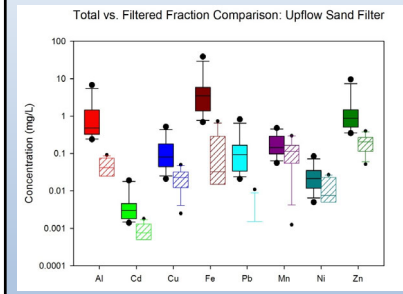
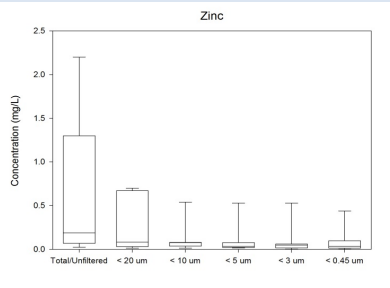
Understanding the Influent: Particle Size Association of Metals





- For those samples where size fractionation was performed, metals often were associated with larger particles in the runoff.
- Not commonly seen in "generic" urban runoff where metals associate with smaller particles, but associations with larger particles improve sedimentation effectiveness.

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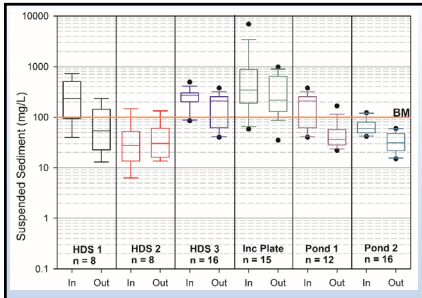
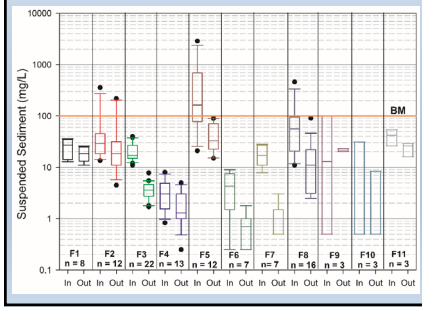
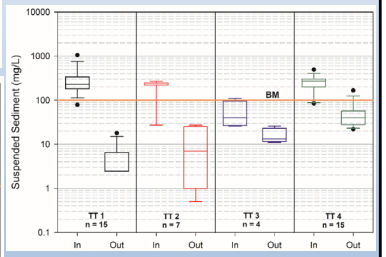




Suspended Sediment



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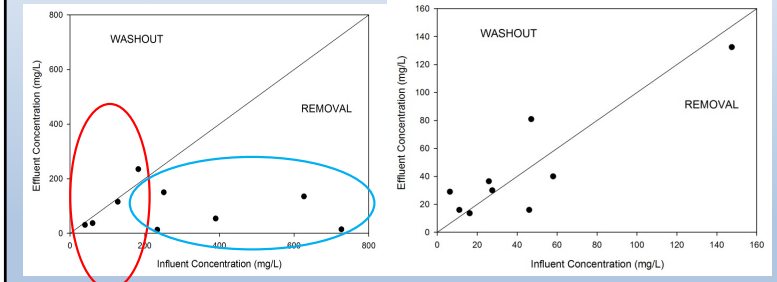
Individual Treatment System Performance for Suspended Sediment: Hydrodynamic Separators

HDS 1: Average flow rates < 10 – 20% of manufacturer sizing recommendation for all storms

HDS 2: Average flow rates near manufacturer sizing recommendation for most storms



- Concentration range same as HDS 2 (similar removals)
- Higher concentrations, better removals because of lower flow rates and particle interactions

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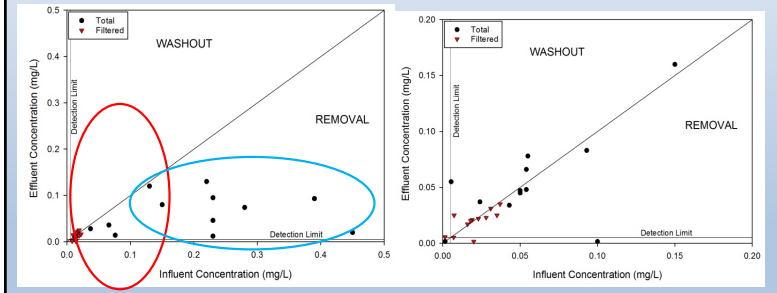
Individual Treatment System Performance for Copper: Hydrodynamic Separators

HDS 1: Average flow rates < 10 – 20% of manufacturer sizing recommendation for all storms

HDS 2: Average flow rates near manufacturer sizing recommendation for most storms



- Concentration range same as HDS 2 (similar removals)
- Higher concentrations, better removals because of lower flow rates, association with settleable solids, and particle interactions

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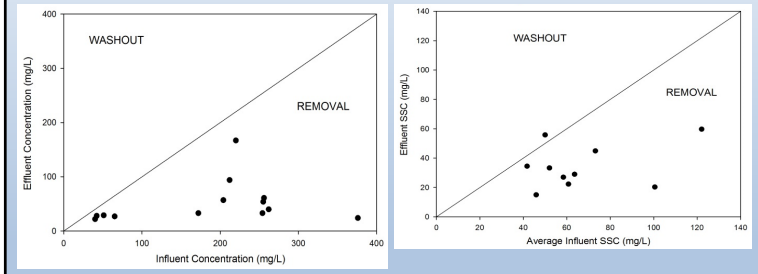
Individual Treatment System Performance for Suspended Sediment: Dry Detention Ponds

Pond 1: 4.81% of Drainage Area

Pond 2: 0.73% of Drainage Area



- Increasing pond size relative to drainage area reduces the surface overflow rate (SOR) SOR = Runoff Rate/Pond Surface Area.
- Reduced SOR reduces size of particle that can be settled effectively

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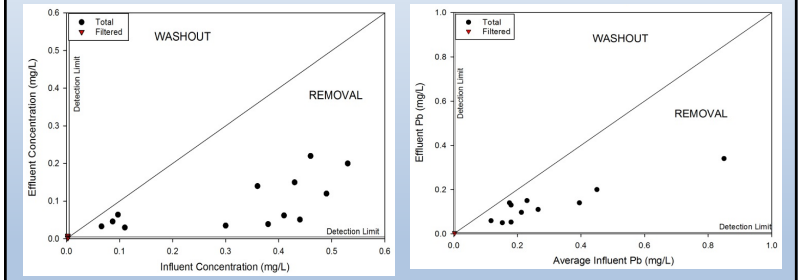
Individual Treatment System Performance for Lead: Dry Detention Ponds

Pond 1: 4.81% of Drainage Area

Pond 2: 0.73% of Drainage Area



- Increasing pond size relative to drainage area reduces the surface overflow rate (SOR).
- Reduced SOR reduces size of particle that can be settled effectively
- However, both ponds are effective at higher concentration because of large-particle associations (most metals associated with particles greater than 20 µm).

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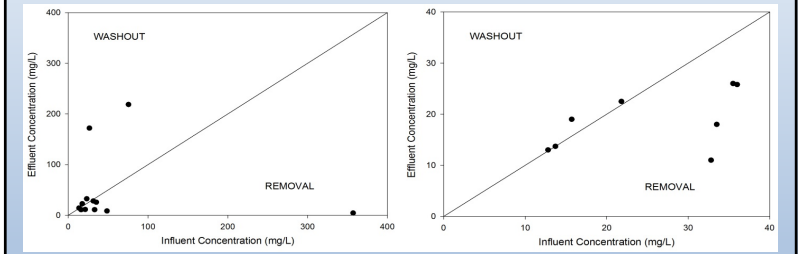
Individual Treatment System Performance for Suspended Sediment: Media Filters

Filter 1: Carbon-Zeolite Media

Filter 2: Upflow Sand



- Filter 2 influent concentrations equal to the lower influent concentrations in Filter 1 with similar performance for most storm events. "Hard to clean up clean water."
- Sand usually is very good at suspended sediment removal. These results potentially could be a result of bed expansion to pore sizes similar to that in carbon and zeolite media.

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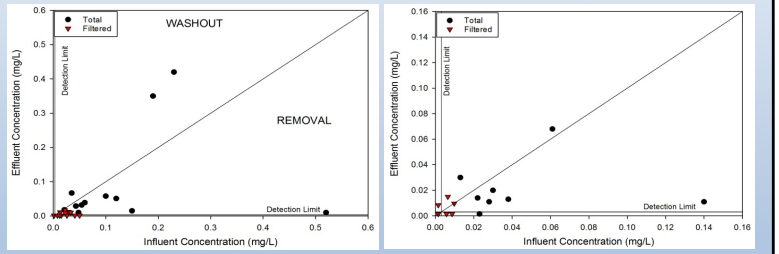
Individual Treatment System Performance for Copper: Media Filters

Filter 1: Carbon-Zeolite Media

Filter 2: Upflow Sand



- Filter 2 influent concentrations equal to the lower influent concentrations in Filter 1 with similar performance for most storm events. "Hard to clean up clean water."
- The performance may be a function of copper association with solids that are too small to be physically trapped. Chemical reasons exist why zeolite may not work well at low concentrations.

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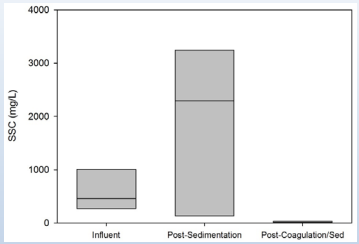
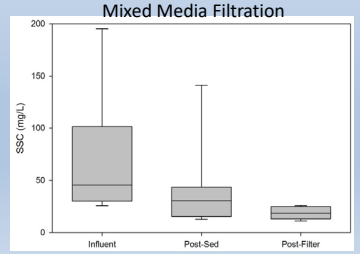
Treatment Train Performance for Suspended Sediment

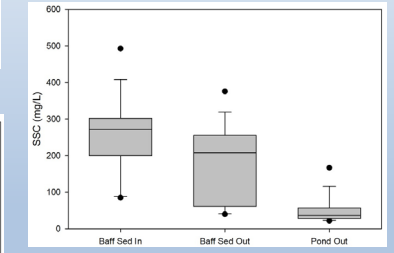
Treatment Train: Sedimentation → Coagulation-Flocculation/Sedimentation



Treatment Train: Sedimentation → Mixed Media Filtration



Treatment Train: Sedimentation → Dry Detention Pond



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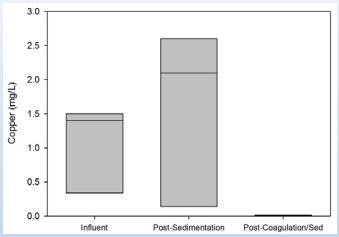
Treatment Train Performance for Copper

Treatment Train: Sedimentation → Coagulation-Flocculation/Sedimentation



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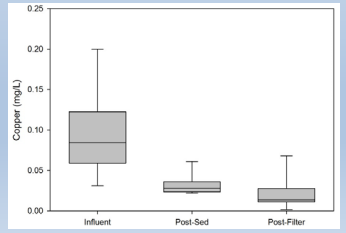

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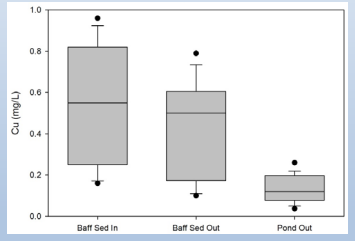

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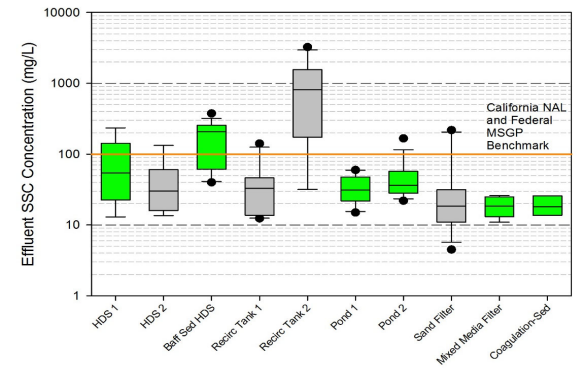
Meeting Benchmarks: Suspended Sediment



- Green boxes are statistically significant removals (but may not be 80%).
- Gray boxes are not statistically significant.
- TSS concentrations ≤ SSC concentrations, so meeting benchmarks with SSC measurements should ensure that the TSS measurements meet the benchmark.

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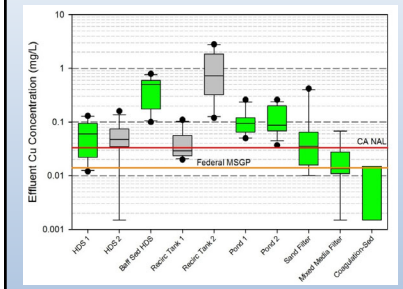
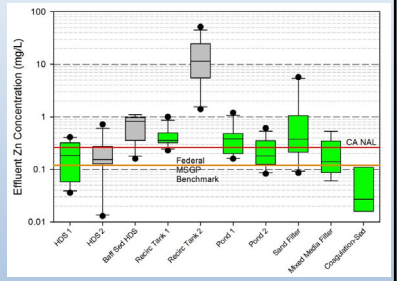
Meeting Benchmarks: Copper (left) and Zinc (right)





- Federal metals MSGP benchmarks used in this analysis based on 100 mg/L hardness (benchmark increases as hardness increases).
- While many systems had significantly significant removals, only coagulation system was able to meet benchmark for metals.
- Slow filtration operated in downflow mode has been successful in other applications. Filter operation may need adjustment to reduce flow rate through the filters.

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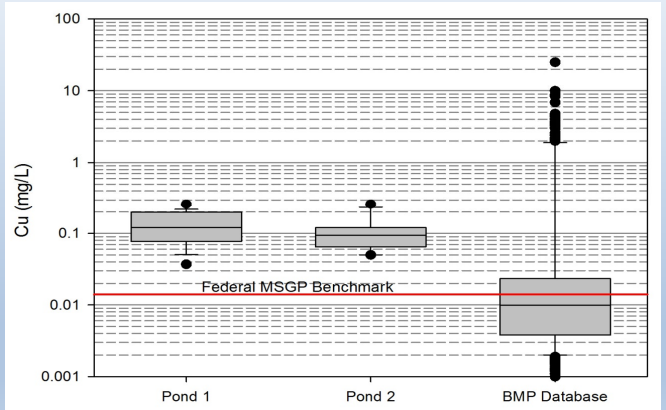
Comparison to International BMP Database and Federal MSGP Benchmark: Copper and Detention Ponds



- Outflow concentrations were between the 75th and 90th percentile of BMP Database values.

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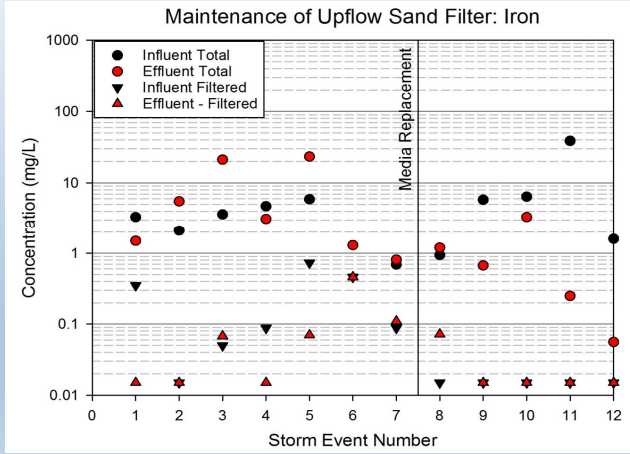
Impact of Maintenance



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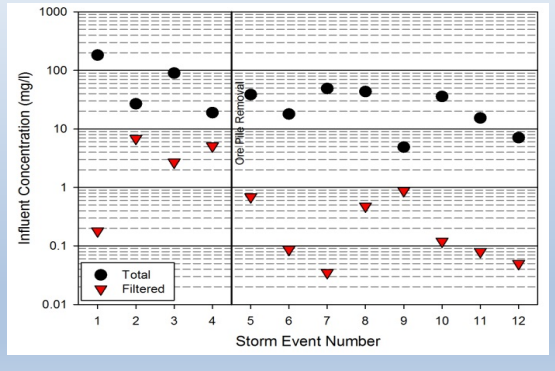
Impact of Site Operations: Impact of Iron Ore Removal on Iron Stormwater Concentrations Pre-treatment



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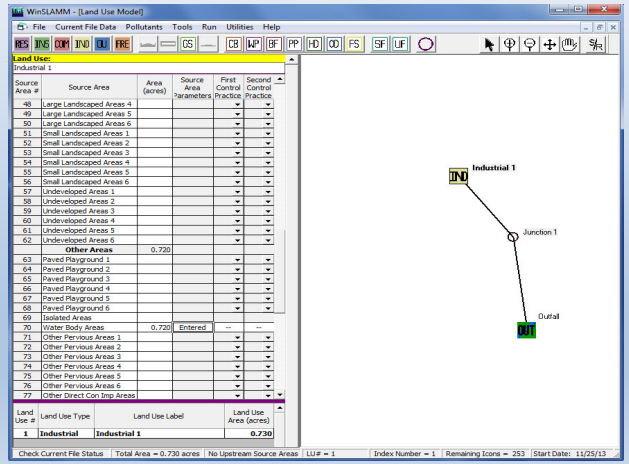
WinSLAMM: Primary Model Screen

(describe land uses and connect drainage system)



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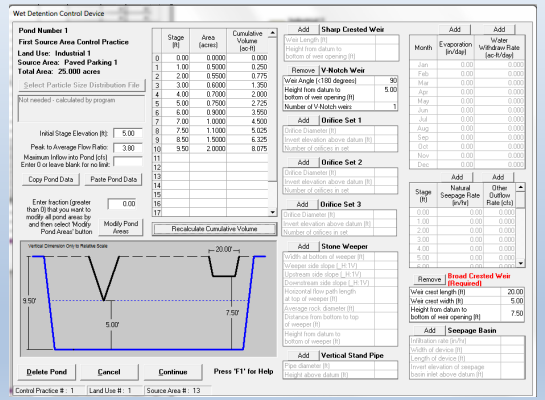
WinSLAMM Pond Entry Screen



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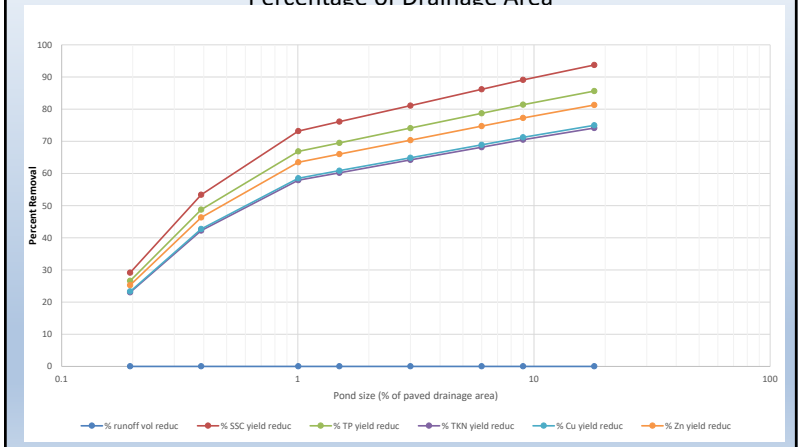
Example WinSLAMM Production Function:

Wet Detention Ponds Percent Removal vs. Pond Size as Percentage of Drainage Area



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Findings and Recommendations

- Every volunteer site implemented good housekeeping practices and, during the course of the study, two covered/removed stormwater sources. The impact was visible on runoff quality.
- Sedimentation systems were effective at reducing concentrations of sediment and metals, but the pond size needed to be around 5% of the drainage area to be effective. This applies to underground detention systems also.
- HDS systems performed surprisingly well when they were oversized (comparing estimated flow rates on site to manufacturer suggested operational flow rates). These reduced flow rates compared to sizing criteria resulted in reduced SORs and improved sedimentation.
- Filtration units should be operated in the range of slow sand filters to be effective. Contact time is required for pollutant removal to the lower levels suggested by the federal MSGP permit. Media size affects pore size. Pore size affects sediment and pollutant trapping. (If operated in upflow mode, filtration performance may be affected by bed expansion).

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Findings and Recommendations

- Treatment trains are recommended because small sedimentation systems/hydrodynamic separators can protect the operation of the final treatment process and reduce time between maintenance of the final treatment step. Many HDS proprietary units have been designed for easy cleanout.
- Treatment trains are straightforward in their modeling in WinSLAMM and performance can be predicted of treatment devices in series.
- WinSLAMM has been calibrated using the data generated in this study. WinSLAMM can be used by site owners and consultants to predict the effectiveness of various treatment practices, including good housekeeping practices of street sweeping and source removal/covering.
- WinSLAMM can be used to develop performance functions that can relate design information (such as the ratio of treatment device surface area to the drainage area) to anticipated performance.

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