Plants for Stormwater Pollution Removal

Greenhouse Research and Field-Study at Green Meadows Subdivision
Logan, UT

Utah Water Research Laboratory, USU

Introduction
Greenhouse
Green Meadows
Cost Savings

Presentation Outline
Introduction

Protecting Stormwater

- Much of the stormwater protection in Cache Valley is done with respect to prevention of TSS contamination during construction activities.

- Preventing contamination of stormwater from construction activities is critical, but stormwater can still be highly polluted.
Some plant species remove more N and/or P from runoff than other species.

Harvesting plant material can remove N and/or P from the site and keep it from entering downstream water bodies.

Hypotheses

Greenhouse Experiment
Method Diagram

- **Initial Flush Solution** (represents 8.3% of the total volume)

- **Drip Irrigation** 0.95 L/hr for 14 hr

- **Vegetation** (7 species)

- **Soil mixture** (50% sand & 50% Kidman sandy loam)

- **Composite Effluent** (volume recorded)

- **Sample analyzed** (begin, mid, end of growing season)

---

**Sample Analysis**

- **Initial Flush concentration**:
  - TP = 7.2 mg/L
  - TN = 48.2 mg/L
  - Cu = 482 µg/L
  - Pb = 1204 µg/L
  - Zn = 3251 µg/L

- **Event Mean concentration**:
  - TP = 0.6 mg/L
  - TN = 4.0 mg/L
  - Cu = 40 µg/L
  - Pb = 100 µg/L
  - Zn = 270 µg/L

- **Event Total Load**:
  - TP = 8.67 mg
  - TN = 57.8 mg
  - Cu = 578 µg
  - Pb = 1445 µg
  - Zn = 3901 µg

---

**Vegetation Species**

- Common Reed
- Cattail
- Soft-stem Bulrush
- Hard-stem Bulrush
- Sedge A
- Sedge B
- Sunflower
- Controls
Harvest

- Harvest of Above and Below Ground plant material occurred after 6 months of growth
- Plant material weighed, dried, ground and analyzed for N&P and metals

<table>
<thead>
<tr>
<th>Plant Species</th>
<th>Event Total Load</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>TP = 8.67 mg</td>
</tr>
<tr>
<td></td>
<td>TN = 57.8 mg</td>
</tr>
<tr>
<td>Sedge 1</td>
<td>Cu = 578 µg</td>
</tr>
<tr>
<td>Common Reed</td>
<td>Pb = 1445 µg</td>
</tr>
<tr>
<td>Sedge 2</td>
<td>Zn = 3901 µg</td>
</tr>
<tr>
<td>Soft-stem Bulrush</td>
<td>Sunflower Control</td>
</tr>
<tr>
<td>Hard-stem Bulrush</td>
<td></td>
</tr>
<tr>
<td>Broadleaf Cattail</td>
<td></td>
</tr>
</tbody>
</table>

Mean values with 95% C.I.
Planted samples have lower TDN & TDP mass discharge than controls and sunflower*

Mean values with 95% C.I.

**Greenhouse**

**TDN mass discharge**

Increased biomass yields lower N & P mass discharge in effluent water
There is significantly more below ground (root) mass than above ground (leaf) mass.

*Only the above ground mass can be harvested.*
Greenhouse

Total P in Above Ground Biomass

Mass In:
32 rain events * 14.45 L
* 0.6 mg/L
= 277 mg P

Common Reed removes the most P in the above ground material.

Error bars represent 95% C.I.

Greenhouse

Total N in Above Ground Biomass

Mass In:
32 rain events * 14.45 L
* 4 mg/L
= 1,850 mg N

Common Reed and Sedges remove more N mass than the other species

Error bars represent 95% C.I.
Green Meadows Field Site

[Map of Green Meadows Field Site]

Notes:
- The site is the detention basin on the south side of 600 South.
Naturally seeded treatment had visually more growth, yet there is no significant difference in biomass production among treatments.
**Field Site**

**Total P in Above Ground Biomass**

Sunflower and Control show a significantly higher P removal than Sedge and Cattail.

- Sunflower: 31.49
- Control (Naturally Seeded): 1.49

Error bars represent 95% C.I.

---

**Field Site**

**Total N in Above Ground Biomass**

There is no significant difference in N removal among the treatments.

- Sunflower: 15.7
- Control (Naturally Seeded): 30.3

Error bars represent 95% C.I.
Cost Savings

15' x 5' bay

Typical BMP = 3% of developed land (1,900 m² vegetated area)
Money saved by avoiding Chemical N&P removal

Control (naturally seeded) treatment produces the greatest N & P Removal cost savings and Compost cost benefits during the first growing season.
## Basin Wide

Money saved by avoiding Chemical N&P removal

### Kilograms of Hazardous materials Reduced (by biomass only)

<table>
<thead>
<tr>
<th>P2 Efforts (for first growing season of Field Site Study)</th>
<th>Dry Biomass Production (kg)</th>
<th>Pollutant Removed (kg)</th>
<th>Total (kg)</th>
<th>Dollars Saved</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vegetative Stormwater Detention Basins (based on Field Site data)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Basin Wide (1.9E6 m^2)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Species</th>
<th>Dry Biomass Production</th>
<th>Pollutant Removed</th>
<th>Total</th>
<th>Dollars Saved</th>
</tr>
</thead>
<tbody>
<tr>
<td>C - Sedge B (Carex microptera)</td>
<td>50334.7</td>
<td>652 N 93 P</td>
<td>745.4</td>
<td>$127,905 N&amp;P Removal Compost</td>
</tr>
<tr>
<td>H - Sunflower (Helianthus maximilian)</td>
<td>92378.8</td>
<td>482 N 245 P</td>
<td>726.5</td>
<td>$124,670 N&amp;P Removal Compost</td>
</tr>
<tr>
<td>T - Broadleaf Cattail (Typha latifolia)</td>
<td>65691.1</td>
<td>392 N 48 P</td>
<td>439.2</td>
<td>$75,362 N&amp;P Removal Compost</td>
</tr>
<tr>
<td>X - Control (Naturally Seeded)</td>
<td>425723.9</td>
<td>8022.2 N 800.2 P</td>
<td>8822.5</td>
<td>$1,513,937 N&amp;P Removal Compost</td>
</tr>
</tbody>
</table>

### Biomass Images

- **Sedges**
  - July 11, 2011
  - June 12, 2012

- **Cattails**

  - Naturally Seeded
Preliminary Conclusions

- Some Plants (sedge and sunflower) have higher concentrations in their biomass and are better at removing N and/or P than others.

- Biomass production is a key factor!

- Proposed site design parameters for BMPs:
  - Plant and maintain more vegetation!
  - Irrigate BMPs to promote growth of desired species for desired pollutant removal
  - Harvest vegetation and remove off-site before leaves begin to shoot nutrients back into their roots
Next Steps

Green Meadows:

- Collect more influent data to compare to EPA estimates
- Collect and analyze 2nd year plant data
- Harvest in mid season to promote greater biomass growth and analyze mid-season vs. end of season harvest results.

Questions?

Funded by: Utah Mineral Lease Fund
In kind matching: Logan City

Special THANKS to:

Dr. R. R. Dupont  Bill Young
J. McLean           Jed Al-Imari
A. Goodwin         T. Hammer
A. Restad          T. Guy
A. Lewis           A. Abu-Ramaileh

Plants make a difference?
Event Mean Concentration Comparison

**Greenhouse**
- Event Mean conc: TP = 0.6 mg/L
  - TN = 4.0 mg/L
  - Cu = 40 µg/L
  - Pb = 100 µg/L
  - Zn = 270 µg/L

**Field Site**
- Event Mean conc: TDP ≈ 0.105 mg/L
  - TDN ≈ 1.84 mg/L
  - Cu ≈ 8.9 µg/L
  - Pb = BDL
  - Zn ≈ 92.5 µg/L

Initial Flush conc:
- TP = 0.25 mg/L
- TN = 4.05 mg/L
- Cu = 8.91 µg/L
- Pb = BDL
- Zn = 164.5 µg/L

**Total P in Above Ground biomass**
- Error bars represent 95% C.I.
- Common Reed removes the most P in the above ground material

```
Mass In:
32 rain events * 14.45 L
* 0.6 mg/L
= 277 mg P
```
Total N in Above Ground Plant biomass

Error bars represent 95% C.I.

<table>
<thead>
<tr>
<th>Plant</th>
<th>Total N (mg)</th>
<th>Error bars</th>
</tr>
</thead>
<tbody>
<tr>
<td>Common Reed</td>
<td>6.6 mg</td>
<td></td>
</tr>
<tr>
<td>Broadleaf Cattail</td>
<td>7.9 mg</td>
<td></td>
</tr>
<tr>
<td>Soft-stem Bullrush</td>
<td>10.3 mg</td>
<td></td>
</tr>
<tr>
<td>Hard-stem Bullrush</td>
<td>9.8 mg</td>
<td></td>
</tr>
<tr>
<td>Sedge 1</td>
<td>12.5 mg</td>
<td></td>
</tr>
<tr>
<td>Sedge 2</td>
<td>12.6 mg</td>
<td></td>
</tr>
<tr>
<td>Sunflower</td>
<td>15.4 mg</td>
<td></td>
</tr>
</tbody>
</table>

Greenhouse

TP removed by biomass

Error bars represent 95% C.I.

<table>
<thead>
<tr>
<th>Plant</th>
<th>mg P</th>
<th>Sedge</th>
<th>Sunflower</th>
<th>Cattail</th>
</tr>
</thead>
<tbody>
<tr>
<td>Field Site</td>
<td></td>
<td>1.91</td>
<td>2.82</td>
<td>0.74</td>
</tr>
<tr>
<td>Greenhouse</td>
<td></td>
<td>1.96</td>
<td>1.19</td>
<td>1.08</td>
</tr>
</tbody>
</table>
Stormwater in Utah

- Utah has 2nd highest population growth in nation
- Large increases in P and N discharged into downstream water bodies from untreated stormwater runoff

<table>
<thead>
<tr>
<th>mg P g plant^-1</th>
<th>Sedge</th>
<th>Sunflower</th>
<th>Cattail</th>
</tr>
</thead>
<tbody>
<tr>
<td>Field Site</td>
<td>17.65</td>
<td>5.72</td>
<td>7.29</td>
</tr>
<tr>
<td>Greenhouse</td>
<td>12.55</td>
<td>15.4</td>
<td>7.9</td>
</tr>
</tbody>
</table>
**Stormwater in Utah**

- Cutler Reservoir is included in Utah’s “Impaired Waters” list and is required to be part of Utah’s TMDL process (Wilbur 2009)
- Mean seasonal total P concentrations are limited to 0.075 mg/L at Cutler Dam outfall (UDEQ, 2009)

**Protecting Stormwater**

- Cutler Reservoir is included in Utah’s “Impaired Waters” list and is required to be part of Utah’s TMDL process (Wilbur 2009)
- Mean seasonal total P concentrations are limited to 0.075 mg/L at Cutler Dam outfall (UDEQ, 2009)
What is in stormwater?

- Runoff from urbanized areas, agricultural lands, fertilized lawns, roofs, driveways, rain gutters, roads, etc. that flows into a downstream water body without treatment

Traditional management approach

- Collect and convey water off site as quickly as possible

- Collection in concentrated points of discharge generate high velocity and high volumes of flow

Images: WERF 11-35-06 Presentation (Wenk Associates, Conservation Design Forum, Meyer/Reed, and Barr Eng.)
What is a BMP?

- BEST MANAGEMENT PRACTICES (BMP’s): activities, prohibitions of practices, maintenance procedures, and other practices (such as on-site structures) to prevent or reduce the pollution of waters of the United States

- BMP’s also include practices to control site runoff, spillage or leaks

National stormwater regulations

- EPA’s NPDES require large and medium municipalities (including Logan) to include BMPs as a part of new developments (US EPA 2006)

- This includes building on-site structural stormwater BMPs
Structural stormwater BMPs

BORING!

Structural stormwater BMPs
Structural stormwater BMPs

Structural stormwater BMPs
Structural stormwater BMPs

- Plants are often used to aid in the removal of pollutants

Conclusion

- **Volume** of water discharged is reduced over the growing season
- Sedge 1 saw lower **concentrations** and **mass** discharges of P, and **mass** discharge of N over time
- Common Reed saw lower **concentrations** and **mass** discharges of N over time
Conclusion

- Controls had significantly higher P concentrations and mass discharge than all planted totes (except sunflower)
- Controls had significantly higher N concentrations and mass discharge than all planted totes
- Some species had significantly lower concentrations and mass discharge of N and P than other species
- N and P concentration and mass discharge decreases with total biomass production