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Sustainable Technologies Evaluation Program

- Multi-agency program led by TRCA
- Main program objectives:
  - Evaluate clean water and energy technologies;
  - Assess barriers to/opportunities for widespread implementation;
  - Develop knowledge transfer tools, guidelines and policy alternatives;
  - Education, advocacy, and technology transfer.
- Program web address: www.sustainabletechnologies.ca
Presentation overview

1. The case for better soil management during urban construction
2. Introduction to the best practices guide
3. Recommended standards and implementation options
Hydrologic cycle

Evapo-transpiration (ET)

Precipitation

Recharge

Runoff

Discharge

Abstraction

Generalized Water Budget (Humber River watershed, 2002 conditions)

- Recharge, 16%
- Runoff, 16%
- ET, 68%

Courtesy of Conservation Ontario
IMPACTS OF URBANIZATION ON THE WATER CYCLE

- **Natural Ground Cover**: 40% evapotranspiration, 25% shallow infiltration, 25% deep infiltration.
- **10%-20% Impervious Surface**: 38% evapotranspiration, 21% shallow infiltration, 21% deep infiltration.
- **35%-50% Impervious Surface**: 35% evapotranspiration, 30% runoff, 20% shallow infiltration, 15% deep infiltration.
- **75%-100% Impervious Surface**: 30% evapotranspiration, 55% runoff, 10% shallow infiltration, 5% deep infiltration.

Changes in land use and land cover lead to changes in geomorphology and hydrology, affecting the flow of water and the function of the water cycle.
Conventional soil management practices on Ontario construction sites

- Topsoil stripped, stockpiled in mounds and stored 6 months or more;
- Stockpiled topsoil is reapplied as is on pervious areas at depths of 10 to 15 cm over compacted subsoil;
- Produces landscaped areas that function more like impervious surfaces.
Stormwater management functions of healthy native soil
• Provides high rates of water infiltration and retention;
• Minimizes surface runoff and erosion;
• Traps sediments, metals, excess nutrients and biodegrades chemical contaminants;
• Supports vigorous vegetative cover;
• Supports beneficial soil life that fight pests and disease and supply plant nutrients.

During land development soil functions are often impaired by topsoil loss and compaction:
• Decreases porosity, soil organisms, organic matter, infiltration and water holding capacity;
• Increases runoff, risk of contamination from paved surfaces and yards;
• Increases erosion and risk of flooding;
• Impairs plant growth, pest and disease resistance;
• Increases needs for irrigation, fertilizers and pesticides.
Stormwater Management (SWM)

Potential impacts are mitigated through the implementation of a “treatment train” of stormwater management practices consisting of:

Lot Level Controls
- Permeable pavement

Conveyance Controls
- Perforated pipe system

End-of-Pipe Controls
- Wet Pond
Flaws in the detention pond approach

- No “safe” way to discharge 2x to 6x more runoff;
- Design assumptions are unrealistic;
- Still alters stream flow regimes;
- Does not mitigate loss of natural flow pathways or temperature impacts;
- Cumulative effects of watershed development are not managed.
WHY DO WE NEED TO IMPROVE CURRENT PRACTICES?
Conventional end-of-pipe SWM strategies don’t address all impacts

Changes to water budget (increased runoff & decreased recharge & ET)

- Accelerated stream channel erosion and/or sedimentation;
- Risk of damage to infrastructure & property;
- Degraded water quality (increased temperature and pollutant loads);
- Degraded aquatic and terrestrial habitats;
- Less diverse aquatic communities.
Low Impact Development (LID) is a stormwater management strategy that seeks to mitigate the impacts of increased runoff and stormwater pollution.

LID comprises a set of site design strategies and distributed stormwater management practices that harvest, filter, evapotranspire, detain and infiltrate rainwater.
LOW IMPACT DEVELOPMENT PRINCIPLES

2. Focus on runoff prevention

- Minimize impervious cover (e.g., innovative road network design, shared parking areas, permeable pavement, green roofs);
- Create absorbent landscapes through soil restoration
- Infiltrate roof runoff on site
- Rainwater harvesting.
LOW IMPACT DEVELOPMENT PRINCIPLES

4. Emphasize simple, low-tech, low-cost practices

- Soil restoration on all pervious (landscaped) areas
- Rain barrels
- Rain gardens
- Soakaways
- Grass swales
Key benefits of preserving and restoring healthy soils

- Restores porosity and organic matter which increases infiltration and water holding capacity;
- Improves filtration & trapping of contaminants in runoff;
- Restores conditions needed by beneficial soil organisms;
- Promotes vigorous growth of plantings;
- Minimizes maintenance;
- Creates more attractive & marketable properties.
Effectiveness of soil restoration practices

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Malone et al., 1996</th>
<th>Chow et al., 2002</th>
<th>Balousek, 2003</th>
<th>Faucette et al., 2005</th>
<th>Reinsch et al., 2007</th>
</tr>
</thead>
<tbody>
<tr>
<td>Native soil type</td>
<td>Silty loam</td>
<td>Gravelly loam</td>
<td>Silty clay loam</td>
<td>Sandy clay loam</td>
<td>Clay</td>
</tr>
<tr>
<td>Treatment</td>
<td>Yard waste compost (YWC) incorporation (15 cm depth)</td>
<td>Pulp fibre incorporation (20 – 25 cm depth)</td>
<td>Deep tilling, chisel plowing and YWC incorp. (15 cm depth)</td>
<td>Compost blankets (37.5 mm depth &amp; 4 diff. compost sources) plus filter berms</td>
<td>YWC blanket; YWC incorp.; YWC incorp. plus filter berm</td>
</tr>
<tr>
<td>Runoff volume reduction*</td>
<td>67%</td>
<td>23%</td>
<td>88%</td>
<td>30 to 55%</td>
<td>96% (blanket) 69% (incorp.) 74% (incorp. &amp; filter berm)</td>
</tr>
<tr>
<td>Sediment load reduction*</td>
<td>77%</td>
<td>71%</td>
<td>n/a</td>
<td>97 to 99%</td>
<td>&gt;99%</td>
</tr>
<tr>
<td>Nutrient load reduction**</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
<td>29 to 62%</td>
<td>&gt;99%</td>
</tr>
</tbody>
</table>

* Values are % reductions over all events monitored relative to a bare soil control.
** Value is % reduction of dissolved reactive phosphorus load after vegetation was re-established.
Soil Management Best Practices: An Urban Forest Perspective

- Trees are a major component of the hydrologic cycle
- Trees reduce runoff through processes of
  - Interception
  - Transpiration
  - Infiltration

Figure 4. Conifer over an impervious surface.
Quantifying the benefits of trees

- cityGREEN Software™
- GIS software which is used to analyze:
  - Stormwater runoff
  - Air pollution removal
  - Carbon storage and sequestration
  - Land cover breakdown
  - Alternate scenario modeling
Urban Watershed Forestry (Stormwater Forestry)

- Def’n: The integration of the fields of Urban Forestry and Watershed Planning
- Field Study Research by the EPA, USDA Forestry Service and others have demonstrated and quantified the value of trees in stormwater management
City of Ottawa example

- Analysis based on existing urban forest cover of 27%
  - Removed 630,000 kg of air pollutants/year at a dollar value of $3.95 million
  - Stored 1.01 million tonnes of carbon and sequestered 7,900 kg/year
  - Provided the equivalent of 3.84 million m$^3$ of stormwater storage representing a savings of $219 million if this was captured in built SWM facilities
For trees to provide these benefits, they require

- Sufficient soil volume and soil quality to allow them to reach maturity

- The same benefits and requirements apply to turf and all other plants also

- **Organic matter** is the key to a fully functional soil
Components of soil organic matter (SOM)

- Decomposing organic matter (active fraction): 33% - 50%
- Stabilized organic matter (humus): 33% - 50%
- Fresh residue: <10%
- Living organisms: <5%
Physical and chemical soil properties depend on micro-organisms and other soil dwellers found abundantly in healthy soils:

- Structure
- Water holding capacity
- Infiltration
- Cation exchange capacity
Another world underground which creates low maintenance landscapes

Healthy soils have constant cycling of water, oxygen and nutrients which meets the requirements of plants and trees. This reduces or eliminates the need for irrigation, fertilizers and pesticides.
How much soil does a tree require?

James Urban
Target tree canopy covers for increased benefits from trees

<table>
<thead>
<tr>
<th>Municipality</th>
<th>Present Canopy Cover</th>
<th>Target Canopy Cover</th>
</tr>
</thead>
<tbody>
<tr>
<td>City of Toronto</td>
<td>17%</td>
<td>30 to 40%</td>
</tr>
<tr>
<td>Town of Oakville</td>
<td>29%</td>
<td>40%</td>
</tr>
<tr>
<td>City of Guelph</td>
<td>30%</td>
<td>40%</td>
</tr>
</tbody>
</table>

Questions:
- Are these targets attainable?
- Are some present canopy covers decreasing?
Challenges to maximizing the benefits of trees in the urban watershed

- Poor soil quality
- Limited volume
- Construction activities
- Intensification and infill development
- Conflicts with infrastructure
- Construction practices since 1950
What is the difference between then and now?

- Mass grading and master planned communities
Modern development processes

- Vastly alter large blocks of land
- Compact subsoil to levels not possible prior to 1950

- Degrade topsoil resources through handling and storage practices
- This is actually no longer topsoil
What is expected of this site?

This site will be graded, topsoil added and the finished landscape expected to perform as a natural and pervious site.
This planting site contains............

- Compacted fill
- “A” gravel
- Screenings
- Concrete washout
- Anaerobic topsoil
- 1% – 2% organic matter
- Compaction levels approaching 2 g/cm³
Planting

- Correct tree for the site?
- Correct planting procedure?
- The truth?
  Often no tree is suitable for many sites
- What will be the contribution of these trees in 40 years?
Are we counting on these trees for future benefits such as SWM?

- These trees are 40 years old
- Have caused extensive infrastructure damage
- Received significant injury
- Will decline and be removed

Sidewalk replacement due to damage from tree roots
Time for change

Soil management best practices can help restore the natural functions of soils and vegetation in future developments.
Ensuring healthy soils, tree and vegetation cover can reduce stormwater impact on natural channels and other infrastructure.
Expenses which are a direct result of past development practices can be significantly reduced in future developments by applying soil BMP’s.

- Recommended minimum standards for post-construction soil quality and depth, BMPs to achieve them and inspection and testing;
- Toronto Remedial Action Plan funding in 2011/12;
- Review of standards and guidelines from several U.S. jurisdictions.
Key resources

Soils for Salmon, 2010, Western Washington
www.soilsforsalmon.org
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Soil management best practices for preserving and restoring healthy soils

• Leaving native trees, vegetation and soil undisturbed;
• Stripping, stockpiling and preserving existing topsoil on-site for reapplication;
• Restoring post-construction soils in areas to be landscaped to meet minimum soil quality and depth standards.
## Recommended soil quality and depth standards

<table>
<thead>
<tr>
<th>Type of area</th>
<th>Organic Matter (% by dry wt.)</th>
<th>pH</th>
<th>Topsoil depth</th>
<th>Subsoil scarifying</th>
<th>Total uncompacted soil depth</th>
</tr>
</thead>
<tbody>
<tr>
<td>Turf area</td>
<td>5 to 10%</td>
<td>6.0 to 8.0</td>
<td>20 cm</td>
<td>10 cm</td>
<td>30 cm</td>
</tr>
<tr>
<td>Planting bed</td>
<td>10 to 15%</td>
<td>6.0 to 8.0</td>
<td>20 cm</td>
<td>10 cm</td>
<td>30 cm</td>
</tr>
<tr>
<td>Tree pit</td>
<td>10 to 15%</td>
<td>6.0 to 8.0</td>
<td>60 cm</td>
<td>30 cm</td>
<td>90 cm</td>
</tr>
</tbody>
</table>
Application of the recommended standards

• Should apply to all soils disturbed during construction within a site that will not be covered by impervious surfaces, incorporated into a drainage facility, nor engineered as structural fill or slope and will be maintained in a vegetated state (i.e. landscaped areas), esp. those receiving roof runoff.
Limitations to soil restoration practices

- Should not be implemented on slopes greater than 3:1;
- On slopes between 4:1 and 3:1, slope stabilization practices such as turf reinforcement grids or erosion control matting recommended;
- Should not be undertaken on wet or frozen soils nor in late fall;
- Consideration of shallow underground utilities (e.g. natural gas, hydro, cable lines) and roots of adjacent trees and shrubs – shallower uncompacted soil depths may be warranted.
Soil management best practice options

1. Leave native veg. and soil undisturbed and protect during construction.

2. Strip, stockpile and preserve site topsoil during construction and replace and amend before planting to meet the standard.

3. Amend site subsoil in place to meet the standard.

4. Import a topsoil mixture that meets the standards.
Implementing soil quality and depth standards

- In Ontario there are no requirements to restore healthy functioning soils post-construction;
- Could become part of municipal engineering or urban design standards and CA policies;
- Soil management plans could be required through clearing/grading/fill/site alteration permitting;
- Could take voluntary approach, promote through professional associations, training programs, demonstration and evaluation.
Soil management plans

- Scale drawing of the construction site identifying BMPs;
- Detailing of treatments/products to be used for each disturbed area;
- Volume calculations of compost and stockpiled topsoil or imported topsoil, and mulch to be applied;
- Copies of laboratory analyses of compost and imported topsoil products to be used (required) and pre-construction topsoil quality over the site (optional) documenting at a minimum:
  - Particle size distribution (% sand, silt and clay sized particles);
  - Bulk density;
  - Organic matter content (% by dry weight);
  - pH;
  - Proof the compost meets Ontario guidelines for the production and use as a soil conditioner.
Preparing soil management plans

**Step 1:** Review site grading and landscaping plans

**Step 2:** Visit site to determine pre-construction soil conditions

**Step 3:** Select soil management best practice options

**Step 4:** Identify amendment materials

**Step 5:** Calculate amendment, topsoil and mulch volumes
Verifying post-construction soil quality and depth

- Native vegetation and soil preservation areas remain undisturbed;
- Provision of the appropriate depth of topsoil (20 cm for turf and planting beds, 60 cm for tree pits);
- Provision of the appropriate total depth of uncompacted soil (30 cm for turf and planting beds, 90 cm for tree pits);
- Placement of 5 to 10 cm mulch on planting beds and tree pits.
Verifying post-construction soil quality and depth

Step 1: Compare site conditions with approved Soil Management Plan

Step 2: Inspect delivery tickets for compost, imported topsoil, mulch

Step 3: Verify depth of topsoil and total uncompacted soil depth

Step 4: Check for soil compaction in several locations

Step 5: Check mulch depth

Step 6: Record results on Field Inspection Form
Next steps

- Develop implementation tools (soil amendment calculator, template specifications for construction contracts);
- Half or full day training courses on guide content;
- Field demonstrations and effectiveness evaluations (cost, runoff reduction, plant growth/health);
- Further consultation on tools for effective implementation.
Acknowledgements

TORONTO & REGION
REMEDIAL ACTION PLAN

Fisheries and Oceans Canada
Pêches et Océans Canada
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