Module 8.2 Advanced Soil Protection & Amended Soils

ADVANCED TOPICS IN LID DESIGN
Soil Protection and Amended Soils

Learning Objective:
Know the options for meeting Amended Soils guidance, strategies for determining site soil conditions, and how to develop a soil management plan.

Introduction
Determining Site Soil Conditions
Developing a Soil Management Plan
Soil Protection
Soil Amendment

Amended Soils: Guidance

- Applications & Limitations
- Design
- Sizing
- Runoff model representation
- Construction
- Infeasibility criteria
- Maintenance

4/24/15
Amended Soils: Definition
- Soil/landscape system with adequate depth, permeability, and organic matter
- Retains native soil functionality in a post-development landscape

Amended Soils: Applications
- All pervious areas
- Incorporated into designs for dispersion BMPs

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Design Goal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Organic matter content (non-turf)</td>
<td>6 to 8%</td>
</tr>
<tr>
<td>Organic matter content (turf)</td>
<td>3 to 5%</td>
</tr>
<tr>
<td>pH</td>
<td>6.0 to 8.0</td>
</tr>
</tbody>
</table>

Amended Soils: Runoff Model Representation
- Areas meeting the design guidelines may be entered into approved runoff models as “Pasture” rather than “Lawn”
- Can be used in designs for dispersion BMPs to improve dispersal and adsorption of stormwater flows and help satisfy Ecology’s Core Element requirements for flow control and runoff treatment
Module 8.2 Advanced Soil Protection & Amended Soils

Ecology-approved Building Soil manual

- Source of content in Eastern WA LID Manual
- Manual developed regionally with experts
- Develop a “Soil Management Plan” for each site
- **Four options for soil management (can use 1 or more per site):**
  1) Retain undisturbed native soil & vegetation, protect from compaction
  2) Amend existing soil in place with compost
  3) Stockpile topsoil prior to grading, and reuse on site (amend if needed)
  4) Import topsoil meeting organic matter content requirements
- Choose pre-approved or custom calculated amendment rates
- Simple field inspection and verification procedures

Available [www.soilsforsalmon.org](http://www.soilsforsalmon.org) or [www.buildingsoil.org](http://www.buildingsoil.org)

How can we protect or restore soil functions on every site?

Development typically degrades soil functions.

How can we make this Function more like this?

Native forest

After development

Available [www.soilsforsalmon.org](http://www.soilsforsalmon.org) or [www.buildingsoil.org](http://www.buildingsoil.org)
Restoring soil life, to restore soil functions

Soil organisms create:
• soil structure
• fertility = nutrient cycling
• plant disease protection
• biofiltration
• erosion control
• stormwater detention

How does soil life create soil structure?
• Bacteria secretions glue clays, silts and sands together into micro-aggregates.
• Micro-aggregates are bound together by fungal hyphae, root hairs and roots.
• Spaces are made by moving arthropods & earthworms, and decaying roots.
• Only when all organisms are present can roots and water move into the soil with ease.

How does soil life provide fertility (nutrient cycling)?
• Soil foodweb stores nutrients in living & dead organic matter
• Nutrients are released in root zone as organisms eat and excrete “waste” (nitrogen, etc.)
• Mycorrhizal fungi bring nutrients and water to roots of plants
How does soil life provide plant disease protection?

Diversity \rightarrow predation, parasitization & competition with the few disease-causing organisms

• Bacteria cover leaf surfaces, block infection
• Ecto- and endo-mycorrhizae prevent root infection
• Many organisms prey on the few disease-causing organisms

How does soil life filter & remove pollutants?

• Creates soil structure
• Breaks down hydrocarbons, pesticides, etc.
• Converts fertilizers/nutrients to stable forms, so they are available to plants but won’t wash away
• Increases cation exchange capacity, binding nutrients & other ions
• Binds metals in soil, so they don’t wash into streams
• Creates “dissolved organic carbon” (DOC) complexes, which sequester metals & other pollutants in water, reducing toxicity.

WsDOT: Compost Amended Vegetated Filter Strip - 2004 pollutant & flow reduction trials along I-5

These 3 slides courtesy of: Mark Maurer, WSDOT maurem@wsdot.wa.gov
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### WSDOT 2004:
10 ft. wide compost-amended strip treats stormwater from 2 lanes

“first flush” – first winter’s rain events

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Untreated Runoff</th>
<th>Composted Runoff</th>
<th>% Reduction</th>
<th>% Loss Reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td>TSS</td>
<td>622</td>
<td>36.5</td>
<td>6</td>
<td>64</td>
</tr>
<tr>
<td>Phosphate</td>
<td>0.088</td>
<td>3.00</td>
<td>-192</td>
<td>-2</td>
</tr>
<tr>
<td>COD</td>
<td>71.5</td>
<td>464</td>
<td>33</td>
<td>76</td>
</tr>
<tr>
<td>BOD</td>
<td>39</td>
<td>21</td>
<td>72</td>
<td>56</td>
</tr>
</tbody>
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<table>
<thead>
<tr>
<th></th>
<th>mg/l</th>
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</thead>
<tbody>
<tr>
<td>Total Copper</td>
<td>24.71</td>
<td>9.74</td>
<td>69</td>
<td>59</td>
</tr>
<tr>
<td>Dissolved Copper</td>
<td>3.15</td>
<td>0.11</td>
<td>99</td>
<td>97</td>
</tr>
<tr>
<td>Total Iron</td>
<td>12.60</td>
<td>8.64</td>
<td>72</td>
<td>59</td>
</tr>
<tr>
<td>Dissolved Iron</td>
<td>0.25</td>
<td>0.83</td>
<td>59</td>
<td>59</td>
</tr>
<tr>
<td>Total Zn</td>
<td>129.79</td>
<td>31.86</td>
<td>76</td>
<td>57</td>
</tr>
<tr>
<td>Dissolved Zn</td>
<td>94.52</td>
<td>26.71</td>
<td>69</td>
<td>59</td>
</tr>
</tbody>
</table>

*Note: Stormwater Discharge Effluent, WSDOT Water Quality Standards.

Cation exchange capacity = binding sites

<table>
<thead>
<tr>
<th>Soil Type</th>
<th>Cation Exchange Capacity (CEC) for soil mixes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low fertility soil</td>
<td>Less than 5 meq/100g</td>
</tr>
<tr>
<td>Medium fertility</td>
<td>5-10</td>
</tr>
<tr>
<td>High fertility</td>
<td>10-30</td>
</tr>
<tr>
<td>Compost/humus</td>
<td>up to 200</td>
</tr>
</tbody>
</table>

- Fine sand 0.24mm
- Silt 2.4mm
- Clay 24mm

The smaller the particle the greater the CEC, but organic complexes multiply binding sites.

Humus/clay colloids have the most!
Organic-amended soil removes pollutants and binds remainder to Dissolved Organic Carbon (DOC)

Soil removes most toxics, adds dissolved organic complexes that bind remaining metals, nutrients, PAH's and other pollutants. DOC-bound pollutants are much less toxic to aquatic organisms.

"DOC" is the fraction of water-borne organics that pass through a 0.45 μm filter.

How does soil life control erosion?

• Creates pore spaces, increases infiltration
• Sticks soil particles & aggregates together with bacterial slime, fungal hyphae, & root hairs (bigger aggregates are harder to move) → “aggregate stability”
• Promotes rapid plant growth & deep root development

How does soil life provide stormwater detention and infiltration?

• Builds soil structure, pores, & moisture-holding capacity
• Increases surface porosity
• Modifies underlying sub-soils

Learn more: USDA-NRCS Soil Biology Primer

Learn more: USDA-NRCS Soil Biology Primer
How can we enhance & restore soil biodiversity, to improve plant growth, water quality, and reduce runoff?

- Prevent/correct compaction
- Reduce use of pesticides & soluble fertilizers
- Incorporate compost into soil to feed soil life

organic matter + soil organisms + time creates

soil structure, biofiltration, fertility, & stormwater detention

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Soil Amendment: A cost-effective solution for new development

- Much better plant survival = fewer callbacks
- Easier planting
- Can cut irrigation needs by 50% = 3-7 year payback on irrigation savings alone

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Improving & maintaining soil functions in existing development

- Amend soil when re-landscaping
- Plant native trees & shrubs, especially near waterways
- Mulch beds annually with leaves, chips, compost, etc.
- Mulch-mow (leave clippings) & top-dress turf areas with compost
Module 8.2 Advanced Soil Protection & Amended Soils

Determining Site Soil Conditions

USDA Soil Surveys: a good starting point, but use with caution!

- Compare site soil to the existing USDA survey description.

Changes since development:
- Consistency with existing conditions
- Graded and compacted conditions
- Imported soils

Limitations of traditional soil analysis methods for disturbed urban soils

- Soils vary across site: fill? native? subsoil?
- Mixed or missing horizons – topsoil layer often removed
- Sharp interface problems (between native and fill soils)
- Compaction
- Low pH, anaerobic?
- Low organic matter
- Debris, toxins?

Soil information sources

Soil tests:
- Organic Matter
- Bulk Density
- Nutrients
- Contaminants (if suspected)
Creating a soil profile with a Dutch auger

Compile information on a site soil survey map

- Record different soil types, test results, and issues
- Identify potential soil & vegetation protection zones

Developing a Soil Management Plan (SMP)

- A scale-drawing identifying areas where each soil treatment option will be applied.
- A completed SMP form identifying treatment options, amendment products and calculated application rates for each area.
- Copies of laboratory analyses for compost and topsoil products to be used, with OM content and C:N
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1: Review Landscape and Grading Plans

Working with plans, check the soil in each area to assess how grading will impact soil conditions and potential for reuse of topsoil excavated from building foundations, stormwater detention facilities, and planned pavement areas.

Identify potential vegetation and soil protection zones—

If you don’t mess it up, you don’t have to fix it!

2. Identify Areas Suitable for Each Option

- Established “native” plants and duff—to be left undisturbed.
- Areas to be protected from compaction during construction.
- Areas to be cleared of native vegetation but not graded—may be amended at reduced rate.
- Excavated or graded topsoil suitable for stockpiling and reuse on site.
- Compacted layers less than 12 inches deep (after grading)—require scarification or soil import.
- Existing organic content in soil to be retained or stockpiled and reapplied—reduced amendment rate.

Soil Treatment Options

<table>
<thead>
<tr>
<th>Option</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Option 1.</td>
<td>Retain undisturbed native vegetation and soil, and protect from compaction during construction.</td>
</tr>
<tr>
<td>Option 2.</td>
<td>Amend existing soil at pre-approved or custom calculated rates based on soil and amendment tests.</td>
</tr>
<tr>
<td>Option 3.</td>
<td>Import topsoil mix of sufficient organic content and depth.</td>
</tr>
<tr>
<td>Option 4.</td>
<td>Stockpile native topsoil during grading, and reapply after construction. (import soil if needed to achieve depth). Amend stockpiled soil if needed to meet 5% O.M. (turf) or 10% (planting beds)</td>
</tr>
</tbody>
</table>

Amendment Rate Options

- Pre-approved Amendment Rate
  - Turf: Mix 1.75” compost in to 8” depth (≥ 5% OM by loss-on-ignition test)
  - Beds: Mix 3” compost in to 8” depth (≥ 10% OM by loss-on-ignition test)
- Custom-Calculated Rate
  - Test soil and amendment for organic content and bulk density, to determine amendment rate needed to achieve 5 or 10% organic content
Clearing up the confusion about “% organic”

“% Soil Organic Matter Content” in lab soil tests is by “loss-on-ignition method” (= amount of combustible carbon by dry weight)
- Most composts are 40-65% organic matter (OM) content by this method

Recommended soil amendment rates
(for low-organic soils or sand-compost mixes):
- 5% Soil Organic Matter Content for Turf
  =15-25% compost amendment by volume
- 10% Soil Organic Matter Content for Landscape Beds
  =30-40% compost amendment by volume

3. Tests to Conduct for Custom Calculated Amendment Rates

If planning to use calculated amendment rate, sample and test soil. Request compost test results from supplier.

Soil
- Bulk density
- Percent organic matter

Compost
- Bulk density
- Percent organic matter
- Moisture content (to determine dry weight, to compute bulk density)
- Carbon to nitrogen ratio

Sampling and calculations should be performed or verified by a licensed Soil Scientist, Geologist, Civil Engineer or Landscape Architect.

4. Select Amendment Options

Outline areas where each amendment option will be applied on plan. Assign each area a letter (A, B, C...) on the plan and Soil Management Plan form.
5. Calculate Amendment, Topsoil & Mulch Volumes on Soil Management Plan Form

- For Pre-Approved Amendment Rates: Calculate the square footage of each area, and complete calculations for each area to convert inches of amendment into cubic yards.
- To Compute Custom Calculated Amendment Rates: Use soil and amendment test results, and the Model Amendment Rate Calculator.
- List products on the Soil Management Plan form.
- Procure recent product test sheets showing that compost or other organic materials specified meet requirements.

Amendment calculators at:
www.buildingsoil.org
www.soilsforsalmon.org
or (King County example)
http://your.kingcounty.gov/solidwaste/compost_calculator.htm
or (Seattle soil amendment std. plan)

Exercise – Soil Management Plan
Fill in the SMP worksheet, using the pre-approved amendment rates:
- Turf – 1.75 inches of compost tilled in 8 inches
- Planting Beds – 3 inches of compost tilled in 8"

King County’s SMP form, available at
http://your.kingcounty.gov/solidwaste/compost_calculator.htm
example site plan for exercise
King County’s Amendment Rate Calculator

http://your.kingcounty.gov/solidwaste/compost-calculator.htm

- Need to test organic content and bulk density of compost and native soil for custom amendment rates.
- Just enter square footage for default rates.

Suggested Inspection Procedures

• Pre-Grading Inspection
• Grading Progress Inspection
• Post-Construction Inspection
• Mulch Verification

Exact number of inspections will vary between jurisdictions and project type.

Example form and guide at www.soilsforsalmon.org

Inspection / Verification Supplies

• Field Verification Form
• Soil Management Plan
• Site drawing
• Shovel
• Tape measure
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Pre-Grading / Grading Progress Inspection

- Verify native soils & vegetation delineation and protection (fencing or other) per SMP
- Review SMP with general contractor and/or grading equipment operator
- Verify subcontractors informed of SMP
- Verify erosion controls in place
- Verify excavation & stockpiling of native soils consistent with SMP
- Check sub-grades consistent with SMP

Post Construction (prior to planting)

- Compare conditions to SMP / drawings
- Confirm volumes on amendment delivery tickets match approved SMP
- Dig test holes to check depth of amended soil & scarification
- Use shovel test to check un-compacted depth in multiple locations

Dig Test Holes to Check Depth of Amended Soil & Scarification

- At least three 12 inch deep test holes per acre (3 minimum) for each treatment
- 8” depth of amended soil (excluding mulch layer)
- Scarified subsoil
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Check Soil Depth

- Use shovel or rod “driven only by inspectors weight” to test for compaction
- Test 10 locations per landscaped acre (10 minimum).

In Case Of Dispute

Referred to third party for sampling and testing of organic matter:
- Independent Certified Agronomist, Crop Advisor or Soil Scientist; Licensed Civil Engineer, Landscape Architect or Geologist
- Accredited Soil Testing Lab

Best to avoid this, by having clear SMP and delivery tickets that match volumes/products listed on SMP.

How to Select Compost

Know your supplier!

- Field tests:
  - earthy smell - not sour, stinky, or ammonia
  - brown to black color
  - uniform particle range
  - stable temperature (does not get very hot if re-wetted)
  - not powdery or soaking wet
  - Solvita field maturity test
- Soil/compost lab test info:
  - Nutrients
  - Salinity
  - pH
  - % organic content (OM)

- Mfr.-supplied info:
  - C:N ratio
  - Weed-seed trials
  - Nutrients, salinity, contaminants
  - Size: “screen”, % fines

- Specifications:
  - WsDOT
  - Bioretention Soil: Compost spec

www.seattle.gov/util/GreenInfrastructure
“Composted Material” per WAC 173-350-220

- Produced at “Permitted Facilities” with environmental safeguards to protect streams and groundwater.
- Process monitored to ensure temperatures that destroy most pathogens.
- Tested at frequencies dictated by feedstock & output, for:
  - Heavy metals
  - Pathogens
  - Physical contaminants
  - Biological stability (affects odors and plant response)

Bioretention spec compost meets WAC and STA

Carbon to Nitrogen ratio of composts

- For turf & most landscapes
  C:N ratio of 20:1 to 25:1 - good nutrient availability for first year of growth (no other fertilizer needed)
- For native plants and trees
  C:N ratio of 30:1 to 35:1, and coarser (1” minus screen)
  - less nitrogen better for NW natives, discourages weeds
  - for streamside, unlikely to leach nitrogen
Importing “Topsoil”

• “Topsoil” is not a defined, regulated product. Topsoil products often include subsoil, uncomposted organic material, land-clearing and construction debris...

• Best to use mixes containing only clean compost and mined sand or “sandy loam” as defined by USDA.

• Important to avoid excess clay that can inhibit drainage – spec <5% passing #200 sieve

• Good soil specs for planting, turf, & other areas available at www.seattle.gov/util/engineering/standardspecsplan Div. 9-14

Protecting soil & vegetation during construction

• Fence vegetation & soil protection zones

• Inform all contractors & subs: no stockpiles etc.

• If temporary vehicle access required, place steel plates over 6” coarse wood chip.

Fence to protect from construction impacts
Communicate vegetation & soil protection zones and Soil Management Plans to all contractors and crews.

Soil and tree preservation are similar, but trees sometimes need extra effort in tight urban spaces.

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**Compost Application Methods**

Compost application & incorporation methods:

- Blowing
- Spreading
- Tilling / ripping
- Blending off-site

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**Blowing & spreading**

- Blower trucks
- Various construction grading equipment
- Other equipment: golf course & farm spreaders
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Incorporating amendments into soil

- Range of equipment for different-sized sites
- Till in to 8” depth
- If compacted, rip (scary) to 12” depth before/while amending

Stockpile site soils & amend, after road & foundation work

- Allows mass grading
- Can reduce hauling & disposal costs
- Set grade to allow re-application of topsoil & allow for settling
- Amend stockpile to spec offsite, or after reapplication
- Spread after concrete work
- Rip in first lift, to reduce sub-grade compaction, and break up sharp soil horizons that can limit water penetration
Redmond Ridge
- Large, master-planned development
- Forest left undisturbed where possible - no compaction
- Cleared vegetation & duff stockpiled for use as soil amendment
- Removed topsoils stockpiled
- All soils amended to 12” depth with organics
- *Early Problems:* Too much organic esp. for turf areas, organic materials *not composted* (landclearing & duff) - soft soil, excessive water retention, low N, plant/turf problems as result

Redmond Ridge: improved method
- Grade site 12 in. below finish
- Install foundation, along with driveway & walkway rock pads
- Spread 14 in. amended soil mix, (will settle to 12 inches) rip in first lift to mix with subsoil
- Soils blended offsite from native duff plus compost
- Soil organic matter controlled to ~10%, pH and C:N ratio for optimal plant growth

Putting organics to work - SEA Streets
Street Edge Alternative
Onsite detention demo, Seattle Public Utilities and SDOT.
- Compost in wet and dry zones
- 98% reduction in runoff.

[www.seattle.gov/util/GreenInfrastructure](http://www.seattle.gov/util/GreenInfrastructure)
Compost Based Erosion Control BMPs

- EPA and Ecology-approved BMPs: blankets, berms, and socks
  see www.buildingsoil.org
- “2 for 1” – use compost for erosion control, then till in at end to meet soil BMP:
  - No disposal costs
  - Faster planting, better growth
- Costs: blankets similar to rolled products, but savings on disposal, plus 2 for 1 benefits
- Learn more at www.buildingsoil.org/tools/Erosion_Control.pdf

Broadview Green Grid, Seattle

Compost-amended soil in bioretention swales, compost blankets on slopes

Broadview -

Erosion control with compost blankets, berms, and socks
day after 100-year storm event – no erosion
WsDOT: Erosion control, water quality, successful landscapes with lower mtce. costs

- SR 14, Vancouver
  - Coarse compost, blown in
  - Note erosion where not applied

- Compost amendment, ripped in

WsDOT projects around Washington

Erosion control and plant establishment on steep site using compost blankets

Chelan

Photo courtesy of Sandy Salisbury, WSDOT

Combine methods as needed for best water quality and flow control

WsDOT - Protecting Wetland Area from I-5 Runoff

Amended area

Wetland
 USING MULCHES
 After planting and for annual maintenance
 MULCH BENEFITS:
 • Limit weed growth, make weeds that sprout easier to pull or cultivate
 • Conserve water, moderate soil temperature, and reduce erosion
 • Replenish soil organic matter, enhancing soil biodiversity, structure, and nutrient cycling = increased plant vigor
 MULCHING BEST PRACTICES
 • Annual, spring or fall, until plant canopy closes
 • Arborist wood chips best (for woody & perennial plants).

Selling soil BMP’s to developers, builders, landscape contractors, & homeowners:

Value to builder/contractor
 • Better erosion control
 • Less plant loss = fewer callbacks
 • Making money on materials and labor
 • Quicker planting in prepped soil
 • Easier maintenance
 • Better appearance sells next job

Sell quality & savings to customer
 • Better plant survival/ health/ growth/ appearance
 • Lower water bills
 • Lower maintenance costs
 • Reduced chemical needs
 • Better for salmon because:
   • reduced storm runoff
   • improved water quality

Which site is selling the next job?
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Links to useful soil specifications:

- Building Soil: Guidelines for Implementing WDOE Soil Quality & Depth BMP (includes APWA & CSI specs)
  www.soilsforsalmon.org or www.buildingsoil.org
- LID Technical Guidance Manual for Puget Sound
  www.wastormwatcenter.org
- Eastern WA: www.wastormwatcenter.org
- WsDOT “Soil Bioengineering” specs
  www.wsdot.wa.gov/Design/Roadside/
- Seattle Green Stormwater Infrastructure specs
  www.seattle.gov/util/GreenInfrastructure
- King County soil regs (in Grading code)
- City of Seattle soil regs (in Stormwater code)

Related national standards:
2014 Sustainable Sites (SITES™)

- SITES is the new national site & landscape equivalent to the USGBC’s LEED™ green building certification system.
- SITES includes soil protection and restoration requirements modeled on Washington’s
- Includes Soil Management Plan requirement
- Similar Green Stormwater BMP requirements to WA LID & DOE stormwater manuals

www.sustainablesites.org
A natural solution - for healthier streams, and healthier landscapes
Conserve existing soils and vegetation where possible.
Restore natural functions in disturbed soils by correcting compaction and using organic amendments.

www.BuildingSoil.org
www.SoilsforSalmon.org