STREAM STABILIZATION:
ACHIEVING DIVERSE GOALS ASSOCIATED WITH STORMWATER CONVEYANCE IN THE URBAN ENVIRONMENT

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PRESENTATION OUTLINE

Watersheds
• Water cycle and the urban watershed
• Rate and volume impacts to streams
• Stormwater solutions to consider

Streams
• The geomorphology of urban streams
• Common problems
• Solutions to consider
STORMWATER CONVEYANCE GOALS

• Infiltrate when possible – Increase base flows
• Detain if not possible - Reduce peak flows
• Reduce flooding
• Improve stream health
  • Improve water quality
  • Improve habitat
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We are creating facsimiles of healthy systems, but are prevented from restoration by constraints of the urban environment
THE WAY IT WAS

- Pervious watersheds
- Significant infiltration/retention
- Sinuous stream channels
- Native soil and vegetation within system
THE WAY IT IS: URBAN WATERSHED IMPACTS

Pavement

Channelization and hard armor
HYDROLOGIC IMPACTS OF IMPERVIOUS COVER

Developed Pre-Development
Urban streams act somewhat like desert streams - Low baseflow and high flood flows.
WHY IS STREAM HEALTH IMPORTANT?

- Indicator of what we’ve lost:
  - Historically intolerant biotic communities have been converted to communities tolerant of sediment and pollution
  - Carp or Trout?
- Good water quality (60% depend on surface water for drinking water)
IMPACT TO URBAN STREAMS AND PROPERTY

- Soil erosion – reduced water quality and reduction in ecological function
- Nutrient loading – downstream algae blooms and reduction of instream ecological diversity
- Erosion threatens private and public property
- Flooding threats
- Impacts to freshwater and coastal marine ecology
INFRASTRUCTURE AT RISK

[Images of damaged infrastructure, including a road with cracks, a bridge with missing parts, a pipe in a dried-up stream, and a person standing in a frozen stream.]
STREAMS AT RISK

Impact of no action

Impact of misapplied action
Achieving Primary Stormwater Management Goals

- Retention / Detention
- Infiltration
- Green Infrastructure
  - Roofs, swales, raingardens, rainbarrels, etc.
STORMWATER MANAGEMENT OPTIONS
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STORMWATER CONVEYANCE GOALS

• Primary
  • Watershed BMPs can mitigate for landuse changes
  • We cannot likely return to pre-development hydrology

• Secondary – Implications for streams and rivers
PART 2
ACHIEVING STREAM AND RIPARIAN GOALS
Energy dissipation

- Streams start with potential energy
- Potential energy becomes kinetic energy and streams dissipate this energy in the form of work (moving water and sediment)

- Linear systems dissipate energy in two principle ways:
  - Sinuosity (meandering)
  - Gradient (riffles, steps, waterfalls, headcuts)
Energy Dissipation: Horizontal

Streams dissipate kinetic energy through work in the most efficient manner possible.
Energy Dissipation: Vertical

Profile

Water surface
high flow

low flow

Plan
Why understand urban stream geomorphology?

• Changes in hydrology = changes in stream power and form

• Understanding these changes can help predict when and where stormwater BMPs should be implemented

• Designing a watershed assessment around geomorphology helps target funding
Channel Evolution and Instability

- Schumm (1977)
- Simon (1986)

Diagram showing stages of channel evolution:

1. **I** (W:D~4.0-7.0)
   - Oversteepened Reach
   - Precursor Nickpoint
   - Plunge Pool
   - Primary Nickpoint
   - Direction of Flow

2. **II** (W:D~3.0-4.0)
   - Oversteepened Reach
   - Primary Nickpoint

3. **III** (W:D~5.0)
   - Oversteepened Reach
   - Secondary Nickpoints

4. **IV** (W:D~6.0)
   - Oversteepened Reach
   - Secondary Nickpoints
   - Aggradational Zone

5. **V** (W:D~8.0)
   - Oversteepened Reach
   - Aggradational Zone

Note: Size of cross section arrows indicate relative importance and direction of dominant processes.
CHANNEL EVOLUTION AND INSTABILITY

As a temporal model, channel evolution can help pinpoint when and where rapid change is going to occur.
IMPACTS: INCISION
Impacts: Incision and aggradation

- Upstream incision often accompanied by downstream aggradation
Channel maturity:
- Stage 2 - incision
- Stage 3 - widening
- Stage 4 - recovery
As a spatial model, channel evolution can help pinpoint where lateral erosion is going to occur.
**IMPACTS: LATERAL EROSION (WIDENING)**

Lateral stability  
- Obvious signs  
- What is bad erosion versus good erosion?
Erosion and deposition

- The degree of allowable lateral migration needs to be established (set meander limits)
- We call this **deformability**

From Thorne et al. 1997
**Belt Width**

- Belt width is generally equivalent to the frequent flood boundary
- Belt width (BW)
Sometimes, bank erosion exceeds the equilibrium condition, and sediment becomes a problem. Infrastructure built inside the belt width = problem.
Bank erosion

- It's important to know the difference between fluvial and gravitational erosion
- Global vs. localized
Bluff Erosion

- Bluff vs bank erosion
- Abutting terraces = bluff
- Mass wasting
  - Rotational failure
  - Dry or wet granular flow
  - Cantilever failure
Perceived instability ≠ instability

- Bank erosion is a normal process in an equilibrium channel
Traditional solutions

- Traditional solutions involve threshold channel design, whereby the stream is locked in place.
- Although engineering goals are met, aesthetic, geomorphic and ecological goals are not.
Shear stress in cross-section

\[ \tau = \gamma DS \]

- \( \gamma \) = weight of water
- \( D \) = depth
- \( S \) = slope

Shear is greatest at the toe
Engineering waterways

- All hard engineering solutions have a design life <100 years
- From an ecological perspective, the cure is much worse than the disease
Other methods

- Fortunately, regulations have evolved so that these types of practices are no longer allowed.
Urban river restoration expands on required disciplines:

- Stream ecology
- Infrastructure engineering
- Public safety
- Landscape architecture
- Cultural resources
- Stormwater & FP mgmt
- Geology/Geomorph
- Hydraulic eng.
- Botany
- Hydrology
- Public safety
- Landscape architecture
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- Botany
- Hydrology
Modes of failure engineering

Strength in one discipline (e.g., Biology), is not enough. You need an understanding of engineering too.
Modes of failure ecological

Projects may meet simple engineering goals, but could be ecological disasters.
Bank Stabilization
Simple grade and shape
15 years post-construction
Simple grading and shaping

- Hard toe for boat wake protection
1 year post construction
Soil encapsulation

1 TYPICAL SECTION VIEW

C10 TYPE 1 BANK TREATMENT

Scale in feet
No traffic areas can be incorporated into high traffic parks

3 months post construction
Combination treatments can protect from high toe shear while allowing for green corridors.
Combination treatments

- Fish habitat can be incorporated into long term bank protection in a variety of ways
Steep bank treatments can replace sheet pile or WPA-type walls.
Steep bank treatment

- 10 years
NATURAL CHANNEL RESTORATION
Step pools and floodplain benches can replace threshold channels.
Wood can be used in urban projects
Complex habitat can be realized together with flood capacity projects in urban streams.
Channel relocation can replace degraded streams with stable, complex habitat.
Channel relocation
High energy waterways

- Immobile pool and riffle habitat is better than no habitat at all
INCISION REPAIR / PREVENTION
Incised channel restoration

- Floodplain excavation

Pre-construction
Incised channel
reclamation
Incised channel elevation

- Incised channels offer opportunities for regenerative stormwater conveyance = in-stream infiltration
Grade control for infrastructure protection

- Drop structures can be replaced with natural looking, immobile riffles
Steep channel elevation/stabilization

- Natural step pool/cascade
Boulders can provide needed roughness elements and also pocket water and holding cover for fish.
Dam removals are an excellent way of vastly increasing healthy river habitat in urban systems.
Questions?

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