City of Springfield

Drainage Criteria Manual
Open Channels

Adapted from Open Channel presentation by Ian Paton, Wright Water Engineers, 2007
Overview

- Design Guidelines
- Types of Channels
- Channel Design
- Grade Control
- Structures
Restored natural channel
Design Probabilities/Flowrates

- 4% AEP Must be contained within the channel
- 1% AEP must be contained within the drainage easement
- Design flowrates assuming fully developed conditions per current zoning
- Upstream detention MAY be considered with approval from Stormwater Services
Upstream Detention

- Upstream detention MAY be considered with approval from Stormwater Services
- Detailed modeling may be required
- Ownership and maintenance must be clearly defined
Flow Regimes

- $F_r < 1.0$ Flow is subcritical
- $F_r = 1.0$ Flow is critical
- $F_r > 1.0$ Flow is supercritical
- $F_r$ for channel design be less than 0.8 or greater than 1.2
- Subcritical channels are preferred
- Check $F_r$ using minimum “n” values for lining material
# Table OC-6 Velocity Limitations

<table>
<thead>
<tr>
<th>Channel Type</th>
<th>Minimum Velocity</th>
<th>Maximum Velocity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grass, seed and mulch</td>
<td>2 ft/s</td>
<td>4 ft/s</td>
</tr>
<tr>
<td>Grass, sod</td>
<td>2 ft/s</td>
<td>6 ft/s</td>
</tr>
<tr>
<td>Grass, TRM</td>
<td>2 ft/s</td>
<td>8 ft/s</td>
</tr>
<tr>
<td>Grass, pre-vegetated TRM</td>
<td>2 ft/s</td>
<td>10 ft/s</td>
</tr>
<tr>
<td>Manufactured hard lining</td>
<td>5 ft/s</td>
<td>12 ft/s</td>
</tr>
<tr>
<td>Riprap</td>
<td>5 ft/s</td>
<td>12 ft/s</td>
</tr>
<tr>
<td>Concrete</td>
<td>5 ft/s</td>
<td>18 ft/s</td>
</tr>
</tbody>
</table>
Block Lined Channels
Longitudinal Slope

- Acceptable maximum longitudinal slope generally dictated by criteria for:
  - Flow regime (i.e., Fr < 0.8)
  - Flow velocity (i.e., type of channel lining)

- Acceptable minimum slope (to minimize ponding):
  - 0.4 percent – for natural linings
  - 0.2 percent – for concrete linings
Slope, cont’d

- Excess velocities require a reduction in slope.
- This may necessitate drop structures
  - Newberry riffle
  - Hard drop
  - Grouted boulder drop
Rock riffle/drop
Concrete vertical drop
Sloping concrete drop
Curvature of Channels

- Minimum radius of three times the topwidth at the design flow (minimum of 100 feet)
- Provide freeboard based on superelevation in curve
- Use minimum ‘n’ value for lining material to determine design velocity
Curvature, cont’d

Superelevation is computed using:

\[ \Delta y = \frac{V^2 T}{2gr_c} \]

Where:

- \( \Delta y \) = superelevation
- \( V \) = maximum velocity
- \( T \) = channel topwidth at design flow
- \( r_c \) = centerline radius of curvature
- \( g \) = acceleration due to gravity
Freeboard Requirements

- The required freeboard for engineered open channels is dependent on the type of channel:
  - Concrete channels, 6 inches above 25-year water surface (subcritical)
  - Other types of channels, 12 inches above 25-year water surface
    - (Except for channels where 25-year flow depth is < 12 inches, then freeboard is only 6 inches above 25-year surface)
Other Requirements

- Conditions may warrant additional freeboard
- Low-flow or pilot channels may be required for 2-yr flows > 5 cfs or for unlined grass channels
Riprap Channel Linings

Solve for K value:

\[ K = \frac{VS^{0.17}}{(g-1)^{0.66}} \]

Where:
- \( K \) = Riprap sizing constant
- \( V \) = Mean channel velocity (ft/sec)
- \( S \) = Longitudinal slope (ft/ft)
- \( g \) = Gravitational constant (32.2 ft/sec\(^2\))
Select Riprap $D_{50}$ from table

<table>
<thead>
<tr>
<th>K Value</th>
<th>Rock Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>$&lt; 3.3$</td>
<td>VL** ($d_{50} = 6$ inches)</td>
</tr>
<tr>
<td>$\geq 3.3$ to $&lt; 4.0$</td>
<td>L** ($d_{50} = 9$ inches)</td>
</tr>
<tr>
<td>$\geq 4.0$ to $4.6$</td>
<td>M** ($d_{50} = 12$ inches)</td>
</tr>
<tr>
<td>$\geq 4.6$ to $5.6$</td>
<td>H** ($d_{50} = 18$ inches)</td>
</tr>
<tr>
<td>$\geq 5.6$ to $6.4$</td>
<td>VH** ($d_{50} = 24$ inches)</td>
</tr>
</tbody>
</table>
Energy Dissipation

See FHWA Hydraulic Toolbox for riprap energy dissipation structures such as:
- preformed scour holes
- Riprap aprons
Summary

- Design flows
- Freeboard
- Velocity Criteria
- Riprap Linings

Questions?