Geomorphic Characteristics of Drainage Ditches in Southern Minnesota, and the concept of a Two-Stage Ditch Design

Brad Hansen, Bruce Wilson, Joe Magner, and John Nieber
University of Minnesota

Outline

• Background
• Site Selection
• Field Methods
• Results

Current Designs

• 27K miles in Mn
• Maintenance
• Biotic potential
• Blue Earth County
  – $650K in 2005
  – $1.2M in 2006
• Ohio
  – $450/mi/yr

Problem: Seepage-induced instabilities

Problem: Management of Surface Runoff

Problem: Design of surface inlets

Problem: Design of surface inlets
**Problem:** Natural geomorphic processes

**Ohio Design:** Geomorphic concepts

Bankfull discharge is the discharge that forms the channel shape because it is the discharge that carries most of the sediment.

Flood-prone width is the width of channel when filled will spill over into the floodplain; defined as having twice the depth of bankfull.

A Two Stage Channel

Maintenance often removes fluvial benches that will rebuild again.

Material commonly removed during cleanout.

Features due to Bank Failure are not fluvial benches.

Bank Failure in an Illinois Ditch
### Bench Characteristics

**Design Discharge**
- RI of 5 to 100 years
- High flows exceed the bench

**Effective Discharge**
- RI <2 years
- From J. D’Ambrosio et al.

**Bench anchors the side slope**

### Experimental Design

<table>
<thead>
<tr>
<th>Category</th>
<th>Number of Sites</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Old or not maintained</td>
<td>24</td>
<td>Presence of bankfull bench</td>
</tr>
<tr>
<td>New</td>
<td>6</td>
<td>Recently built, no bankfull bench</td>
</tr>
<tr>
<td>Natural Stream</td>
<td>6</td>
<td>Natural stream, never channelized</td>
</tr>
</tbody>
</table>

### Range of Main Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Low</th>
<th>High</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drainage Area (mi²)</td>
<td>2.26</td>
<td>223</td>
</tr>
<tr>
<td>Slope (%)</td>
<td>.0017</td>
<td>0.6</td>
</tr>
<tr>
<td>Bankfull Width (feet)</td>
<td>3.5</td>
<td>43.9</td>
</tr>
<tr>
<td>Bankfull Flow (CFS)</td>
<td>30</td>
<td>548</td>
</tr>
</tbody>
</table>

### Site Locations

- **Riffle JD10**
- **New Ulm, Mn**
- **New Ditch:**
  - **No Bench Formation**
  - **Delavan, Mn**

### Not Recently Maintained: Bankfull Bench Present

- **Width from River Left to Right (ft)**
- **Elevation (ft)**

### New Ditch: No Bench Formation

- **Width from River Left to Right (ft)**
- **Elevation (ft)**
Natural Streams

Field Methods
- Cross-section profile
- Longitudinal profile
- Pebble count

Cross-Sectional Data
- Bankfull Width
- Bankfull Mean Depth
- Width/Depth Ratio
- Entrenchment Ratio
- Hydraulic Radius
- Wetted Perimeter

Longitudinal Profile

Entrenchment Ratio in a Natural Channel
- Flood prone-width defined by naturally formed terraces

Entrenchment Ratio in a Ditch
- Flood prone-width confined by ditch banks
Minnesota Entrenchment Ratio
Bankfull Width / Bottom Channel Width

Geomorphoric Parameters
- Bankfull width
- Bankfull mean depth
- Cross-sectional area
- Wetted perimeter
- Hydraulic radius
- Width/depth ratio
- Entrenchment ratio
- Slope
- D50
- D84
- Minnesota entrenchment ratio
- Bottom channel width

Bankfull Width (Our data)

\[ W = 3.95 \times DA^{0.46} \]

R² = 0.84

\[ W = 10.5 + 0.18 \times DA \]

Width vs Drainage Area

R² = 0.84

Bankfull Depth (Our data)

\[ D = 1.53 + 0.013 \times DA \]

R² = 0.76

Bankfull Cross-Sectional Area (Our data)

\[ A = 11.4 + 0.81 \times DA \]

R² = 0.90

Width (Our data and MNDNR data)

\[ y = 6.7462x^{0.3494} \]

R² = 0.6651
Comparison with Natural Rivers

Drainage Area (mi²) vs Bankfull Width (ft)

Ohio Data:
\[ W = 5.12^{\text{DA}}^{0.46} \]

Mn Natural Rivers:
\[ W = 4.67^{\text{DA}}^{0.40} \]

Ohio Data:
\[ W = 4.57^{\text{DA}}^{0.46} \]

Reference for Stream Modules
Dan Mecklenburg, OHDNR
Andy Ward, OSU

Look on the web at
http://www.ohiodnr.com/soilandwater/streammorphology.htm

Width
(Our data and MNDNR data)

\[ y = 6.7462x0.3494 \]
\[ R^2 = 0.6651 \]

Depth
(Our data and MNDNR data)

\[ y = 1.1024x0.1517 \]
\[ R^2 = 0.3101 \]

Cross Sectional Area
(Our data and MNDNR data)

\[ y = 6.3192x0.5321 \]
\[ R^2 = 0.7377 \]

ODNR Ditch Design Spreadsheet

CUT 2110 square feet

From J. D'Ambrosio et al.
A Constructed Two Stage Channel

Summary and Conclusion

• Need for self-sustaining designs
• More than one problem
• Defined two-stage design concept
• Data gathered on 30 ditches and 6 streams
• Geometry characteristics correlated to drainage area
• Ditch geometry consistent with natural streams
• Reduction in chemical contaminants in flows (Ohio study)

Nitrate Load Percent Reduction

<table>
<thead>
<tr>
<th>Site</th>
<th>Median Value</th>
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</thead>
<tbody>
<tr>
<td>Bull Creek</td>
<td>1%</td>
</tr>
<tr>
<td>Crommer Ditch</td>
<td>37%</td>
</tr>
<tr>
<td>Klase Ditch</td>
<td>45%</td>
</tr>
<tr>
<td>Needles Creek</td>
<td>16%</td>
</tr>
<tr>
<td>Pone Creek</td>
<td>20%</td>
</tr>
<tr>
<td>Trapezoidal</td>
<td>-86%</td>
</tr>
</tbody>
</table>

Comments/Questions