6-FT ALUMINUM TOEWALL DROP STRUCTURE

Standard Drawing and Hydraulic Spreadsheet

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Content Overview:

- Background
- Structure Description
- Hydraulic Capacity
- Construction Issues
- Monitoring and Follow-up

Background:

Hydraulic research

- *Hydraulics of Aluminum Structural Plate Drop Structures*
  Model study by Steve M. Becker (U. of Minnesota) & George R. Foster (ARS Sedimentation Lab, Oxford, MS)
  Presented to ASAE 1991
- *Hydraulics of Semicircular-Inlet Drop Structures*
  Peer-reviewed and published by ASAE in 1993

Model study findings provided a more complex picture of hydraulic capacity than simply $Q=3.1LH^{3/2}$

Background:

Structural analysis and prototype

- Prototype structure built in MN in 2008
  Based on RISA-3D finite element analysis, with 6-ft drop and 3-ft weir notch height.
- *Structural Enhancement of the Aluminum Drop Toewall Structure*
  Presentation to ASABE in 2010 of development of RISA-3D model and construction of prototype, by Steve Becker, William Wallace, and Gary Hahn (all NRCS).

Background:

Standard drawing development

- Request to MSDT from WI to make use of hydraulic and structural research for aluminum toewall standard with 6-ft drop.
- Planned for multi-state use.
- Requires variance from national Practice Standard 410 – Grade Control Structure (limits toewall structures to 4-ft drop) – variance granted for IA, WI, MN, ND, SD.
- End product: standard drawing with companion hydraulic design spreadsheet

Structure Description

- Available sizes:
  - 5-ft & 6-ft drop
  - 2-ft & 3-ft (nominal) weir height
  - Structure dimensions based on size of standard aluminum sheets – minimize waste
- Similar to existing smaller aluminum toewall structure, with several differences

Differences:

- Tiebacks and wale beam on headwall to minimize deflection
- Riprap configuration upstream and downstream
- Drain details
- Width limited to 16 ft (based on structural limitations)
- Granular bedding & backfill required
- Concrete base slab is larger, to resist uplift
- Hydraulic capacity must be computed (no tables)

Computing Hydraulic Capacity

- Spreadsheet for hydraulic design, based on model study findings:
  Semicircular_Drop_Structure.xlsx
- Why? Flow capacity affected by more than just weir length.
  - W_c/L (width of approach channel to weir length) > 1.3
  - Minimize tangent length "B" for greatest efficiency
  - D/W (drop to width of headwall opening) – larger D/W is more efficient, but keep D/W < 0.625
  - Tailwater depth – submerged weir decreases capacity

Will the 6-ft toewall work for your project?

Check maximum hydraulic capacity:

- For structure with free outlet, largest available size has capacity Q = **512 cfs**.
- For submerged weir conditions, capacity will be less.

Tailwater

- Analysis of downstream channel capacity
- Manning's equation for straightforward trapezoidal downstream channel
- HEC-RAS for non-uniform channel, downstream culverts, etc.
- Free outlet or submerged weir?
- If you have submerged flow at design discharge, develop a rating curve for downstream channel.

Hydraulic spreadsheet basics:

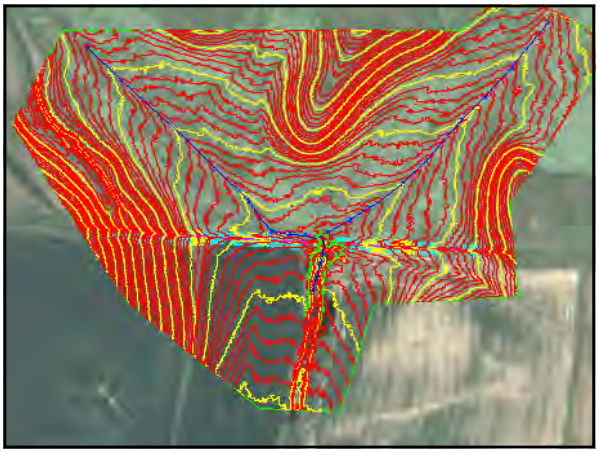
- Separate tabs for Free Outlet and Submerged Outlet
- Hydraulic capacity for free outlet is the lower of:
  - Weir control flow capacity
    $Q_{weir} = (C_{weir})(L)(H)^{3/2}$
  - Headwall control capacity
    $Q_{headwall} = (C_{headwall})(W)(H - Ho2)^{3/2}$
  - Free outlet capacity obtained directly
  - In our range of structure sizes weir control usually governs
- Submerged outlet capacity is computed indirectly by determining increase in head caused by submergence and plotting Head (H_t) vs. Flow (Q).

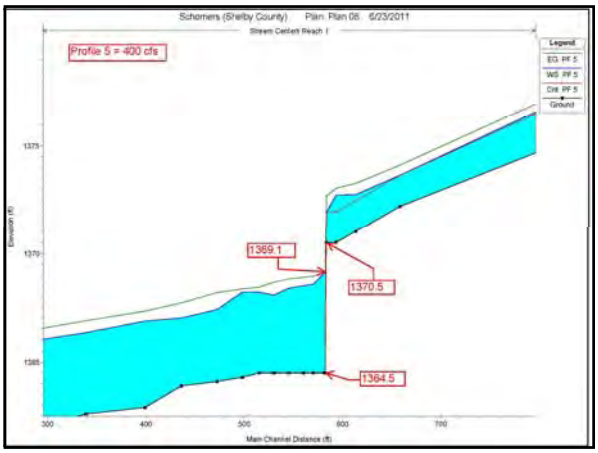
Use of Spreadsheet

- Free outlet example
- Submerged outlet example

Waterway Outlet Structure

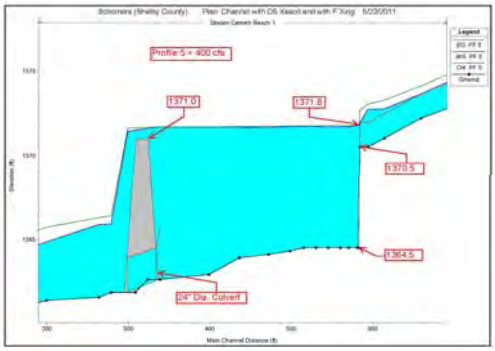
- D. Schomers, Shelby Co., IA
- D.A. = 175 acres
- Principal spillway storm = Q10 = 255 cfs
- Total capacity = Q25 = 341 cfs





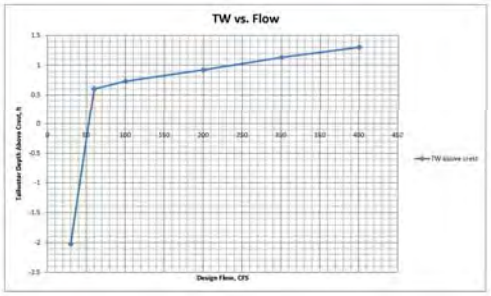
Submerged outlet example

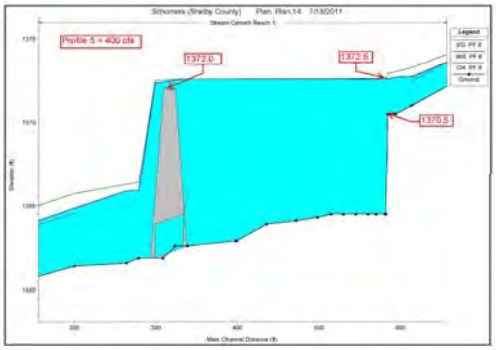
- Assume downstream landowner decides to put in a field crossing just downstream of structure location.
- Assume top of fill of crossing at 1371.0 (weir elevation is 1370.5)
- Assume 24" diameter culvert.



CFS	elev	TW above crest
30	1368.48	-2.02
60	1371.1	0.6
100	1371.23	0.73
200	1371.42	0.92
300	1371.63	1.13
400	1371.8	1.1

With downstream field crossing:
Top elev. 1371
24 in. culvert
Water surface elevations from HEC-RAS





Questions on spreadsheet?

Construction Issues

6-ft drop + 3-ft H makes a very large structure!

- Assembling headwalls in-place is difficult (wind)
- Pre-assembling headwalls (flat) requires larger equipment to place
- Additional support angles added to structure

Tensioning tiebacks is important (limit deflections)

- Tighten nut where rod attaches to deadman
- Press on deadman anchor with backhoe bucket

Monitoring and Follow-up

- Variance from PS-410 requires annual monitoring of first 10 structures built for first 3 years.
- Submit monitoring report to NHQ documenting:
  - Adequacy of design
  - Condition of structures
  - Types of flow experienced
- Provide recommendations for design and modifications to existing practice standard

Questions?