

Over-Capacity Threshold Channel Example – Provo River Delta

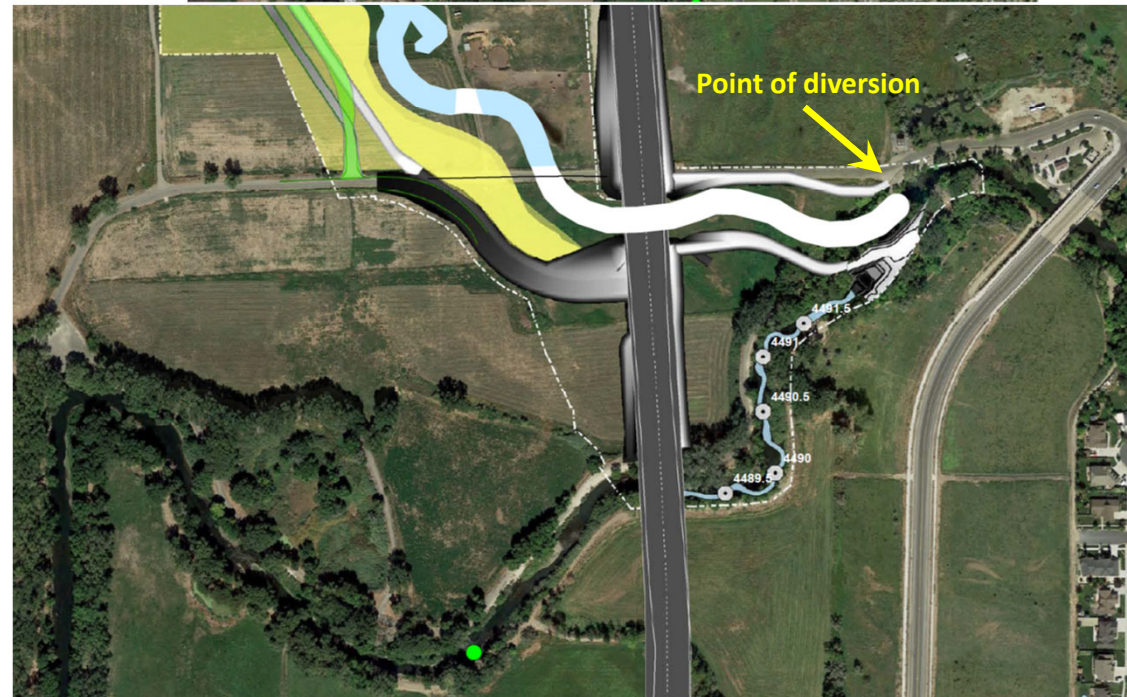
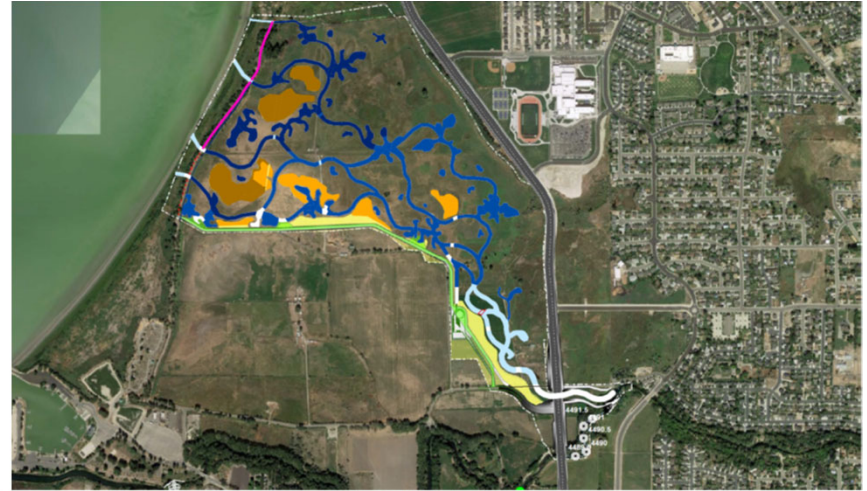
August 2024

Notes by Peter Wilcock

Project Design by Tyler Allred, Allred Restoration Inc.

This exercise is designed to give you experience developing width-slope options for a channel that is to behave as a threshold channel relative to flow competence and as an over-capacity channel relative to sediment supply. The problem is based on the actual design challenge for the River Reach of the Provo Delta Restoration.

The Provo River will be turned out of its existing channel into the Provo River Delta Restoration site. In the remaining fluvial portion of the river (before encountering backwater from Utah Lake), the river must pass under a new highway bridge. In this reach, the river must be engineered to neither scour nor aggrade. It must pass the supplied sediment (without deposition) with the available flow and it must not scour the bed.



Measurements of the bed grain size and of the as-built bed material are provided. Observations of sediment transport rates and grain size were made in 1995 and 2002. Also provided are design discharges used for the 2-, 10-, and 100-year floods. This is sufficient information to define both the threshold and alluvial design problems.

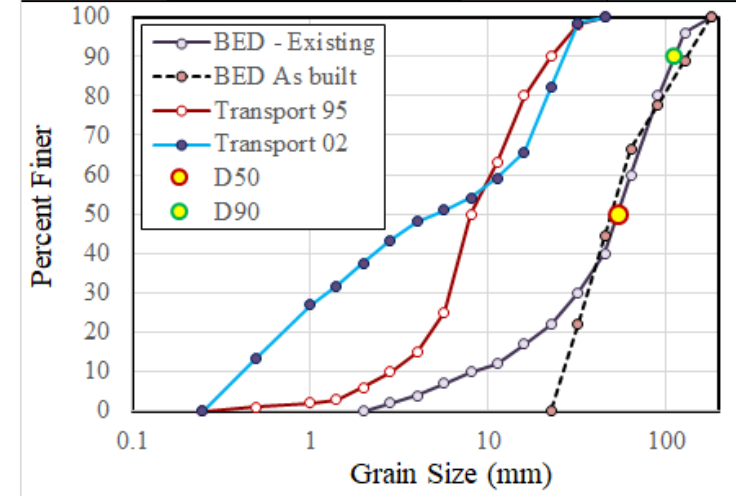
For the threshold channel, we need to pick a design flow (e.g. 10-yr or 25-yr flood) and then evaluate the width, slope combinations that produce incipient motion at this flow. The channel should be built at a *smaller* slope to ensure that the bed does not scour (sediment does not move) at the design flow.

For the over-capacity alluvial channel, we evaluate the slope needed to transport the supplied sediment at different flows. The channel should be built with a slope larger than this slope to ensure that the channel has enough capacity to pass the supplied sediment.

Design Discharges		
Return Int.	Discharge	Discharge
(yr)	(ft ³ /s)	(m ³ /s)
2	825	23.4
10	1,475	41.8
100	2,325	65.8

Sediment Supply Rate			
Q	Q _s	Q	Q _s
(cfs)	(kg/s)	(cms)	(m ³ /s)
650	0.22	18.4	0.000083
750	0.55	21.2	0.00021
1250	0.6	35.4	0.00023

Bed grain size and sediment supply grain size				
Grain Size	BED - Existing	BED - As built	Transport 95	Transport 02
(mm)	% ft	% ft	% ft	% ft
180	100	100		
128	96	89		
90.5	80	78		
64	60	67		
45.3	40	44	100	100
32	30	22	98	98.5
22.6	22	0	90	82.1
16	17		80	65.8
11.3	12		63	59.0
8	10		50	54.2
5.66	7		25	51.0
4	4		15	48.1
2.83	2		10	43.3
2	0		6	37.5
1.41			3	31.7
1			2	26.9
0.50			1	13.5
0.25			0	0.0

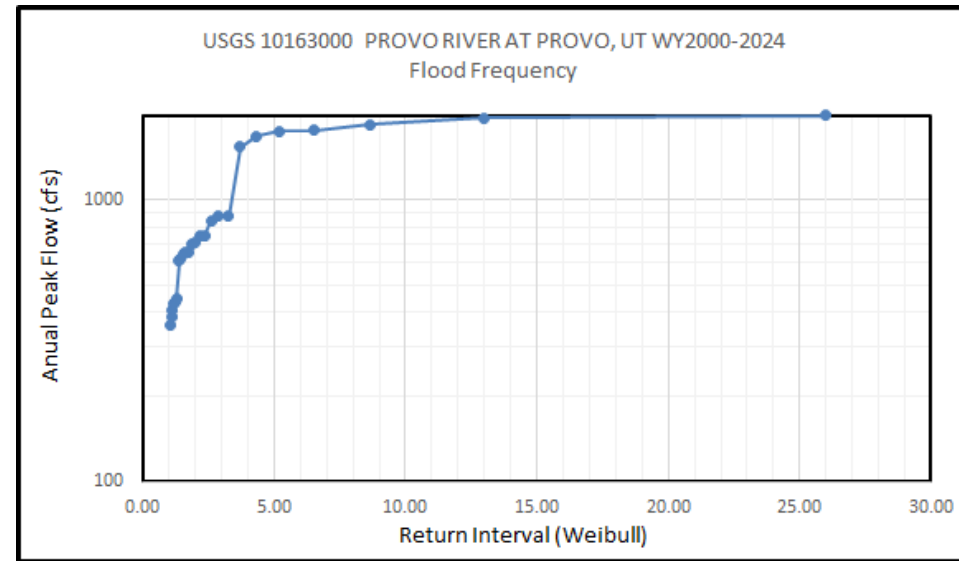


Digging a little into the flow record, let's look at annual peak flows for the last 25 years. There is a long-running USGS gage not far upstream from the Delta. Recall that Jordanelle Dam was closed in 1992, so flows before that might not reflect the joint operation of Deer Creek and Jordanelle Reservoirs.

The WY2000-2024 flood frequency curve at the right has an odd shape, not surprising given that Provo R flow is controlled by two large reservoirs and transbasin diversions. One interpretation for design purposes is

- (i) About 3/4 of the years (or with probability of 0.75 in any given year), the flow won't be very large.
- (ii) In about 1/4 of the years (or with probability of 0.25 in any given year), the flow will be between 1700 cfs and 2000 cfs)

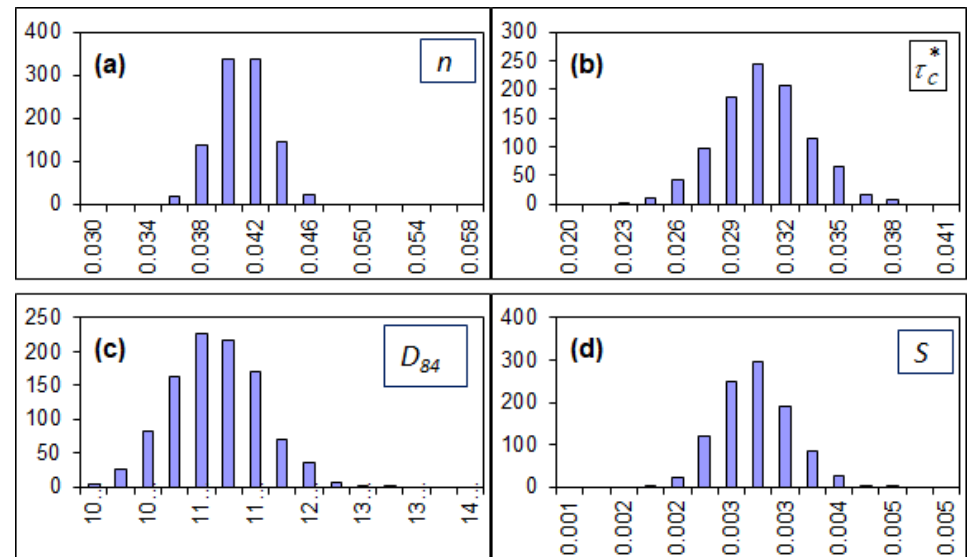
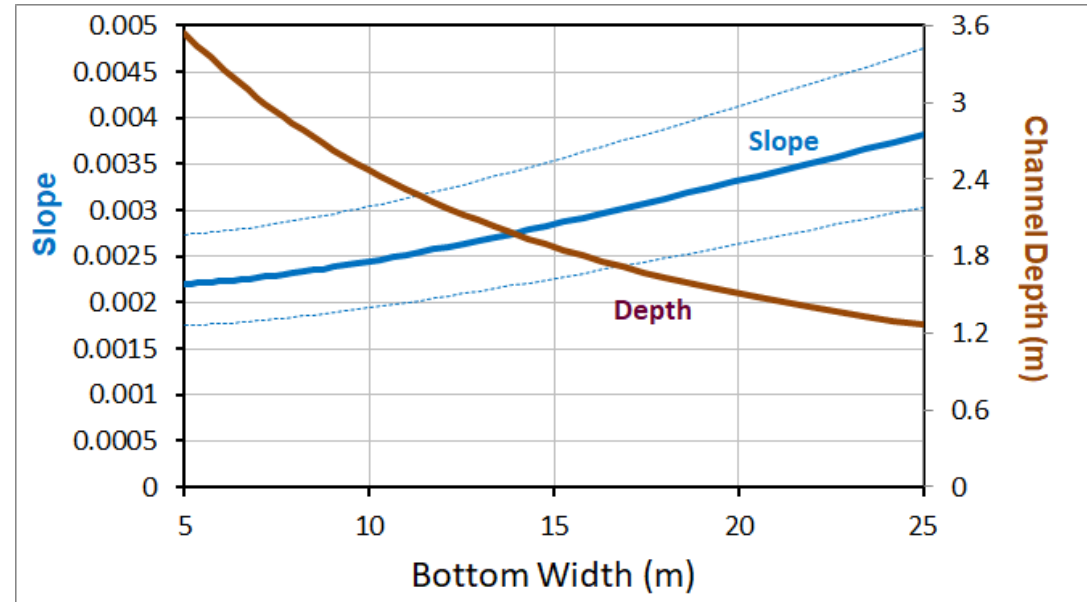
It would seem wise to use 2000 cfs as a design flow for the threshold channel, since 5 flows in the last 25 years have been between 1750-1990 cfs AND it appears possible that flow control prevents larger floods. I would further check with the dam operators about the possibility of a flow greater than 2000 cfs. What are the odds of an "Oroville"? (hopefully very very small)



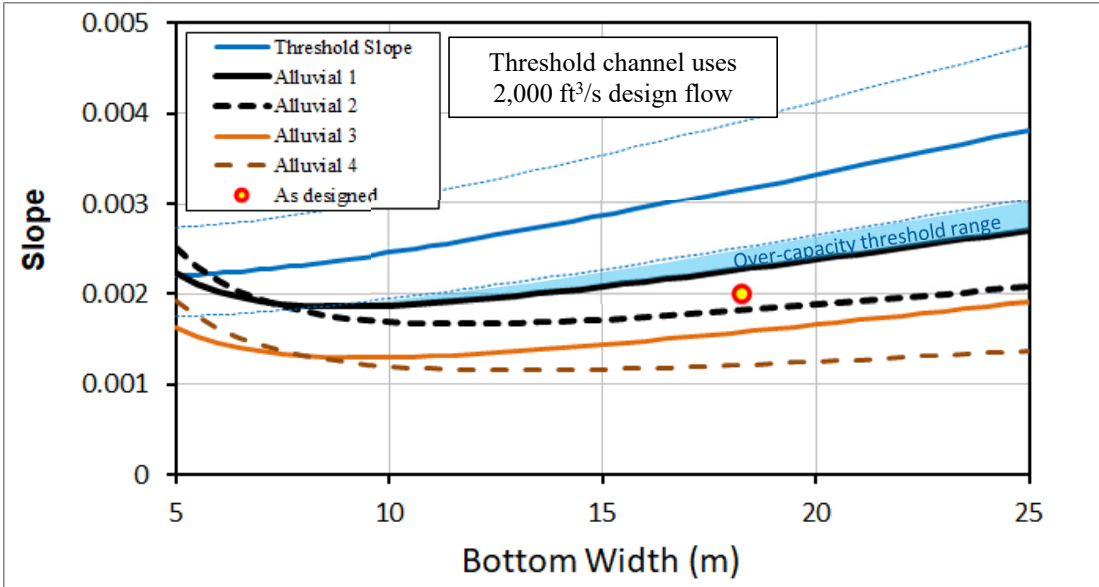
The **threshold channel solution** to the right uses a design discharge of 2,000 ft³/s (56.6 m³/s) and the bed grain size observed in the pre-existing Provo R channel. The as-built bed material is nearly the same size. Workbook OCT PROVO DELTA, worksheet VARYWIDTH calculates grain stress using the Manning drag partition and a specified total channel roughness of $n_t = 0.04$. Details of the calculation are given on the worksheet. A critical Shields Number τ_c^* of 0.03 is used. Understand why this is a *conservative* choice for τ_c^* .

{a smaller τ_c^* means that a smaller slope will be needed to move sediment at the design flow – your objective is to make sure your design slope is *smaller* than the threshold channel slope so you can assert that the design flow will not move the bed material. Hence, choosing a *larger* τ_c^* or a larger bed grain size will give you a *larger* slope and is not conservative.}

The error bars on the slope are the 90% credible interval calculated from the UNCERTAINTY worksheet, which provides the range in slope due solely to uncertainty in the input values of total channel roughness n_t , D_{84} , and τ_c^* . The 1000 Monte calculations are on the spreadsheet itself (not in VBA code), so the error bars recalculate every time you take any action in the spreadsheet. The outcome of one calculation are shown at right.



The **alluvial channel solution** uses the transport data available. Two different GSD for the sediment transport are reported, one from 1995 and one from 2002. Transport rates of about 0.0001 to 0.0002 m³/s are reported for a flow of about 600-700 cfs (about the two year flood). A transport rate of 0.00023 m³/s is reported for a flow of 1250 cfs. We run both flow/sediment supply combinations and choose to increase the high flow transport rate to 0.0004 m³/s for the sake of a conservative design (more sediment supply rate requires a larger slope, and our design slope must exceed the calculated slope). Using the 1995 and 2002 bed GSD with both flows gives the four cases in the table to the right.



Case	1	2	3	4	
Q	20	35	20	35	m ³ /s
Q _s	0.0001	0.0004	0.0001	0.0004	m ³ /s
GSD	1995	1995	2002	2002	

The plot at upper right adds the four alluvial width/slope combinations to the threshold channel plot. The alluvial cases are calculated in the spreadsheet ISURF:STAB and pasted in OCT PROVO DELTA: VARYWIDTH for plotting.

The most conservative **over-capacity threshold range** (slope smaller than will produce incipient motion of bed material at design flow; slope larger than needed to transport supplied sediment) falls between the lower credible interval for the threshold channel and the largest alluvial slope. The as-built design compares favorably. That Tyler is a clever boy!

Some reasons to be optimistic

- (1) As the project ages, the critical Shields Number for the bed material is likely to increase. It won't be smaller because 0.03 is the value for clean, loose, freshly deposited gravel and cobble. A larger value of τ_c^* means the threshold slope becomes *larger* and all is good.
- (2) Note that the alluvial slope needed is smaller for the larger flow (35 m³/s) than the smaller flow. *Perhaps* yet larger flows carrying yet larger sediment loads will not require a larger slope than built (indicating deposition)



Other things to think about:

- (1) The threshold design looks pretty solid. I would check with dam operators to assess the possibility of flow greater than 2,000 cfs.
- (2) I would look for evidence that the potential sediment supply is larger (or coarser) than modeled. If so, sediment could deposit in the design reach, producing undesirable flooding and/or channel shifting. I would look at the history of the approach channel – has it been shifty and hard to control? I would walk the channel looking for large, recent bars, suggesting that a pulse of sediment could be heading my way. The valuable (I would say essential) observations are not just those providing input for formulas but those leading to a narrative about the upstream channel.
- (3) I would develop a full sediment rating curve for the sediment supply, including flows up to 2,000 cfs. I would then calculate how much sediment is delivered by those higher flows, using a flow duration curve and the sediment rating curve. In addition to running iSURF:STAB for higher flows, I would calculate the total volume of sediment delivered over a high flow year: is that total volume a big number or little number compared to the volume of the constructed channel?



The project stood up well to a large snowmelt flood just a month or two after construction was complete and water diverted into the project!