COOL CREEK

Site Information

Site Location: Mt. Hood NF. 2.5 miles off US 26 on Still Ck Rd (FR 2612)

Year Installed: 1984

Lat/Long: 121°53’11.02”W 45°17’53.01”N

Watershed Area (mi²): 1.7

Stream Slope (ft/ft)[1]**:** 0.0519

Channel Type: Step-pool

Bankfull Width (ft): 19.5

Survey Date: 4-6-2007

[1]Water surface slope extending up to 20 channel widths up and downstream of crossing.

Culvert Information

Culvert Type: Open-bottom arch

Culvert Material: Annular CMP

Culvert Width: 13 ft

Outlet Type: Projecting

Culvert Length: 48

Inlet Type: Projecting

Pipe Slope (structure slope): 0.022

Culvert Bed Slope: 0.015

(First hydraulic control upstream of inlet to first hydraulic control downstream of outlet.)

Culvert width as a percentage of bankfull width: 0.66

Alignment Conditions: Culvert placement perpendicular to road likely differs from original steam channel alignment. Outlet possibly oriented further south than original alignment. Lateral scour pool at inlet may be associated with alignment. Energy is directed at left wall of pipe at inlet.

Bed Conditions: Cobbles to small boulders in pipe. Similar to natural channel.

Pipe Condition: Good condition. Only minor rust in places.

Hydrology

Discharge (cfs) for indicated recurrence interval

25% 2-yr	Q_{bf}[2]	2-year	5-year	10-year	50-year	100-year
21	70	83	134	172	262	302

[2]Bankfull flow estimated by matching modeled water surface elevations to field-identified bankfull elevations.

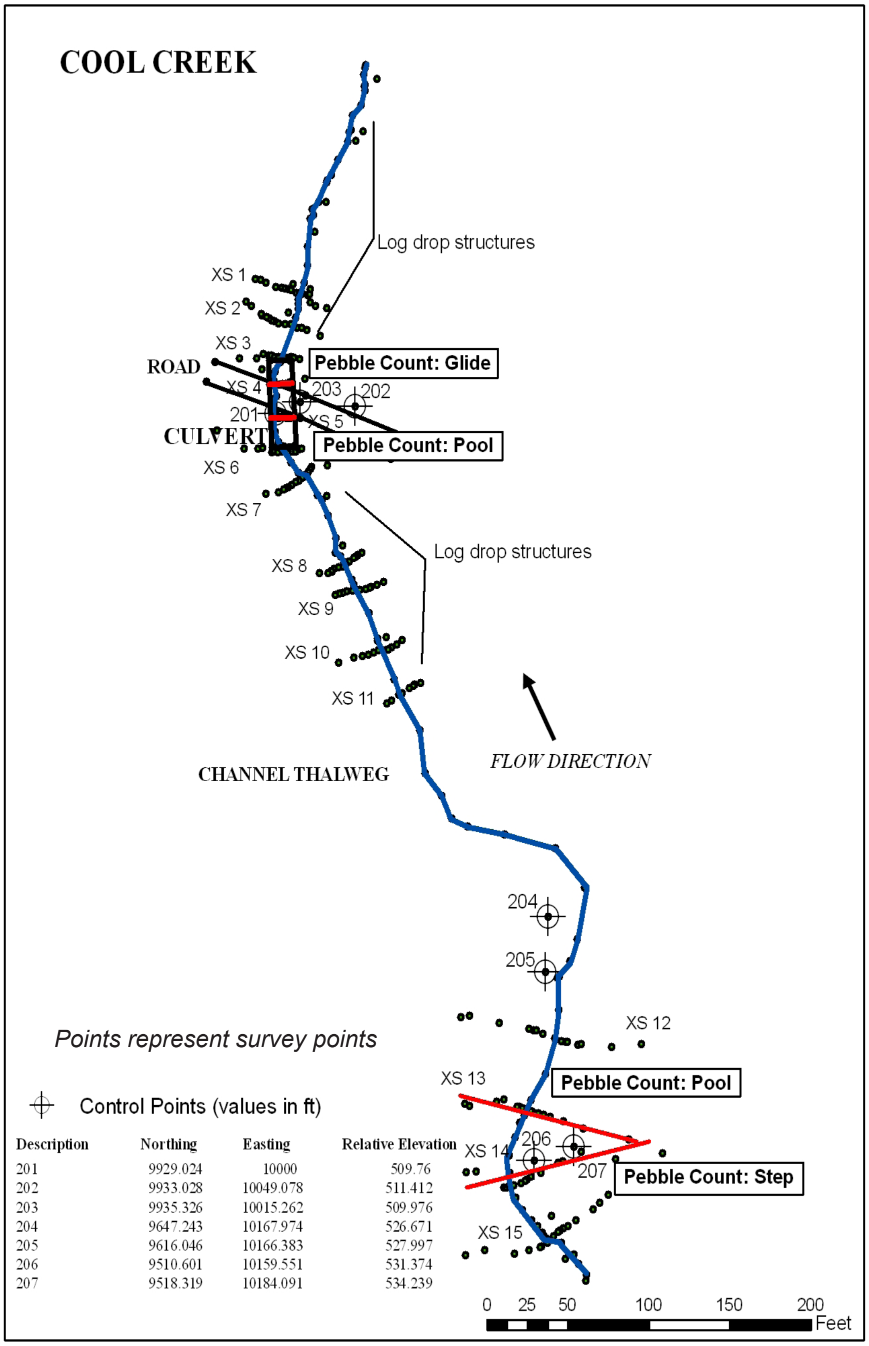


Figure 1—Plan view map.

HISTORY

The exact installation date is unknown, but the culvert was included in the 1987 Western Federal Lands Highway Division (WFLHD) "Oregon Culvert Fish Passage Survey." The field survey for the WFLHD study was conducted on 10/19/1987. Special features that were noted included the observation that the footings were 4 feet below the streambed and "manmade pools were built at outlet with log and rock barriers." With respect to fish passage, Oregon Department of Fish and Wildlife (ODFW) staff described the culvert as a "very good open bottom arch," but they note that the "manmade pools at outlet may require periodic maintenance." WFLHD staff rated overall culvert condition as "poor," culvert capacity as "fair," condition of foundation as "fair," and with "negligible" outlet scour. The culvert hydraulics were considered "compatible" with the natural stream hydraulics. In their comments they note that "despite the poor installation procedures, the Cool Creek culvert is a good fish passage design."

The following are photos from the WFLHD study:

Culvert inlet.

Typical stream channel.

It is unknown whether the log-drop structure 15 to 20 feet downstream of the outlet was placed during construction or was placed in response to scour of the culvert bed at some point following construction. The drop structure was present at the time of these 1987 photos.

SITE DESCRIPTION

The Cool Creek culvert is a short bottomless arch that projects from the roadfill. At the inlet to the culvert the steep channel, predominately comprised of step-pool channel units, abruptly flattens. A deep pool has formed up against the left wall, creating a depositional bar along the right bank. The downstream half of the culvert consists of a relatively plane bed glide. Downstream of the culvert outlet, and extending to the confluence of Still Creek, there are a series of constructed log-drop structures that are serving as the hydraulic controls for this reach. Artificial log-drop structures are also present upstream of the culvert.

The presence of artificial log drops upstream of the culvert required that the upstream representative reach be located a couple hundred yards upstream of the inlet. The upstream reach consisted of a moderate gradient step-pool channel with active flood-plain terraces intermittent along both sides. Large material through the reach provided the framework for the step/cascade units that made up the majority of the reach. A plunge pool adjacent to a log jam was the only pool within the reach and served as a reference cross section.

SURVEY SUMMARY

Thirteen cross sections and a longitudinal profile were surveyed along Cool Creek in April 2007 to characterize the culvert and an upstream reference reach. No downstream reference reach was established due to the presence of artificial log drops. In the culvert, representative cross sections were taken through the pool and the glide. Three additional cross sections were surveyed downstream of the culvert to characterize the outlet as well as the expansion of flow. Two additional cross sections were surveyed upstream to characterize the inlet as well as the contraction of flow.

Due to the complexity of the channel between the upstream representative reach and the culvert, two separate hydraulic models were run to evaluate the hydraulics through these reaches. While a longitudinal profile was surveyed, cross sections did not capture grade breaks and hydraulic controls between reaches.

Four cross sections were surveyed to characterize the upstream representative reach; one at the upstream and downstream boundary, one along the top of a step and one through a pool.

PROFILE ANALYSIS SEGMENT SUMMARY

The profile analysis resulted in 13 profile segments. The culvert consisted of one profile segment that extended into the culvert outlet transition area. The culvert segment was comparable to one representative segment in the upstream channel. A segment in the downstream transition area was comparable to a representative segment in the upstream channel. There was no comparable segment for the upstream transition segment (H). See figure 2 and table 1.

SCOUR CONDITIONS

Observed conditions

Footing scour—There was minor scour along the left bank footing at the inlet. Footings were not scoured to the base or undermined in any way that threatens structure integrity.

Culvert bed adjustment—The culvert bed shows some flattening of the profile based on comparisons of the bed to the slope of the structure itself (assuming the culvert bed was constructed at the same gradient as the culvert structure). This flattening appears to be a combination of scour at the inlet and aggradation towards the outlet. A scour pool has formed along the left edge of the culvert, leaving a raised surface along the upper right channel within the culvert. Material has deposited through the downstream half of the culvert filling in the channel to resemble a glide. Backwatering and grade control has been provided by the presence of log-drop structures downstream of the culvert.

Profile characteristics—The profile has a concave shape through the crossing (figure 2). This shape reflects scour at the inlet region, combined with aggradation in the downstream portion of the culvert and in the channel downstream of the culvert. A significant transition in the channel gradient occurs at the inlet to the culvert as the channel flows through a series of log-drop structures. It is this transition, along with the contraction of flow through the culvert that has created the scour along the left edge of the culvert.

The low crown elevation of the culvert and the deep level of embedment suggest that the installation of the Cool Creek crossing may have been placed too low in relation to the original channel profile, which may have occurred in order to avoid raising the road bed. Deep embedment during construction and/or deposition (partially related to the downstream drop structure) is contributing to reduced capacity during flood flows.

Residual depths —The residual depth of the single pool within the culvert (segment G) is greater (0.94) than the upstream channel (0.36-0.82) (figure 21). Additionally, the downstream transition segment (F) has greater residual depths (0.43-0.54) than does the upstream channel (0.15-0.23). This suggests that the culvert has experienced additional scour beyond what is found in the channel outside of the crossing. No units of measure.

Substrate—Substrate in the upstream channel is coarser than that found in the culvert, with more frequent large particles and less frequent smaller particle sizes (including sand and small gravels). A greater frequency of smaller particles in the culvert may be due to the gradient transition in the culvert and the reduced capacity at higher flows. Backwatering and reduced sediment transport capacity (i.e., low shear stress) allows for the deposition of smaller particles. All values are poorly sorted and positively skewed, which is typical for mountain streams (table 7). Although culvert sorting and skewness values fall outside the range of the natural channel, values do not diverge substantially. Pebble counts are provided at the end of the site summary.

Predicted conditions

Cross-section characteristics—Cross-sectional flow area, wetted perimeter, top width and the width-to-depth ratio are considerably reduced by the culvert (figure 12, figure 15, figure 17) reflecting the reduced capacity of the culvert. Hydraulic radius and maximum depth in the culvert (segment G) are similar to the upstream channel (segment L) for flows up to the Q_{bf} and then become greater within the culvert above the Q_{bf} (figure 14, figure 16). Flow area, top width, and maximum depth are similar for the downstream transition segment (F) as they are for the upstream channel (M) for the range of flows (figure 12, figure 15, figure 16). The wetted perimeter and hydraulic radius of the downstream transition (segment F) are similar to the upstream channel (segment M) up to the Q_{10}, above which the wetted perimeter is less in the downstream transition than in the upstream channel, while the hydraulic radius is greater (figure 13, figure 14). The downstream transition segment (F) has a greater width-to-depth ratio as the upstream channel segment (M) for flows up to the Q_{bf}, above which the transition segment's width-to-depth ratio is less than the upstream channel's (figure 17).

Shear stress—The shear stress within the culvert (segment G) is similar to that of the upstream channel (segment L) for all flows modeled (figure 10, figure 19). Similarly, the shear stress of the downstream transition segment (F) is similar to the upstream channel segment (M) for all flows modeled. However, the range of shear-stress values found in the transition segment is great and the median value is greater than the median value of the upstream channel.

Excess shear—The excess shear analysis shows that the culvert and upstream channel have similar excess shear values for the 25-percent Q_2 and the Q_{bf}, but diverge above the Q_{bf} (figure 20). It is above the Q_{bf} that the potential for bed mobilization in the upstream channel increases at a greater rate than in the culvert. This corresponds with lower shear in the culvert at higher flows.

Velocity—Velocity in the upstream culvert segment (G) is higher than the downstream representative segment (L) for all flows modeled (figure 11, figure 18). These higher culvert velocities correspond to the flow contraction (reduction in flow area) caused by the culvert. Velocity at the downstream transition (F) is similar to the upstream representative segment (M) at all flows.

Scour summary

The Cool Creek culvert showed signs of bed adjustment including inlet scour and downstream aggradation. Scour at the inlet is likely related to inlet-control conditions (limited capacity) during floods. The downstream aggradation is likely caused by the grade control log-drop structures located downstream of the crossing that lower the local slope. The abrupt transition in gradient from the upstream log-drop structures to the culvert may be a function of the placement of the crossing. Continued aggradation in the downstream portion of the culvert could further reduce the capacity of the culvert.

AOP CONDITIONS

Cross-section complexity—The sum of squared height differences in the culvert cross sections are not within the range of those in the channel cross sections (table 3). The upstream culvert cross section, taken through a pool has a higher value than the upstream channel. The inlet scour has created a deep pool along the left channel, leaving a higher bar surface along the right channel creating complexity in the channel. In contrast, the downstream culvert section, taken through the glide is relatively flat and featureless and represents the aggraded portion of the culvert which is backwatered by the downstream log-drop grade control structures.

Profile complexity—Vertical sinuosity in the culvert is similar to that found in the upstream channel (segment L) (table 4). However, the vertical sinuosity of the downstream transition (segment F) is much higher than the upstream channel (segment M), a result of the grade control log structures.

Depth distribution—There is more channel margin habitat in the culvert compared to the channel at 25-percent Q_2 (table 5).

Habitat units—The habitat-unit composition in the culvert is very different than the upstream channel (table 6). Whereas the culvert is made up of one long scour pool followed by a long glide, the upstream channel is composed of steep riffles interspersed by short pools, a step, and a plunge pool.

Residual depths—The residual depth of the plunge pool in the culvert (0.95) is greater than that found in the upstream channel (0.36-0.82) (figure 21). Similarly, residual depths in the downstream transition (0.43-0.54) are greater than those in the upstream channel (0.15-0.23).

Bed material—The bed material in the upstream channel is coarser than that found in the culvert. The distributions of the two pool units are fairly similar, with a slightly greater number of coarser particles and a noticeable lack of sand and very fine gravels in the upstream channel. The step has no rocks less than 11.3 millimeters and the glide has no rocks greater than 362 millimeters. The larger material in the natural channel may provide for velocity refuge for fish that exceeds what is available in the culvert.

Large woody debris—There was no LWD present in the culvert (table 8). The representative channel had high LWD abundance. LWD formed steps and scour pools in the channel outside the crossing and played a primary role in habitat-unit creation and complexity. Features in the culvert did not mimic the role of wood in the natural channel. The culvert, which has a low rise, is unlikely to be able to transport or retain LWD without considerable scour risk. Constructed wood-drop structures were present in the channel upstream and downstream of the crossing.

AOP summary

Some metrics, such as cross-section complexity and shallow-water habitat availability at 25-percent Q_2 are greater in the culvert than the natural channel. However, cross-section shape (e.g., width-to-depth ratio and wetted perimeter) changes sharply at the crossing, with potential impacts on availability of channel margin habitat as flows increase. The habitat unit composition is very different in the culvert with only one long pool unit whose residual depth is greater than that found in the upstream channel. The greater residual depth may create good holding cover in the culvert; however, large substrate elements that are also important for velocity refuge are scarcer in the culvert.

DESIGN CONSIDERATIONS

This culvert is deeply embedded and may have capacity limitations, especially if material continues to aggrade inside the structure. Because of the low height (rise) of the structure, woody debris may become easily impinged at the inlet or inside the culvert, further limiting capacity. Flattening of the gradient through downstream grade control has possibly kept material from scouring out over the years but it also could lead to further aggradation and capacity reduction that could cause overtopping during a large event. Increasing the culvert rise could ameliorate these potential issues, but it would require raising the road prism because of the low elevation of the road fill above the pipe.

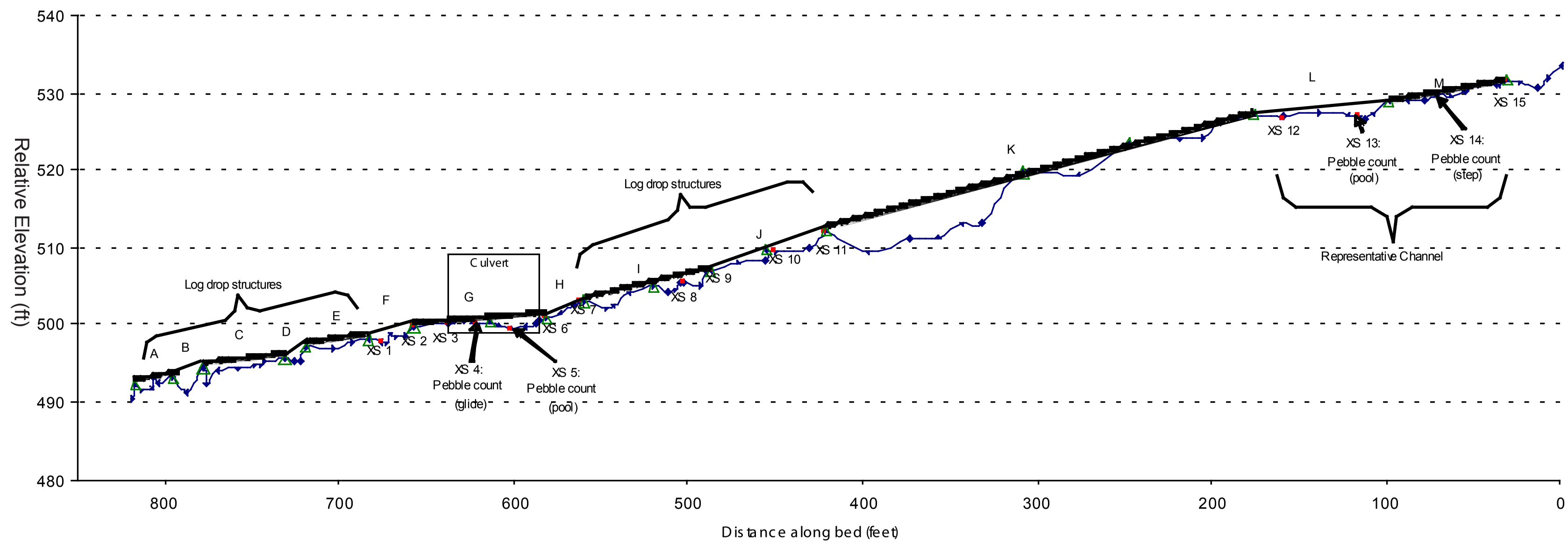


Figure 2—Cool Creek longitudinal profile.

Table 1—Segment comparisons

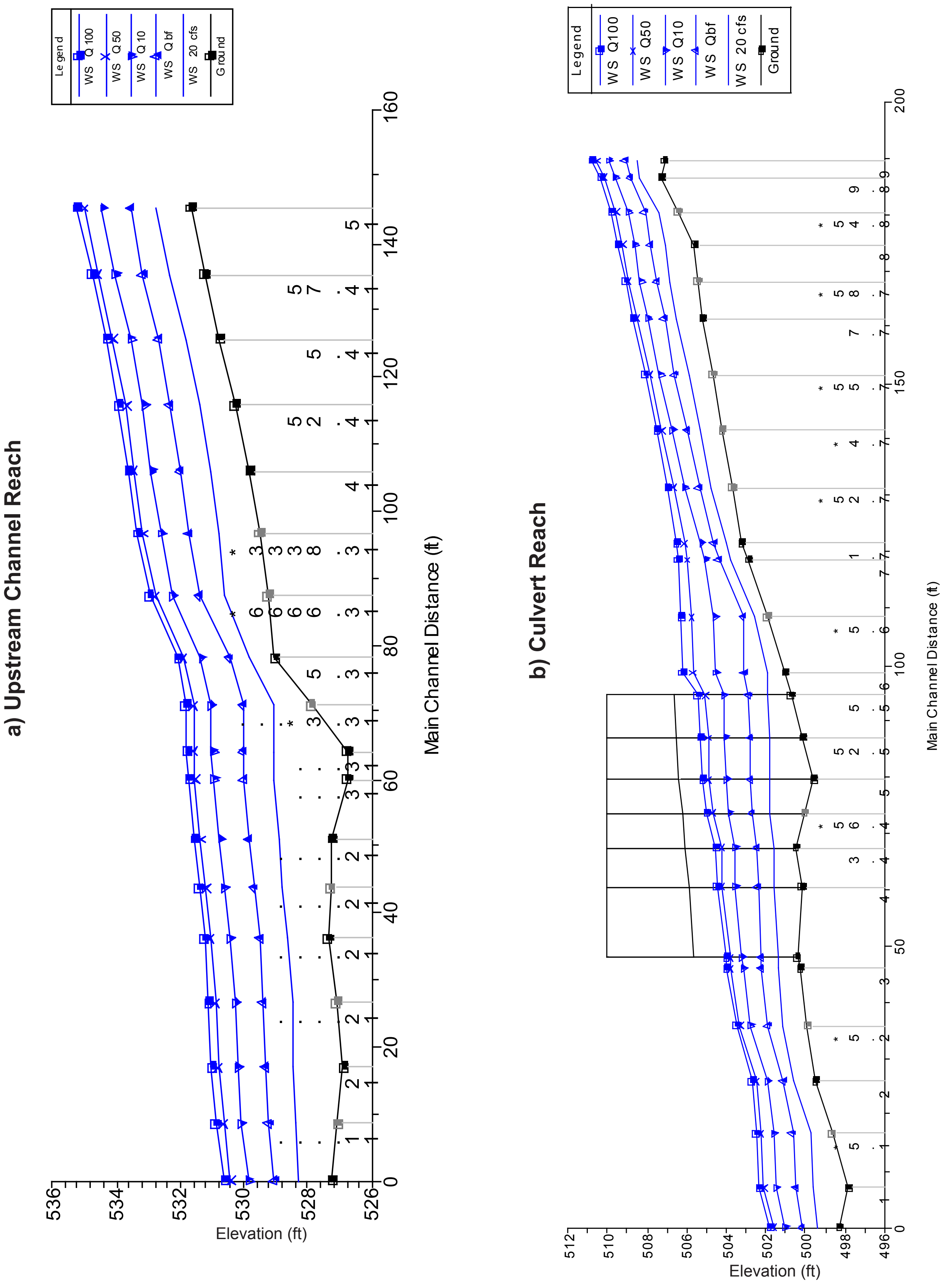
Culvert Segment	Representative Channel Segment	% Difference in Gradient
G	L	34%
Downstream Transition		
F	M	35%

Segment	Segment Length (ft)	Segment Gradient
A	22	0.046
B	17	0.075
C	47	0.022
D	12	0.130
E	36	0.030
F	26	0.060
G	76	0.015
H	22	0.101
I	72	0.054
J	66	0.080
K	245	0.060
L	78	0.023
M	68	0.039

Table 2—Summary of segments used for comparisons

Segment	Range of Manning's n values[1]	# of measured XSs	# of interpolated XSs
F	0.123—0.1279	2	3
G	0.058—0.123	4	6
L	0.1095—0.1179	2	9
M	0.1136—0.1164	2	6

[1]Obtained using equation from Jarrett (1984): $n = 0.39S0.38R-0.16$, where S=stream slope; R=hydraulic radius. Jarrett's equation only applied within the following ranges: S = 0.002 to 0.08, R = 0.5 ft to 7 ft. For cross sections outside these ranges, n was computed either from adjacent sections that fell within the ranges, using the guidance of Arcement and Schneider (1987), or from the HEC-RAS recommendations for culvert modeling.



Stations with decimal values are interpolated cross sections placed along the surveyed profile.

Figure 3—HEC-RAS profile.

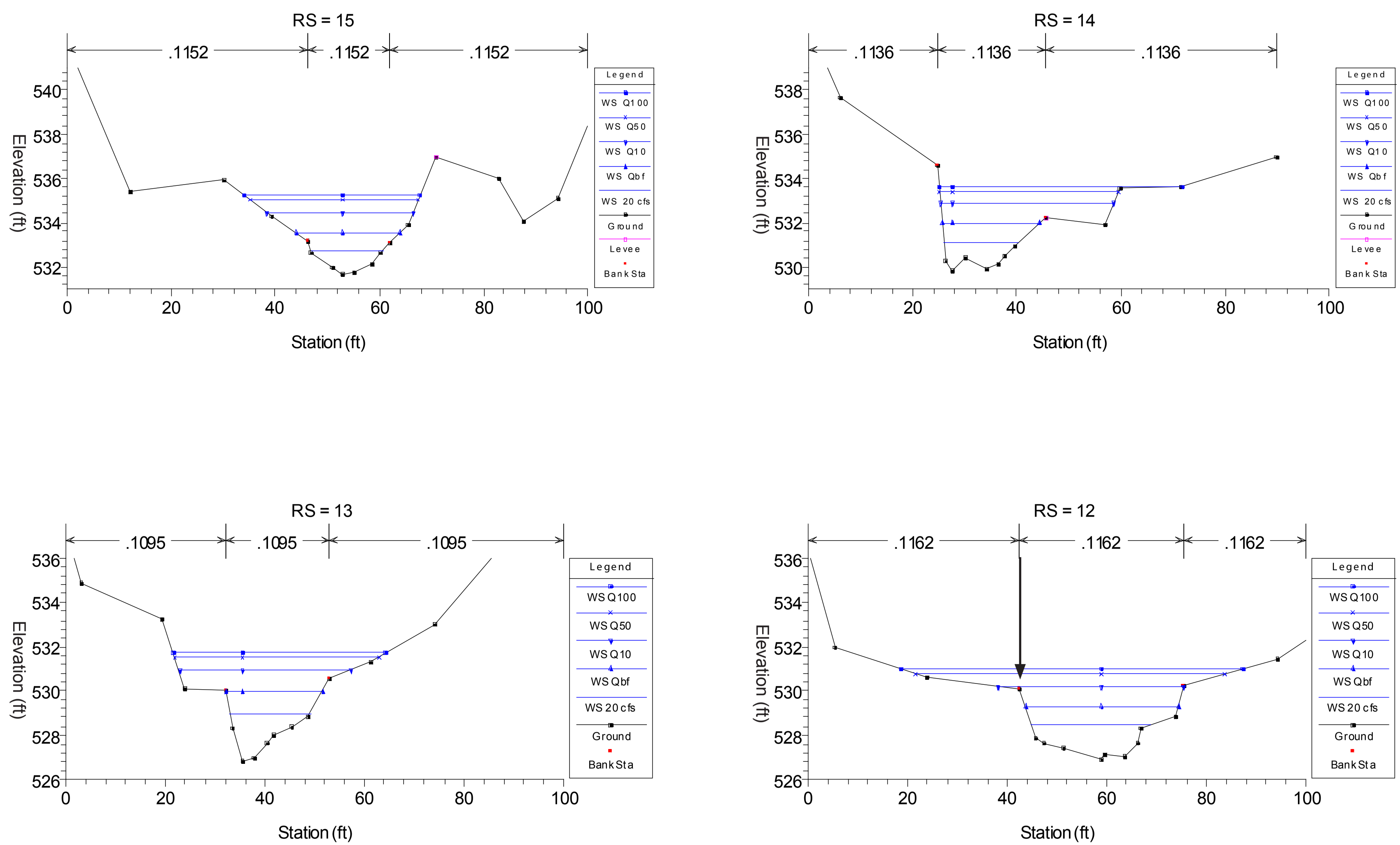
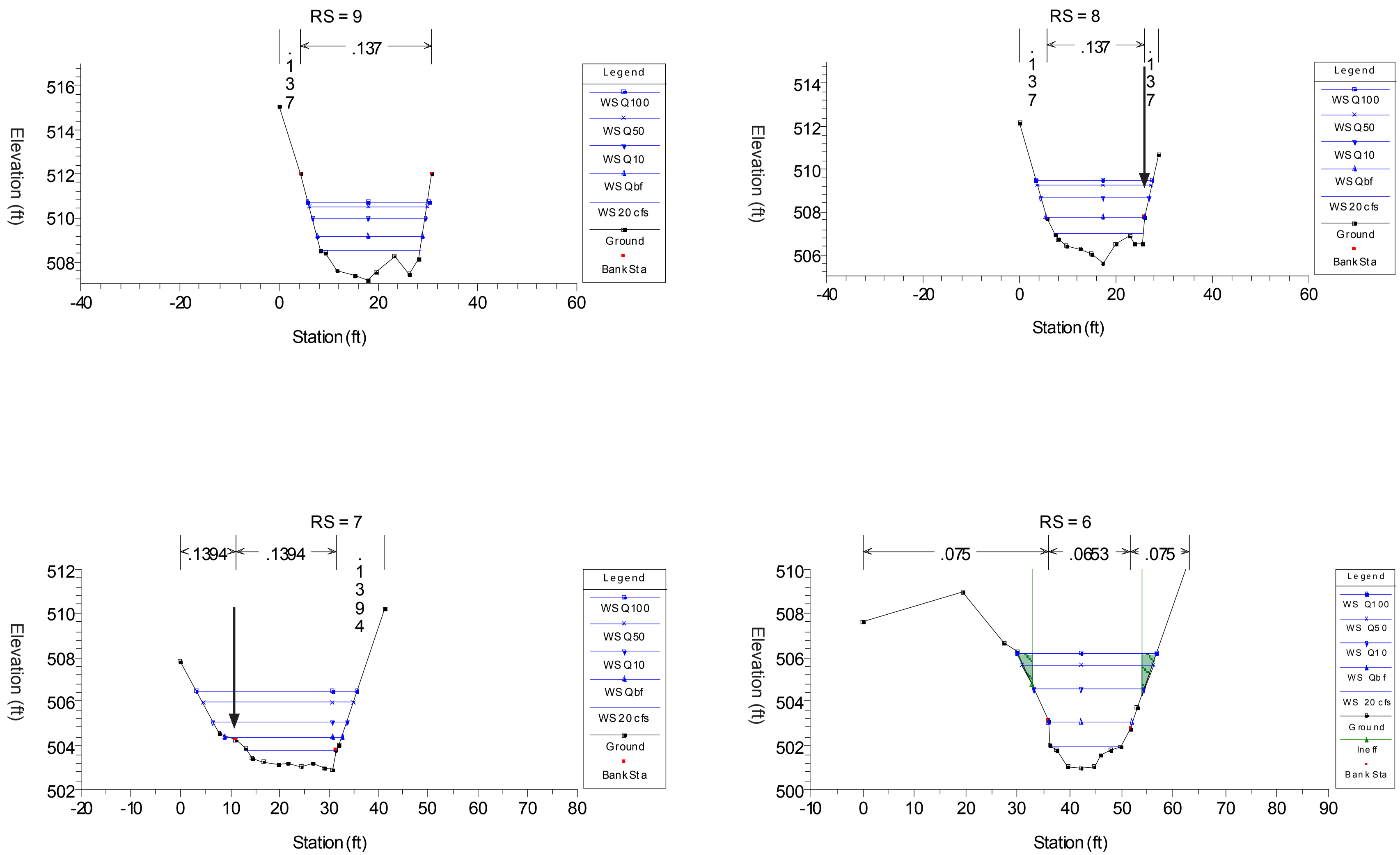


Figure 4—Cross-section plots. Only measured cross sections are included. Manning's n values are included at the top of the cross section. The stationing (RS) corresponds to the stationing on the HEC-RAS profile. Green arrows define the ineffective flow areas. Black arrows represent points identified in the field as the bankfull channel boundary. Only those points identified in the field and supported by hydraulic and topographic analyses are shown below.



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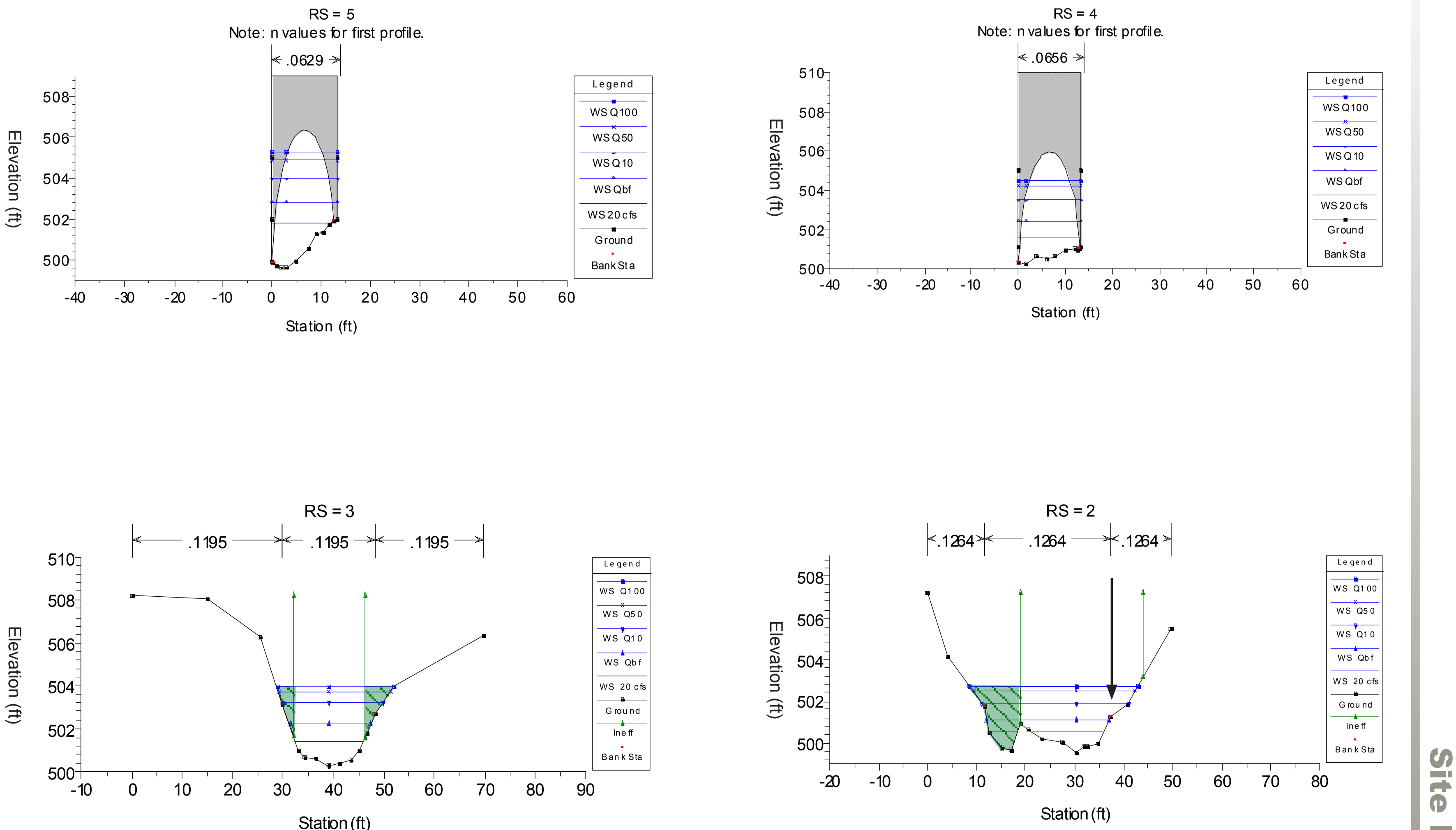

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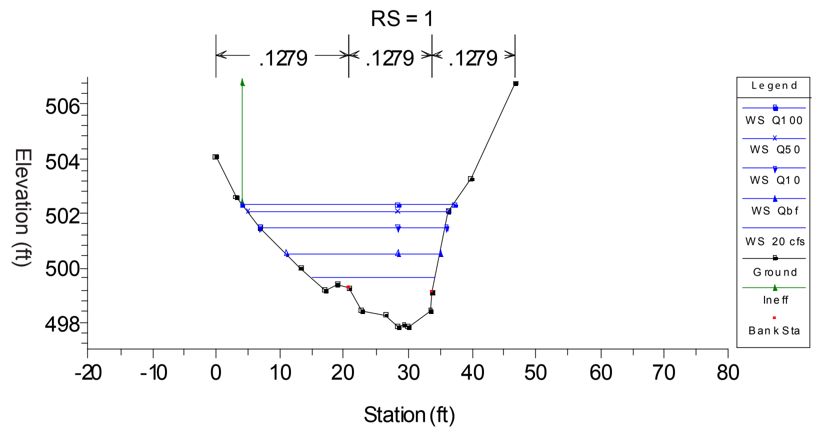

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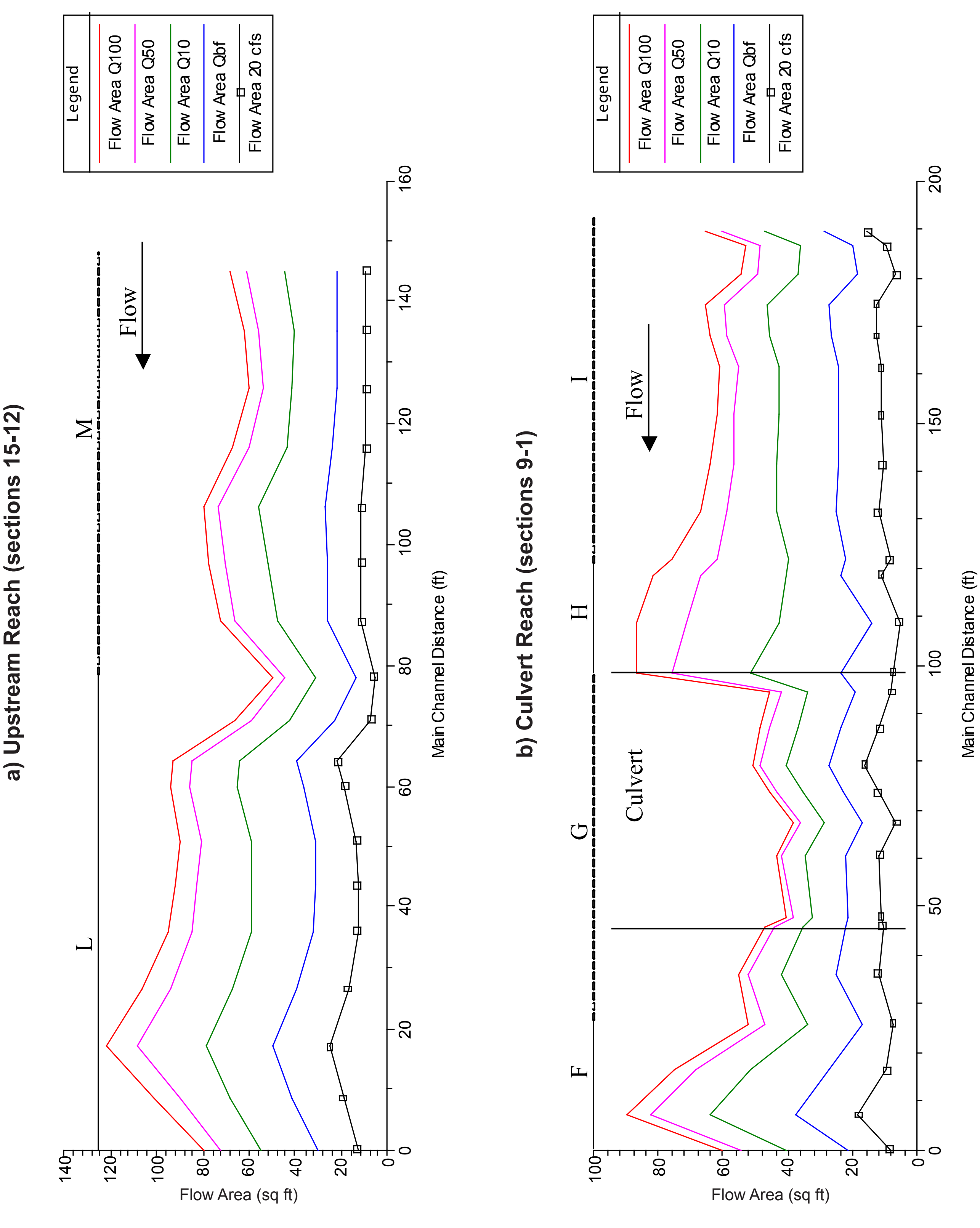


Figure 5—Flow Area (total) profile plot.

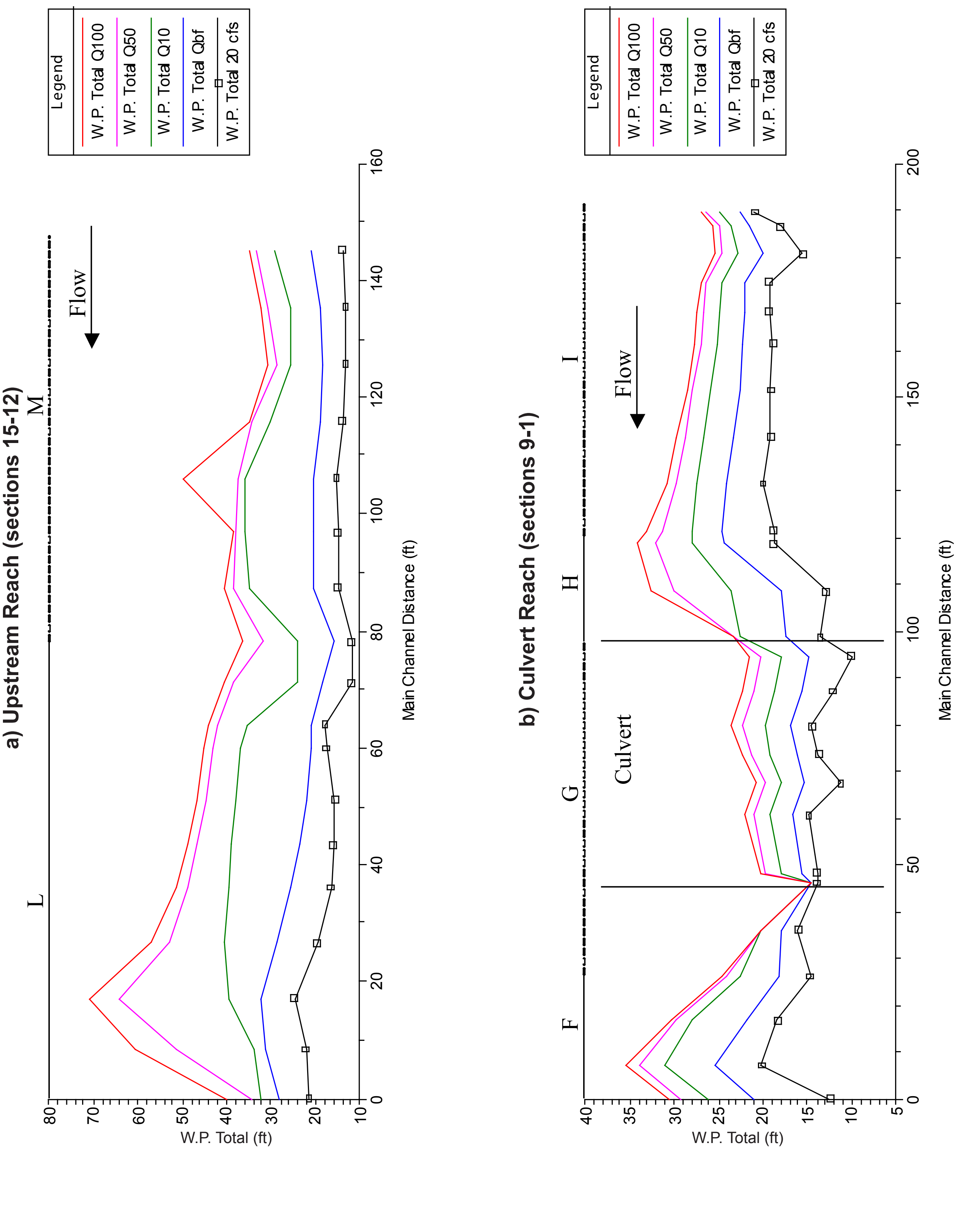


Figure 6—Wetted perimeter.

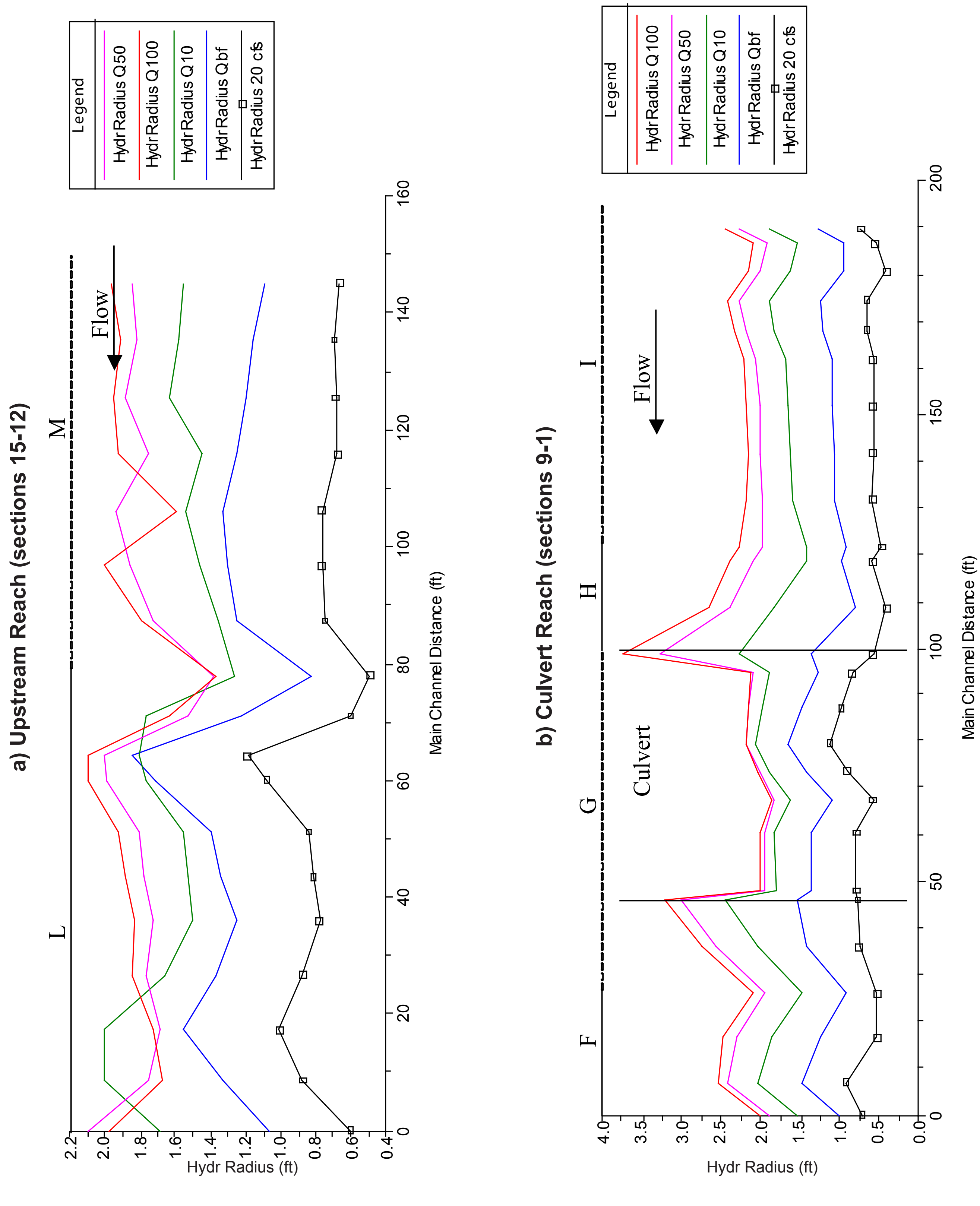


Figure 7—Hydraulic Radius.

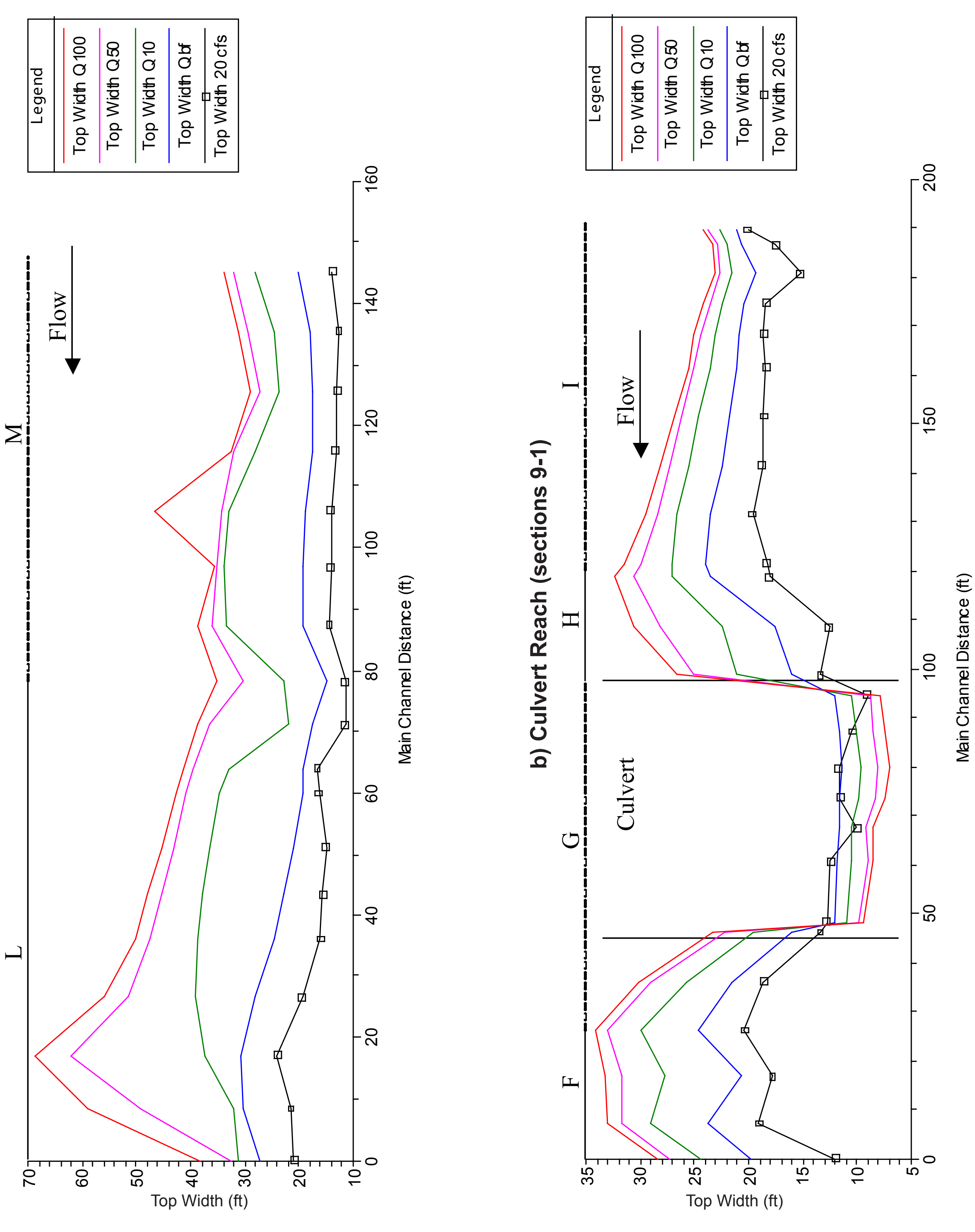


Figure 8—Top Width.

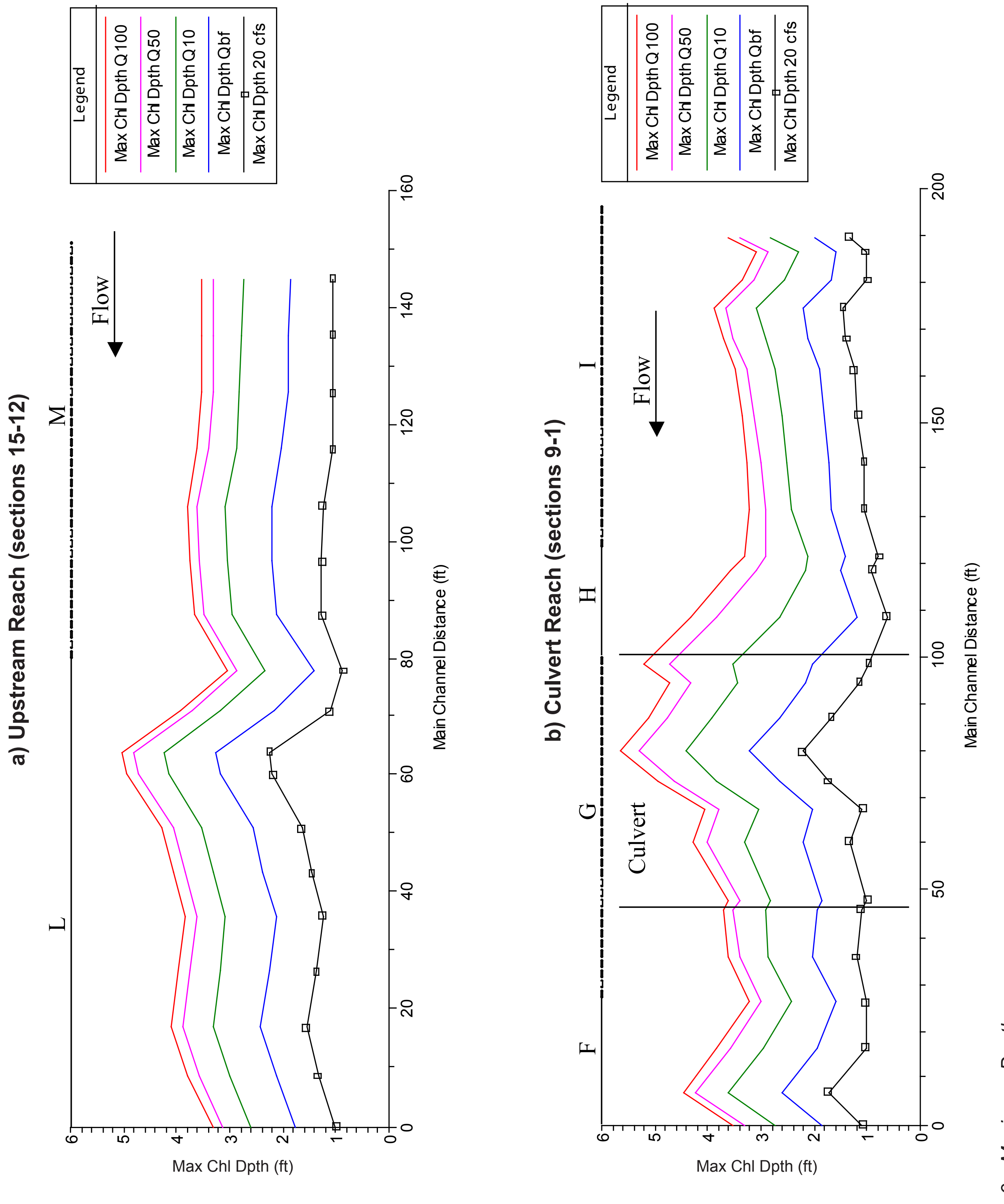


Figure 9—Maximum Depth.

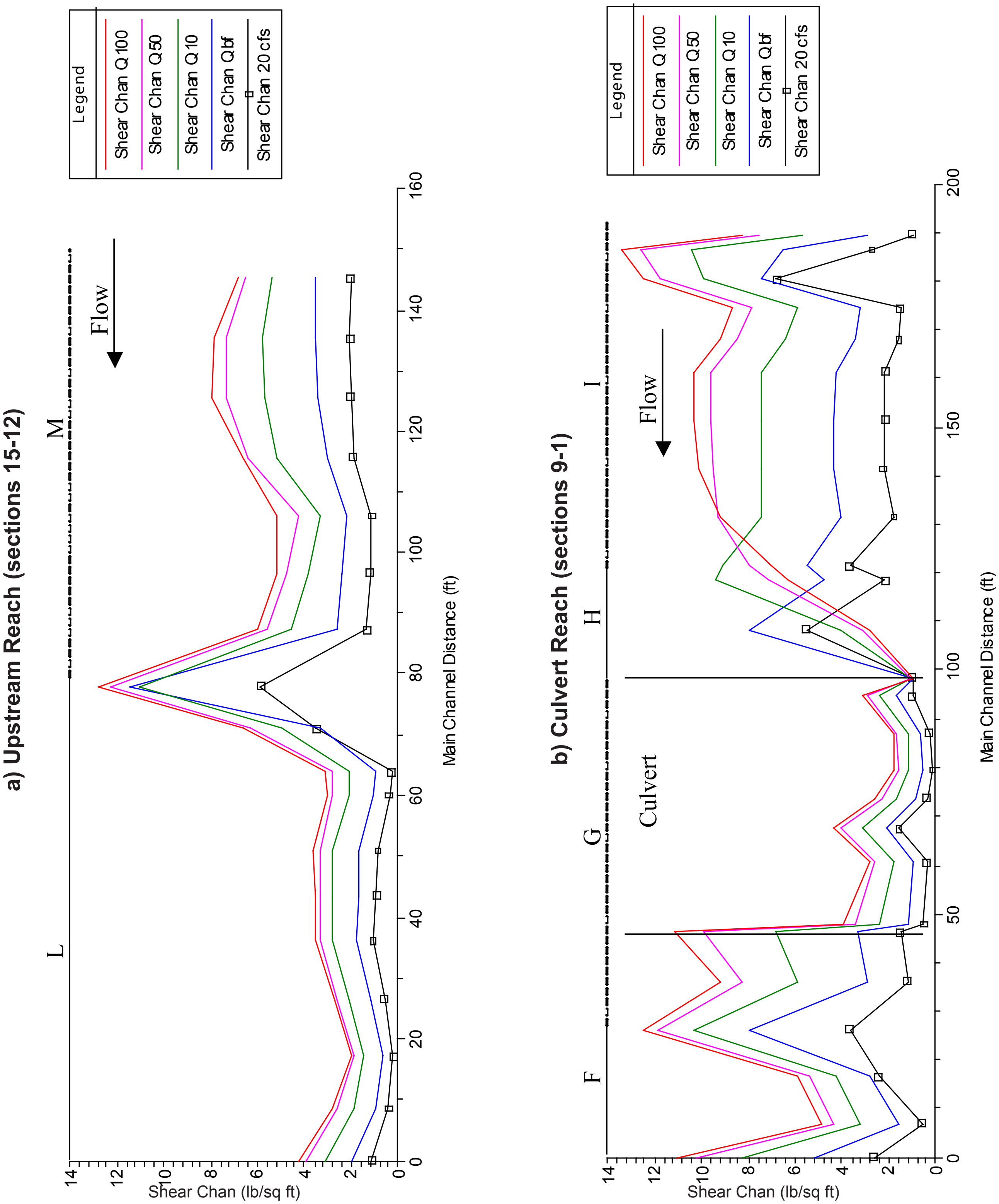


Figure 10—Shear stress (channel) profile.

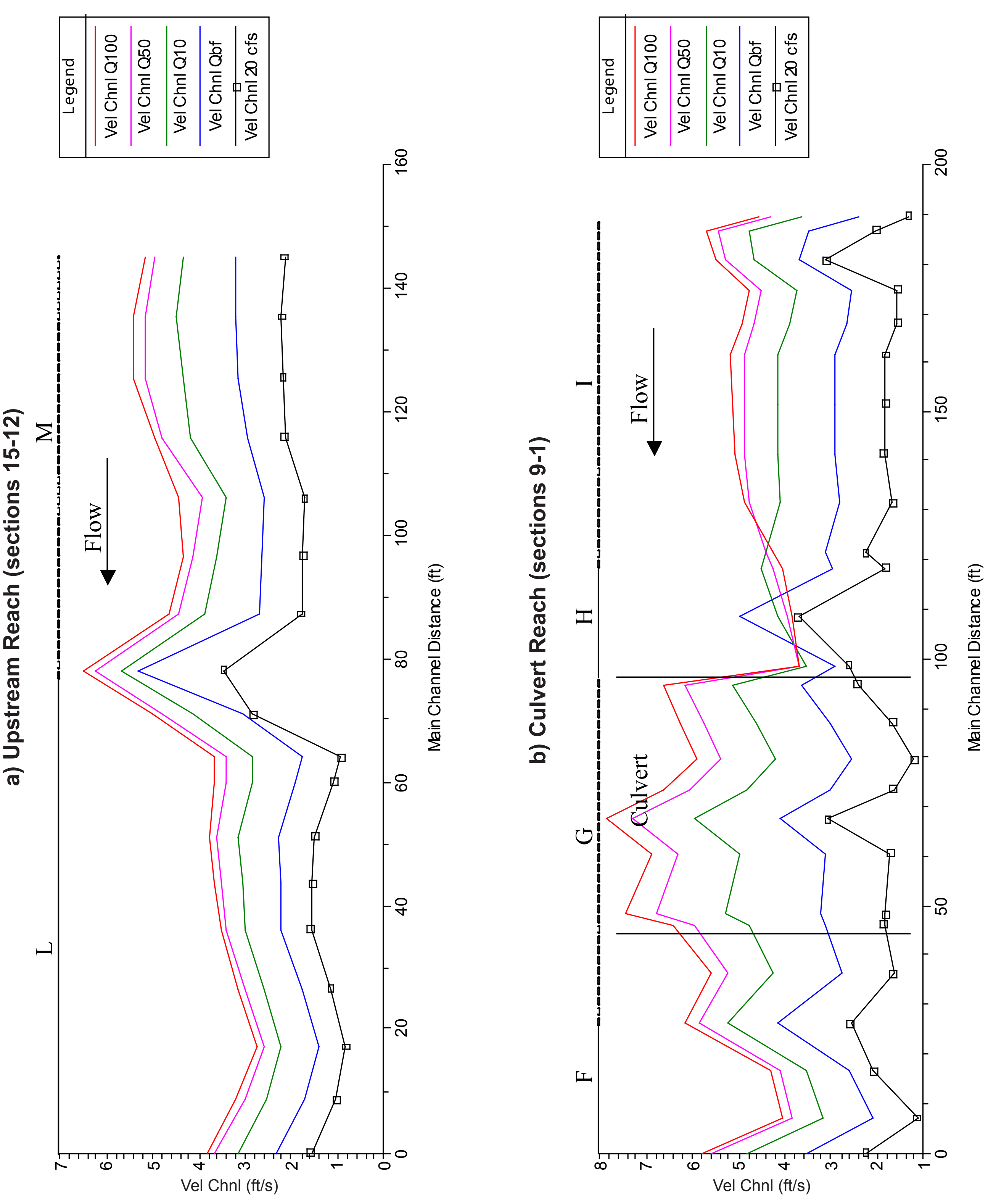
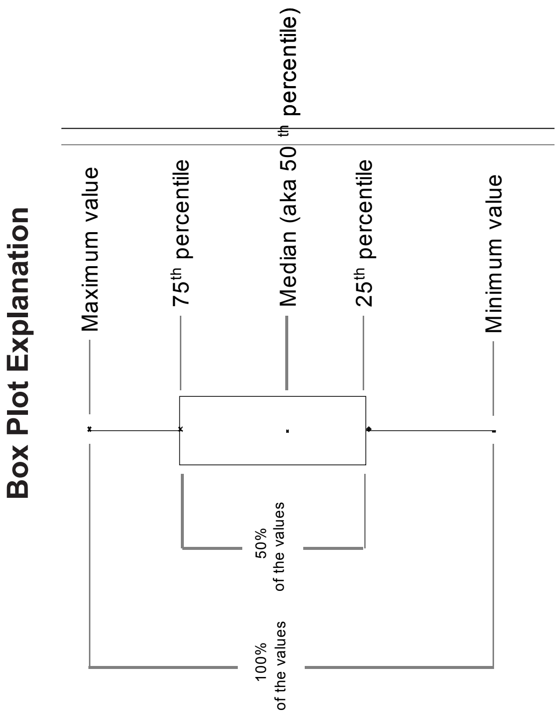


Figure 11—Velocity (channel) profile plot.



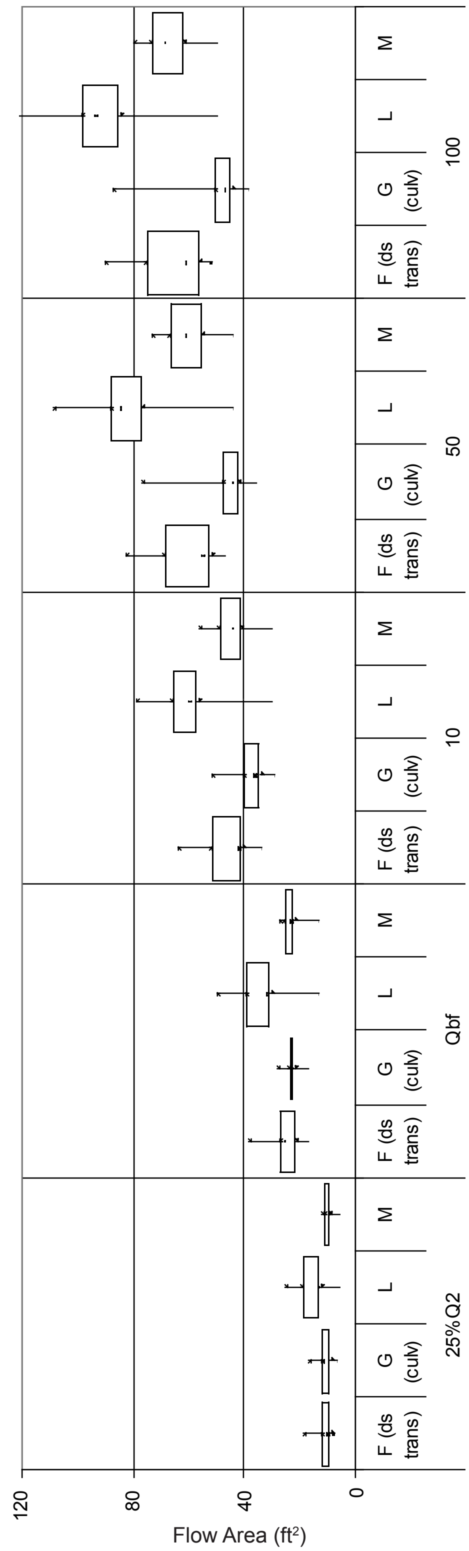


Figure 12—Flow Area (total).

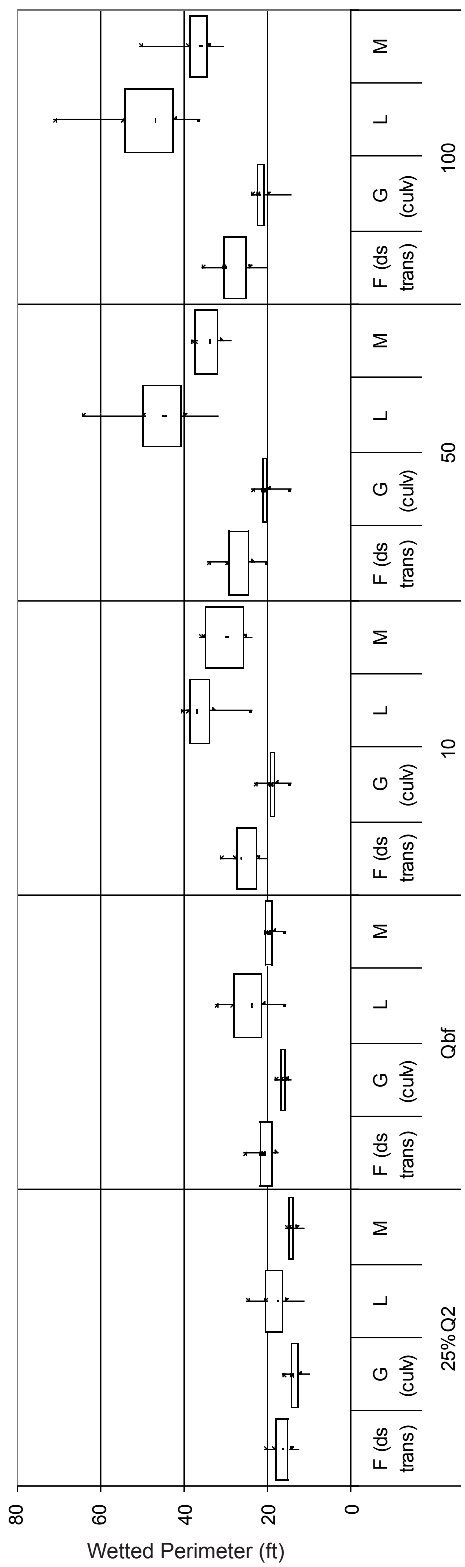


Figure 13—Wetted Perimeter.

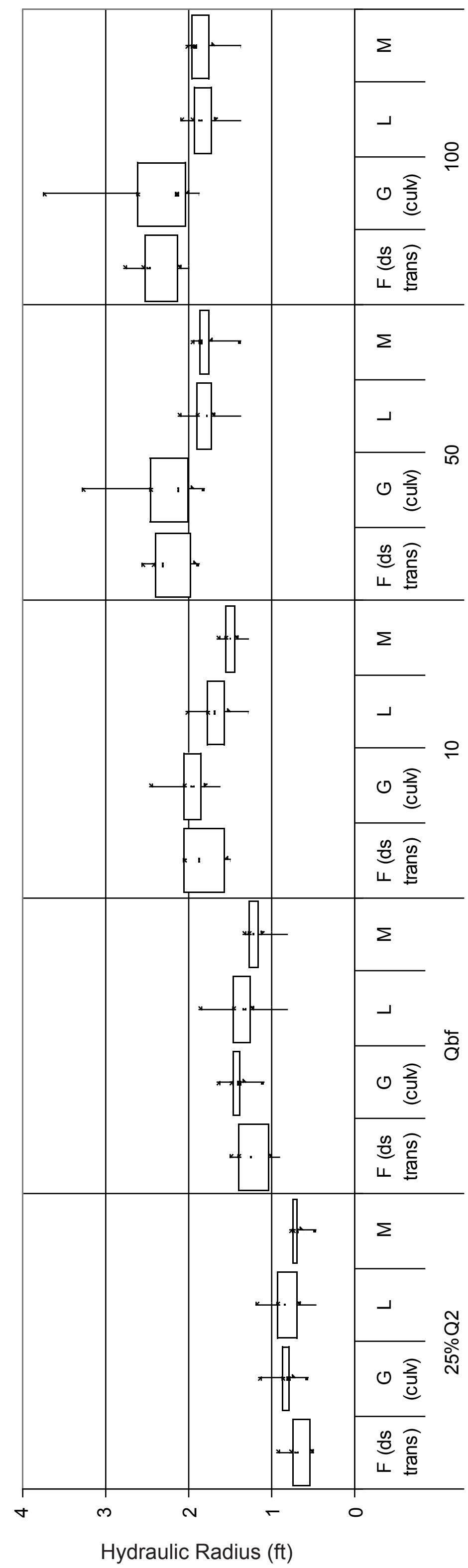


Figure 14—Hydraulic Radius.

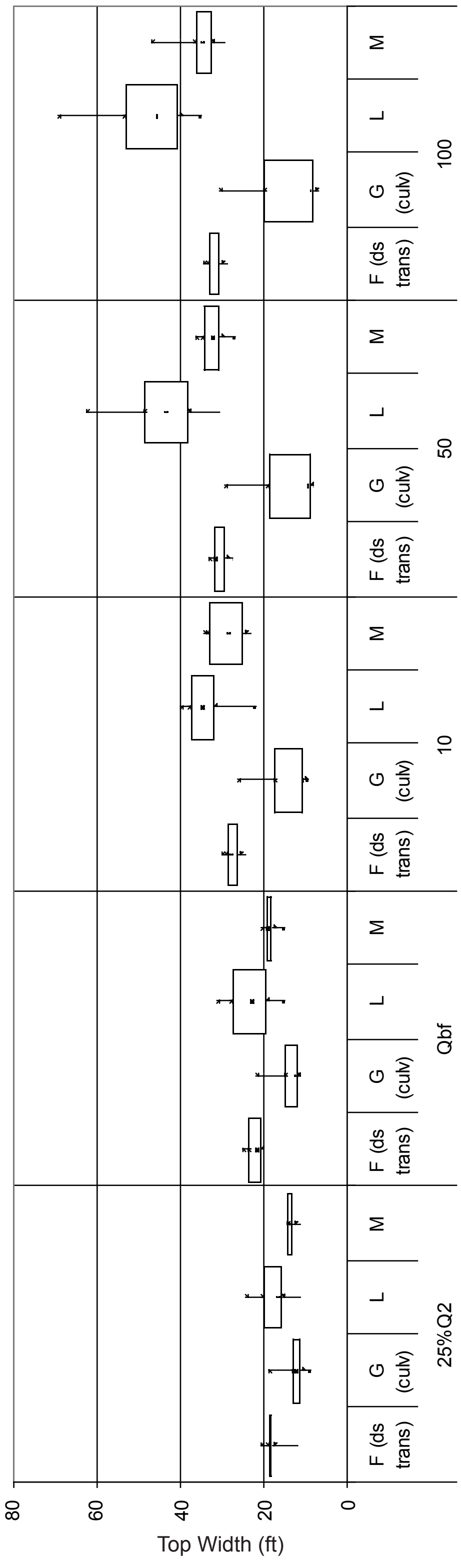


Figure 15—Top Width.

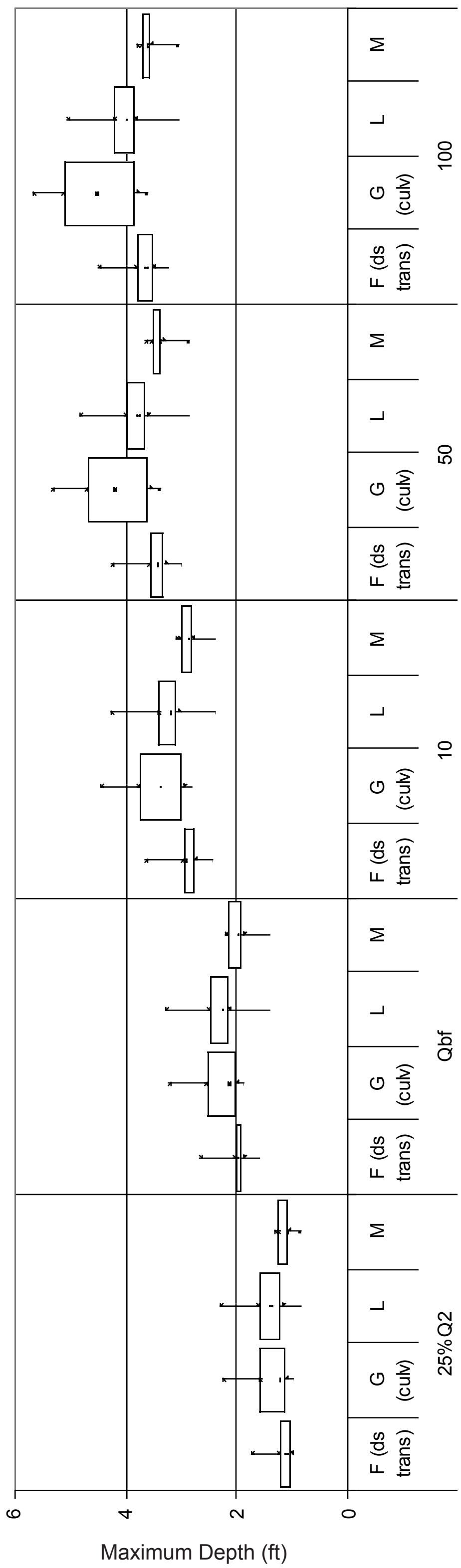


Figure 16—Maximum Depth.

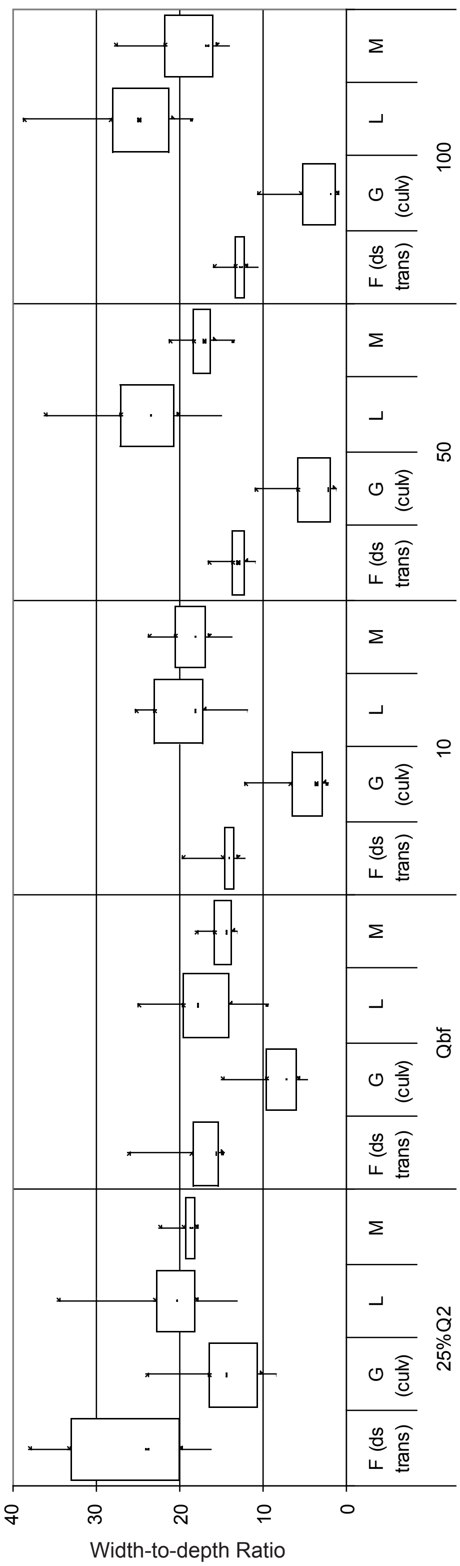


Figure 17—Width-to-depth Ratio.

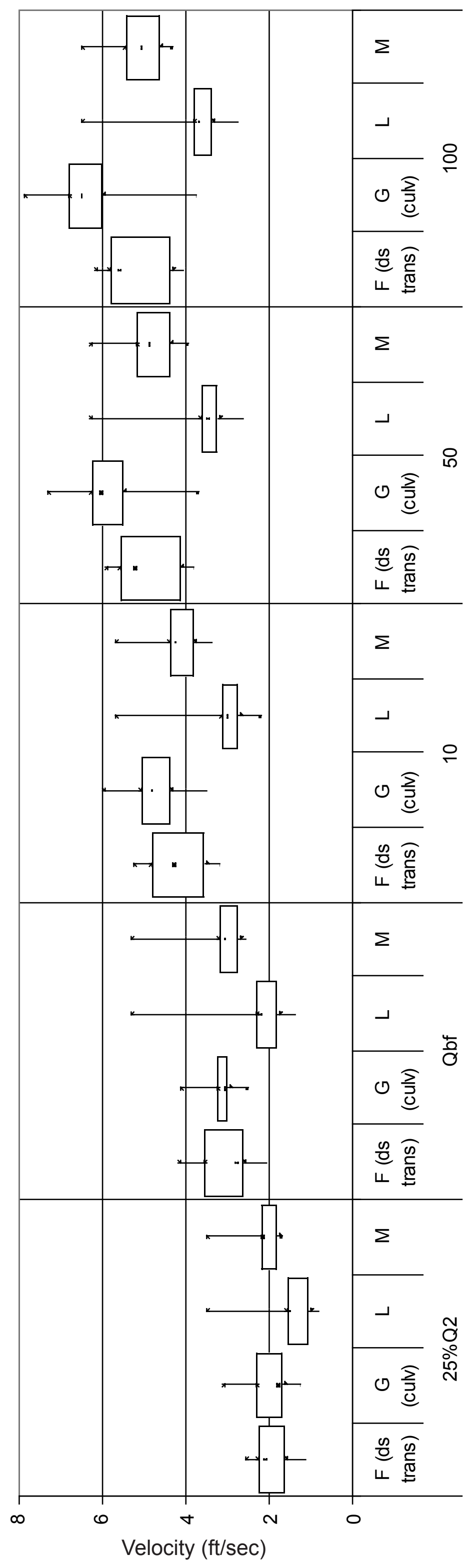


Figure 18—Velocity (channel).

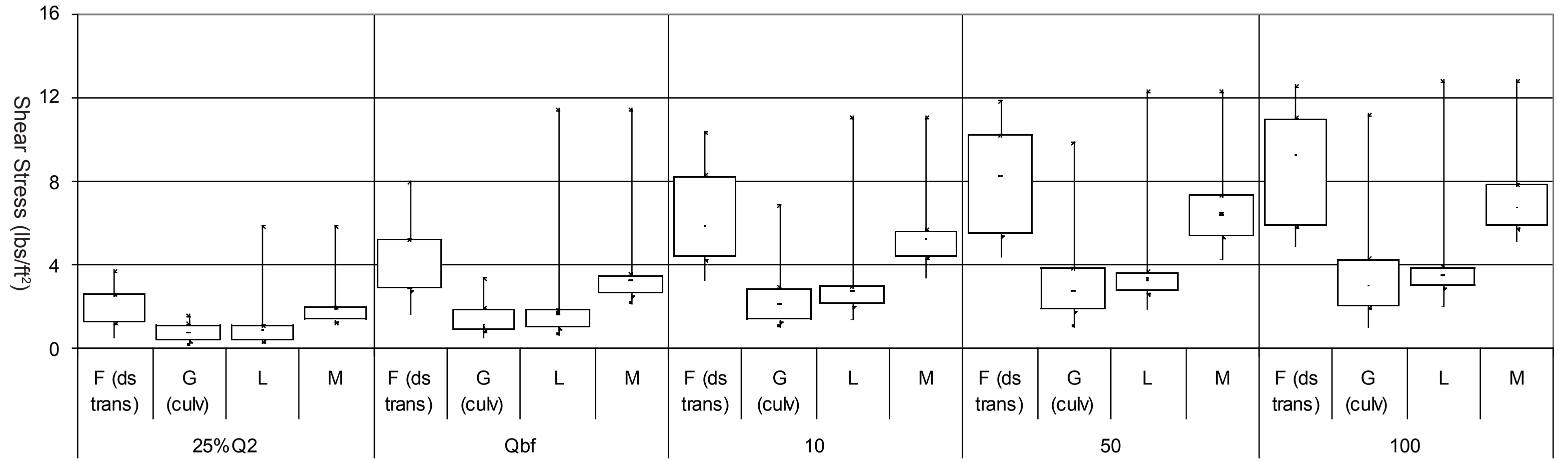
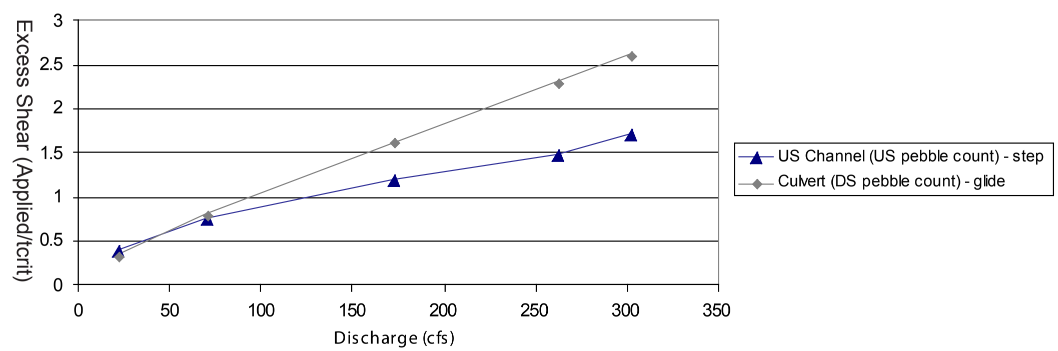


Figure 19—Shear Stress (channel).



Excess shear stress is the channel shear divided by the critical shear for bed entrainment of the D_{84} particle size. Values of excess shear greater than 1 indicate bed movement for the D_{84} particle size.

Figure 20—Excess Shear Stress.

Table 3—Sum of squared height difference

Reach	XS Location	Unit type	Sum of squared height difference	Within range of channel conditions?
Culvert	US	Pool	0.10	No
	DS	Glide	0.03	No
Upstream	US	Step	0.09	
	DS	Pool	0.07	

Table 4—Vertical sinuosity

Segment	Location	Vertical Sinuosity (ft/ft)
A	DS Channel	1.040
B	DS Channel	1.046
C	DS Channel	1.049
D	DS Channel	1.001
E	DS Channel	1.018
F	DS transition	1.018
G	Culvert	1.002
H	US transition	1.006
I	US Channel	1.015
J	US Channel	1.015
K	US Channel	1.007
L	US Channel	1.003
M	US Channel	1.002

Table 5—Depth distribution

Reach	XS Location	25% Q_2	Within range of channel conditions?
Culvert	US	2	No
	DS	0	No
Upstream	US	4	
	DS	4	

Table 6—Habitat unit composition

	Percent of surface area			
Reach	Pool	Glide	Riffle	Step
Culvert	32%	44%	0%	0%
Upstream Channel	15%	0%	76%	7%

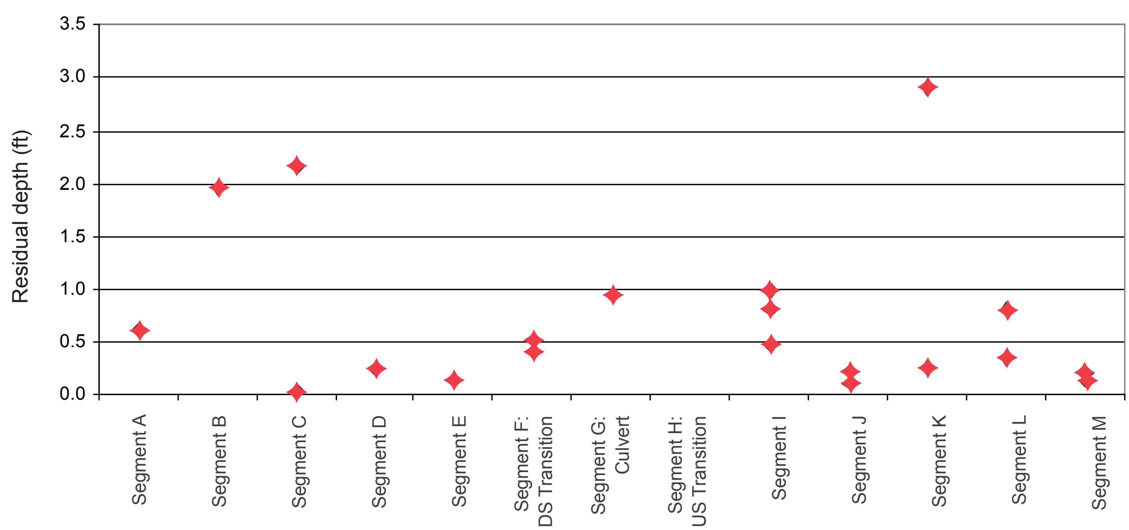


Figure 21—Residual depths.

Table 7—Bed material sorting and skewness

Reach	XS Location	Unit Type	Sorting	Within range of channel conditions?	Skewness	Within range of channel conditions?
Culvert	US	Pool	1.34	No	0.16	No
	DS	Glide	1.70	No	0.15	No
Upstream	US	Step	1.45		0.23	
	DS	Pool	1.64		0.26	

Table 8—Large woody debris

Reach	Pieces/Channel Width
Culvert	0
Upstream	2.6

Terminology:

US = Upstream

DS = Downstream

RR = Reference reach

XS = Cross section

View upstream through culvert.

View downstream through culvert.

Culvert—downstream pebble count, glide.

Culvert—upstream pebble count, pool.

Upstream reference reach—upstream pebble count, riffle.

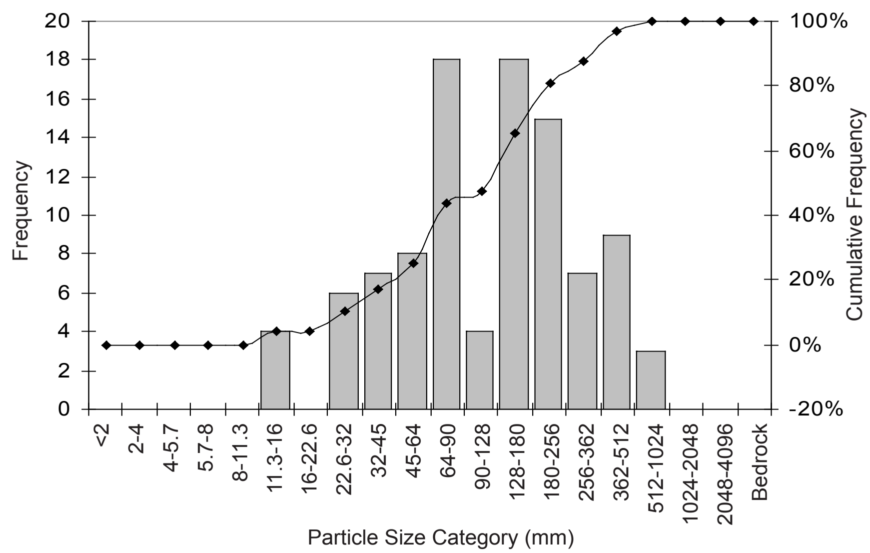
Upstream reference reach—downstream pebble count, pool.

View upstream from culvert.

View downstream from culvert (log step in center).

Cross section: Upstream Reference Reach—Upstream Pebble Count

Material	Size Class (mm)	Count	Item %	Cumulative %
sand	<2	0	0%	0%
very fine gravel	2 - 4	0	0%	0%
fine gravel	4 - 5.7	0	0%	0%
fine gravel	5.7 - 8	0	0%	0%
medium gravel	8 - 11.3	0	0%	0%
medium gravel	11.3 - 16	4	4%	4%
coarse gravel	16 - 22.6	0	0%	4%
coarse gravel	22.6 - 32	6	6%	10%
very coarse gravel	32 - 45	7	7%	17%
very coarse gravel	45 - 64	8	8%	25%
small cobble	64 - 90	18	18%	43%
medium cobble	90 - 128	4	4%	47%
large cobble	128 - 180	18	18%	66%
very large cobble	180 - 256	15	15%	81%
small boulder	256 - 362	7	7%	88%
small boulder	362 - 512	9	9%	97%
medium boulder	512 - 1024	3	3%	100%
large boulder	1024 - 2048	0	0%	100%
very large boulder	2048 - 4096	0	0%	100%
bedrock	Bedrock	0	0%	100%



Size Class	Size percent finer than (mm)
D5	25
D16	41
D50	130
D84	293
D95	450
D100	650

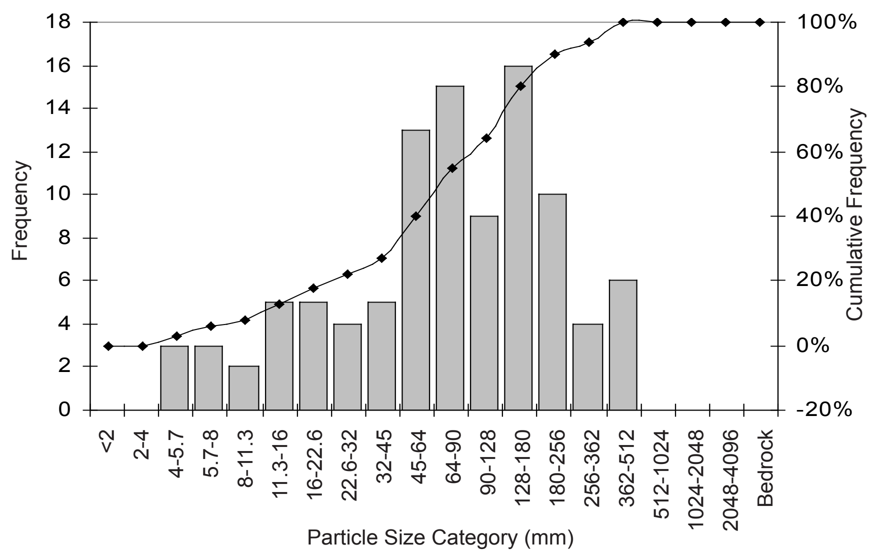
Material	Percent Composition
Sand	0%
Gravel	25%
Cobble	56%
Boulder	19%
Bedrock	0%

Sorting Coefficient: 1.45

Skewness Coefficient: 0.23

Cross section: Upstream Reference Reach—Downstream Pebble Count

Material	Size Class (mm)	Count	Item %	Cumulative %
sand	<2	0	0%	0%
very fine gravel	2 - 4	0	0%	0%
fine gravel	4 - 5.7	3	3%	3%
fine gravel	5.7 - 8	3	3%	6%
medium gravel	8 - 11.3	2	2%	8%
medium gravel	11.3 - 16	5	5%	13%
coarse gravel	16 - 22.6	5	5%	18%
coarse gravel	22.6 - 32	4	4%	22%
very coarse gravel	32 - 45	5	5%	27%
very coarse gravel	45 - 64	13	13%	40%
small cobble	64 - 90	15	15%	55%
medium cobble	90 - 128	9	9%	64%
large cobble	128 - 180	16	16%	80%
very large cobble	180 - 256	10	10%	90%
small boulder	256 - 362	4	4%	94%
small boulder	362 - 512	6	6%	100%
medium boulder	512 - 1024	0	0%	100%
large boulder	1024 - 2048	0	0%	100%
very large boulder	2048 - 4096	0	0%	100%
bedrock	Bedrock	0	0%	100%



Size Class	Size percent finer than (mm)
D5	8
D16	22
D50	80
D84	220
D95	410
D100	490

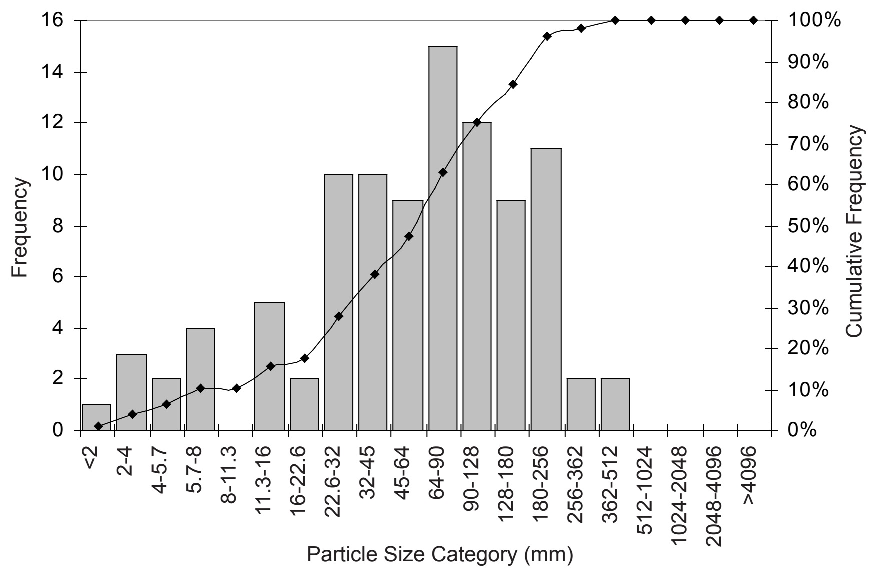
Material	Percent Composition
Sand	0%
Gravel	40%
Cobble	50%
Boulder	10%
Bedrock	0%

Sorting Coefficient: 1.64

Skewness Coefficient: 0.26

Cross section: Culvert—Upstream Pebble Count

Material	Size Range (mm)	Count	Item %	Cumulative %
sand	<2	1	1%	1%
very fine gravel	2 - 4	3	3%	4%
fine gravel	4 - 5.7	2	2%	6%
fine gravel	5.7 - 8	4	4%	10%
medium gravel	8 - 11.3	0	0%	10%
medium gravel	11.3 - 16	5	5%	15%
coarse gravel	16 - 22.6	2	2%	18%
coarse gravel	22.6 - 32	10	10%	28%
very coarse gravel	32 - 45	10	10%	38%
very coarse gravel	45 - 64	9	9%	47%
small cobble	64 - 90	15	15%	63%
medium cobble	90 - 128	12	12%	75%
large cobble	128 - 180	9	9%	85%
very large cobble	180 - 256	11	11%	96%
small boulder	256 - 362	2	2%	98%
small boulder	362 - 512	2	2%	100%
medium boulder	512 - 1024	0	0%	100%
large boulder	1024 - 2048	0	0%	100%
very large boulder	2048 - 4096	0	0%	100%
bedrock	> 4096	0	0%	100%



Size Class	Size percent finer than (mm)
D5	5
D16	19
D50	70
D84	176
D95	242
D100	490

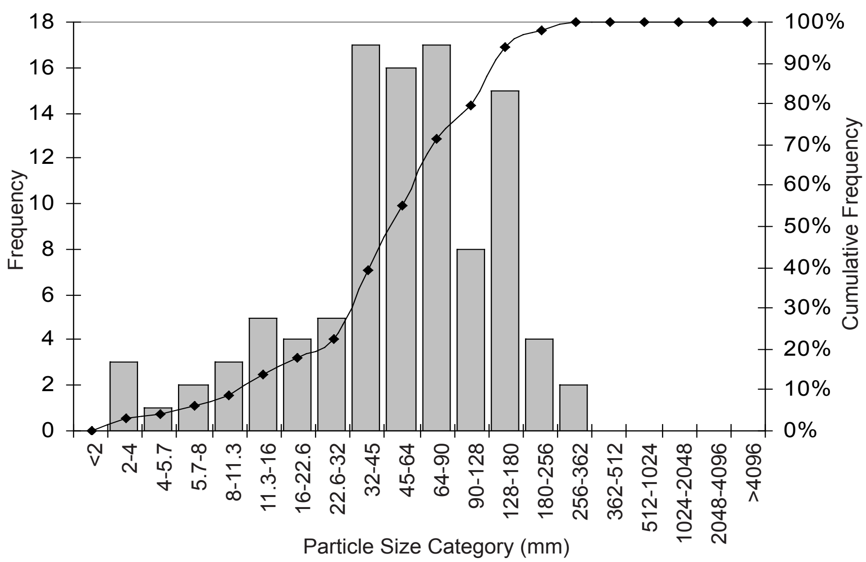
Material	Percent Composition
Sand	1%
Gravel	46%
Cobble	48%
Boulder	4%
Bedrock	0%

Sorting Coefficient: 1.34

Skewness Coefficient: 0.16

Cross section: Culvert –Downstream Pebble Count

Material	Size Class (mm)	Count	Item %	Cumulative %
sand	<2	0	0%	0%
very fine gravel	2 - 4	3	3%	3%
fine gravel	4 - 5.7	1	1%	4%
fine gravel	5.7 - 8	2	2%	6%
medium gravel	8 - 11.3	3	3%	9%
medium gravel	11.3 - 16	5	5%	14%
coarse gravel	16 - 22.6	4	4%	18%
coarse gravel	22.6 - 32	5	5%	23%
very coarse gravel	32 - 45	17	17%	39%
very coarse gravel	45 - 64	16	16%	55%
small cobble	64 - 90	17	17%	72%
medium cobble	90 - 128	8	8%	79%
large cobble	128 - 180	15	15%	94%
very large cobble	180 - 256	4	4%	98%
small boulder	256 - 362	2	2%	100%
small boulder	362 - 512	0	0%	100%
medium boulder	512 - 1024	0	0%	100%
large boulder	1024 - 2048	0	0%	100%
very large boulder	2048 - 4096	0	0%	100%
bedrock	Bedrock	0	0%	100%



Size Class	Size percent finer than (mm)
D5	6
D16	20
D50	60
D84	140
D95	190
D100	300

Material	Percent Composition
Sand	0%
Gravel	55%
Cobble	43%
Boulder	2%
Bedrock	0%

Sorting Coefficient: 1.70

Skewness Coefficient: 0.15