TIRE CREEK

Site Information

Site Location: Willamette NF, Forest Rd 5826 MP 2.63

Year Installed: 1996

Lat/Long: 122°32’3.95”W 43°48’44.85”N

Watershed Area (mi²): 3.9

Stream Slope (ft/ft)[1]**:** 0.0523

Channel Type: Step-pool

Bankfull Width (ft): 22

Survey Date: March 23 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: 17 ft

Outlet Type: Mitered

Culvert Length: 62 ft

Inlet Type: Mitered

Pipe Slope (structure slope): 0.094

Culvert Bed Slope: 0.033

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

Culvert width as a percentage of bankfull width: 0.77

Alignment Conditions: Appears in good alignment with downstream channel but may be placed too close to confluence of upstream tributaries, which is creating scour at inlet.

Bed Conditions: Large cobble/boulder steps in culvert. At current flow, large boulders are functioning as channel banks inside the culvert.

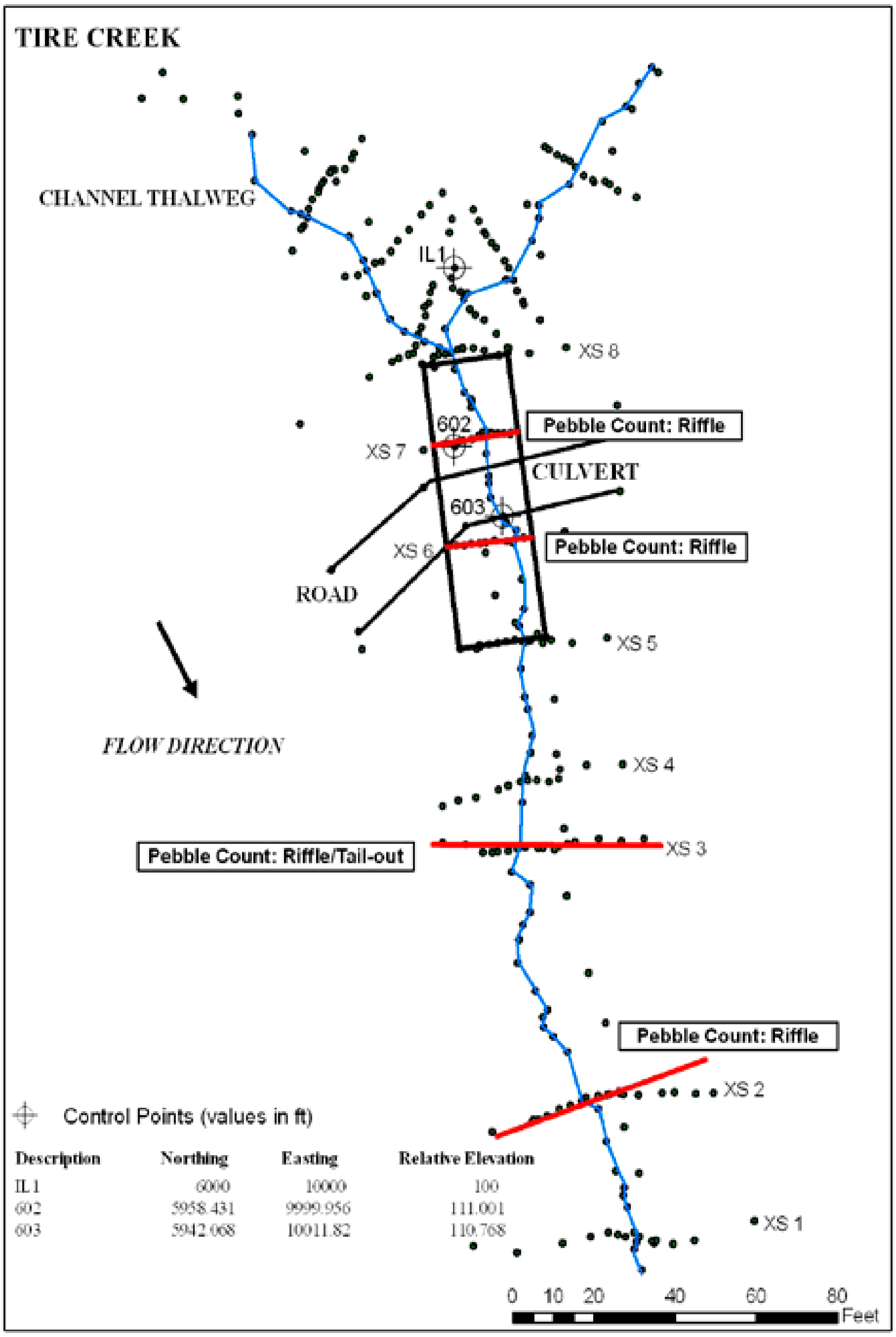
Pipe Condition: Potential risk of footing scour near inlet. Pipe in good condition.

Hydrology

Discharge (cfs) for indicated recurrence interval

25% 2-yr	Q_{bf}[2]	2-year	5-year	10-year	50-year	100-year
48	140	193	308	388	566	644

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



Points represent survey points

Figure 1. Plan view map

HISTORY

There is no information available for site history.

SITE DESCRIPTION

The Tire-Creek culvert is a bottomless arch mitered to conform to the roadfill. The entrance to the culvert sits at the junction of two steep step-pool streams of relatively equal size. The angle at which they join is roughly 45 degrees off the main channel and culvert. The channel through the culvert consists of a scour pool that transitions to a series of steps. The scour pool at the inlet has resulted in exposure of the stem walls and spread footing in places. Downstream of the scour pool the channel flows along half of the pipe width (left side) while the other half remains dry due to the large deposition of material along the right side.

The downstream representative reach consisted of a high gradient step-pool channel with a low but narrow active flood-plain surface. Steep riffles and steps are interspersed by pools. There were a few downed trees that spanned the channel.

SURVEY SUMMARY

Fourteen cross-sections and a longitudinal profile were surveyed along Tire Creek in March 2007 to characterize the culvert and a downstream representative reach. Representative cross sections in the culvert were taken through a step and between steps. One additional cross section was surveyed downstream of the culvert to characterize the outlet as well as the expansion of flow. In order to capture the inlet, the junction of the two channels, and the contraction of flow, seven cross sections were taken upstream of the culvert. Profiles were taken up both channels to obtain slopes. Four cross sections were surveyed to characterize the downstream reach; one at the upstream end, one at the downstream end, one through a riffle, and one between steps.

PROFILE ANALYSIS SEGMENT SUMMARY

The profile analysis resulted in a total of five profile segments. The culvert consisted of two profile segments. The downstream segment in the culvert was compared to two representative profile segments in the upstream channel, although gradients between culvert and representative segments varied by 37 percent for each comparison. There was no suitable comparison segment for the downstream transition segment. The upstream transition segment was unique in its position at the confluence of the two forks; this transition therefore had no comparable representative channel segment. See figure 2, table 1, and table 2.

SCOUR CONDITIONS

Observed conditions

Footing scour – There was evidence of inlet scour along the right bank where the footing is scoured to the depth of the base footing. Observed scour does not appear to be undermining footings or threatening 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. This flattening appears to be mostly due to aggradation within the downstream portion of culvert, with some inlet scour within the upstream portion of the culvert. However, compared to most culverts which exhibit bed flattening, the downstream portion of the culvert is relatively steep, while the upstream relatively flat.

Profile characteristics – The profile has a convex shape through the crossing (figure 2) which is a result of the reorganization of material as some of the material was scoured out from the inlet and the channel upstream of the crossing and deposited downstream.

Residual depths – Culvert-residual depths in segment D ranged from 0.19 feet to 0.80 feet. These values were greater than the single value found in the downstream representative channel segment A (0.06 feet), but well within the range of those found in downstream representative channel segment B (0.08 feet to 0.87 feet) (figure 21). This suggests no significant scour beyond what is found in the channel outside of the crossing.

Substrate – Bed material distributions are similar in the culvert compared to the channel. Culvert substrate is slightly coarser than channel pebble counts, reflecting a higher percentage of boulder-sized particles which may be a result of rock placement during construction. Alternatively, the coarse material may be sourced from the upstream tributaries and deposited within the culvert as the gradient and transport capacity is reduced. Pebble counts are provided at the end of this summary.

Predicted conditions

Cross-section characteristics – Cross-sectional flow area in the culvert is similar to the downstream channel for lower flows but begins to diverge by the Q_{10} (figure 5 and figure 12). Flow area in the culvert is lower than that found in the downstream representative channel segment A above the Q_{bf} but similar to that found in the downstream representative channel segment B for all flows. Above the 25 percent Q_2, the wetted perimeter in the culvert is less than in the downstream channel (figure 13). At the 25 percent Q_2, the hydraulic radius in the culvert is similar to that of both downstream channel segments (figure 14). For flows at or above the Q_{bf}, the hydraulic radius in the channel is greater than in the downstream channel. In contrast, the top width in the culvert is less than the downstream channel at and above the Q_{bf} (figure 15). For all flows, the maximum depth is greater in the culvert than it is in both of the downstream channel segments (figure 16). While width-to-depth ratio in the culvert is within the range of the downstream channel segment A at the 25 percent Q_2, it becomes less than both channel segments at and above the Q_{bf} (figure 17).

Shear stress – Shear stress in the culvert is similar to the downstream channel for lower flows but begins to diverge by the Q_{10} (figure 10 and figure 19). Above the Q_{10} both representative channel segments A and B have greater shear-stress values than does the culvert. It is also above the Q_{10} that the shear stress in the culvert remains relatively similar with a slight decline in magnitude with increasing flows. This is most likely a result of the backwater created through the culvert. However, these results may not be real and may be a function of model limitations.

Excess shear – The excess-shear analysis shows that the downstream channel has greater potential for bed mobility than does the culvert, especially at higher flows (figure 20). This corresponds with lower shear in the culvert at higher flows due to outlet-control conditions in the culvert.

Velocity – Velocity in the culvert is similar to the downstream representative channel segments for all flows (figure 11 and figure 18). Additionally, the range in velocity values for a given flow through the culvert is relatively similar to the range of values in the downstream representative channel segments.

Scour summary

Assuming that the culvert and the culvert bed were originally constructed on the same grade, significant bed adjustment has occurred. The entrance to the culvert sits at the junction of two steep step-pool streams of relatively equal size. The angle at which they join is roughly 45 degrees off the main channel and culvert. Placement of the culvert close to this confluence has likely altered upstream conditions. Flow contraction at the inlet has resulted in scouring of the banks, resulting in the upward retreat of the channel junction. In order to match this, the channels have steepened their profiles, further increasing stream energy and scour upstream as well as around the culvert inlet. The transition in profile at the inlet to the culvert has resulted in scour at the upstream end of the culvert. Reorganization of material has resulted in downstream deposition. The exposure of the footings at the inlet and not at the outlet is likely a result of this adjustment.

Generally a flattening of the bed results in a concave bed profile. However, the profile through the Tire Creek crossing is convex with a relatively flat segment through the inlet which transitions to a steep riffle as the channel goes towards the outlet. This might be a falling limb signature from a recent flood.

Conditions indicate a low-to-medium risk for future scour within the culvert. There is likely to be a continued upstream supply of material as the channel immediately upstream of the inlet continues to widen in response to the culvert installation, potentially resulting in further footing exposure. Continued aggradation in the culvert is possible, especially at high flows where outlet control conditions reduce the energy slope in the pipe.

AOP CONDITIONS

Cross-section complexity – The sum of squared height differences in the culvert cross sections are greater than those measured in the channel cross sections (table 3). These results may be a function of the steep sides of the culvert and may not be representative of the channel bed.

Profile complexity – Vertical sinuosity in the culvert segments is greater than the range of those in the channel segments (table 4).

Depth distribution – There is more channel margin habitat in the culvert compared to the channel at the 25 percent Q_2 (table 5). This can be attributed to a bar along the right channel which was dry during the time of the survey. At the 25 percent Q_2, this bar is covered by 0.30 feet or less providing significant shallow water areas through the culvert.

Habitat units – The habitat-unit composition is similar between the culvert and the downstream channel (table 6). More pool habitat and less riffle habitat exists within the culvert than does in the downstream channel. While the percentage of step habitat is not very high within either the culvert or the downstream channel, there are numerous short steps in the downstream channel that do not exist in the culvert. The result of more numerous short steps, are longer pools in the downstream channel. There is one step at the outlet of the culvert.

Residual depths – Culvert-residual depths are within the range of channel conditions (figure 21).

Bed material – Bed-material distributions are similar in the culvert compared to the channel (see pebble count data provided at end of this site summary). There are slightly less gravels in the culvert but a similar percentage of sand compared with the downstream channel. The size and frequency of the large particles in the culvert are slightly greater than the downstream channel. This may reflect the gradient transition and large source material coming in from the two tributaries. Culvert bed material sorting values represent the range of values found at the Tire Creek site. The upstream culvert cross section, with the lowest gradient of the segments used in the comparison, has the highest sorting value which indicates that it has “very poor” sorting with a relatively wide distribution including both small gravels and sand and large cobbles and boulders. The downstream cross section in the culvert has the lowest sorting value and is more similar to the downstream channel within the range found in the stream channel (table 7).

Large woody debris – There was no LWD present in the culvert (table 8). The representative channel had moderate to 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.

AOP summary

Measurements and observations suggest that the Tire Creek culvert has similar, if not better, conditions to the natural channel with respect to AOP. The two measurements of channel complexity (cross section and profile) indicate that the culvert has greater complexity than does the downstream representative channel. These results must be analyzed with caution, as the vertical walls of the culvert have been shown to artificially increase the cross-section complexity. However, material has aggraded along the right channel within the culvert creating an exposed bar during low flows. This aggraded surface creates good bank habitat, which indeed adds to channel complexity, flow concentration for fish passage, and dry streambanks for passage of terrestrial organisms.

A potential fish passage issue may exist at higher flows. The high percentage of pool habitat evident in the habitat unit composition is in the form of small, short pools, created and maintained by the large rock either placed or transported into the culvert from the steep creeks upstream. This could result in more turbulent conditions in the short pools during high flows, with less resting habitat compared to the channel where pools are longer.

Bed-material composition is similar between the culvert and the channel segments, with only slight differences that can be explained by the gradient transition through the reach. These similar bed compositions suggest that AOP is not impaired by the characteristics of the culvert bed material.

DESIGN CONSIDERATIONS

The Tire Creek culvert was placed very close to the junction of the two tributaries, likely resulting in the observed scour, upstream channel incision, and the upward retreat of the junction location. Placing the culvert further downstream may have lessened these impacts. At high flows, the modeling indicates the potential for outlet-control conditions in the culvert. This condition reduces the energy slope and may cause material to aggrade within the culvert and further limit hydraulic capacity. The culvert may be undersized to adequately convey these high flows. Use of a larger culvert would reduce the risk of significant bed adjustments. Other than these considerations, this is considered a good installation with respect to scour and AOP. There are stable bed elements within the culvert that maintain grade and create habitat complexity. Exposed banks during low flows help to concentrate flows for passage and also allow for passage of terrestrial organisms.

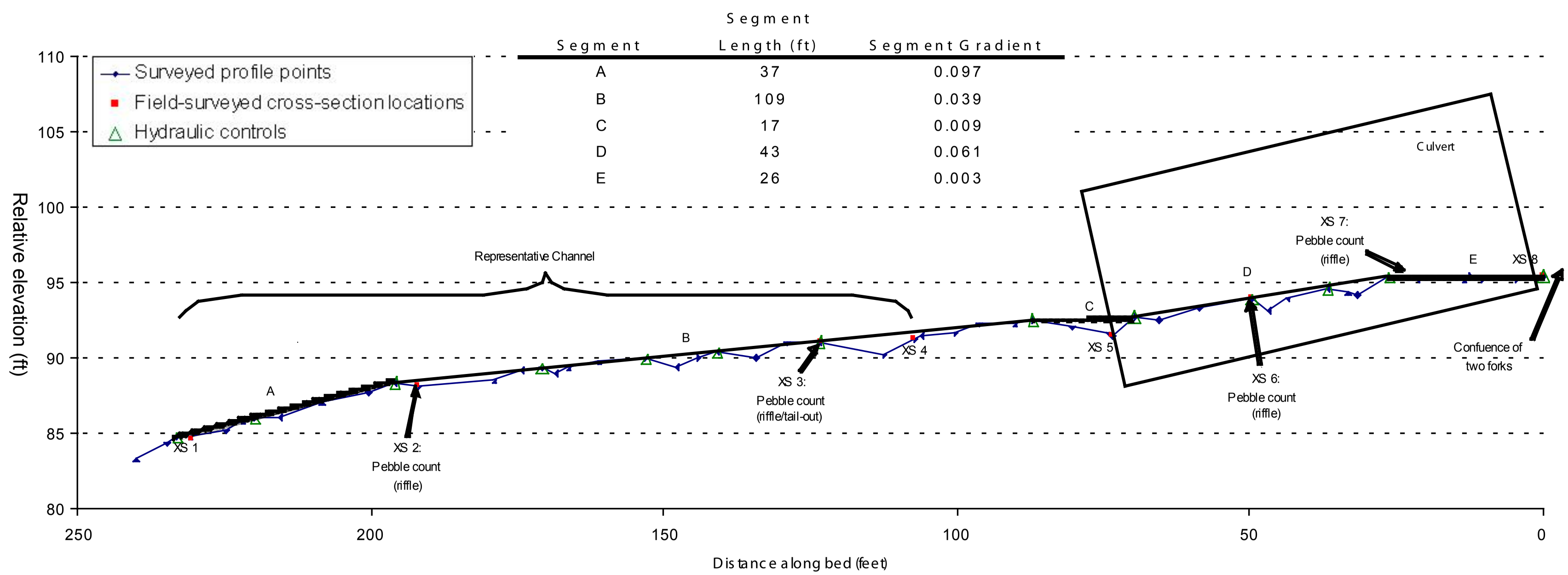


Figure 2—Tire Creek longitudinal profile.

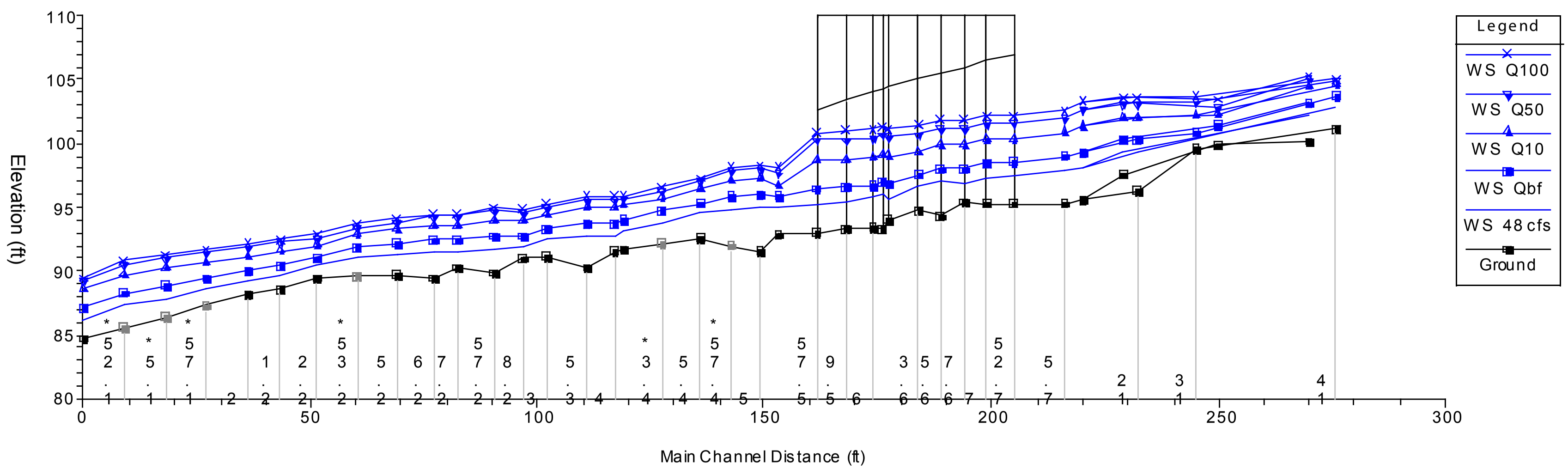
Table 1—Segment comparisons

Culvert Segment	Representative Channel Segment	% Difference in Gradient
D	A	36.7%
D	B	37.0%

Table 2—Summary of segments used for comparisons

Segment	Range of Manning's n values[1]	# of measured XSs	# of interpolated XSs
A	0.1128 – 0.1202	2	4
B	0.1069 – 0.12	2	12
D	0.0989 – 0.116	1	8

[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.

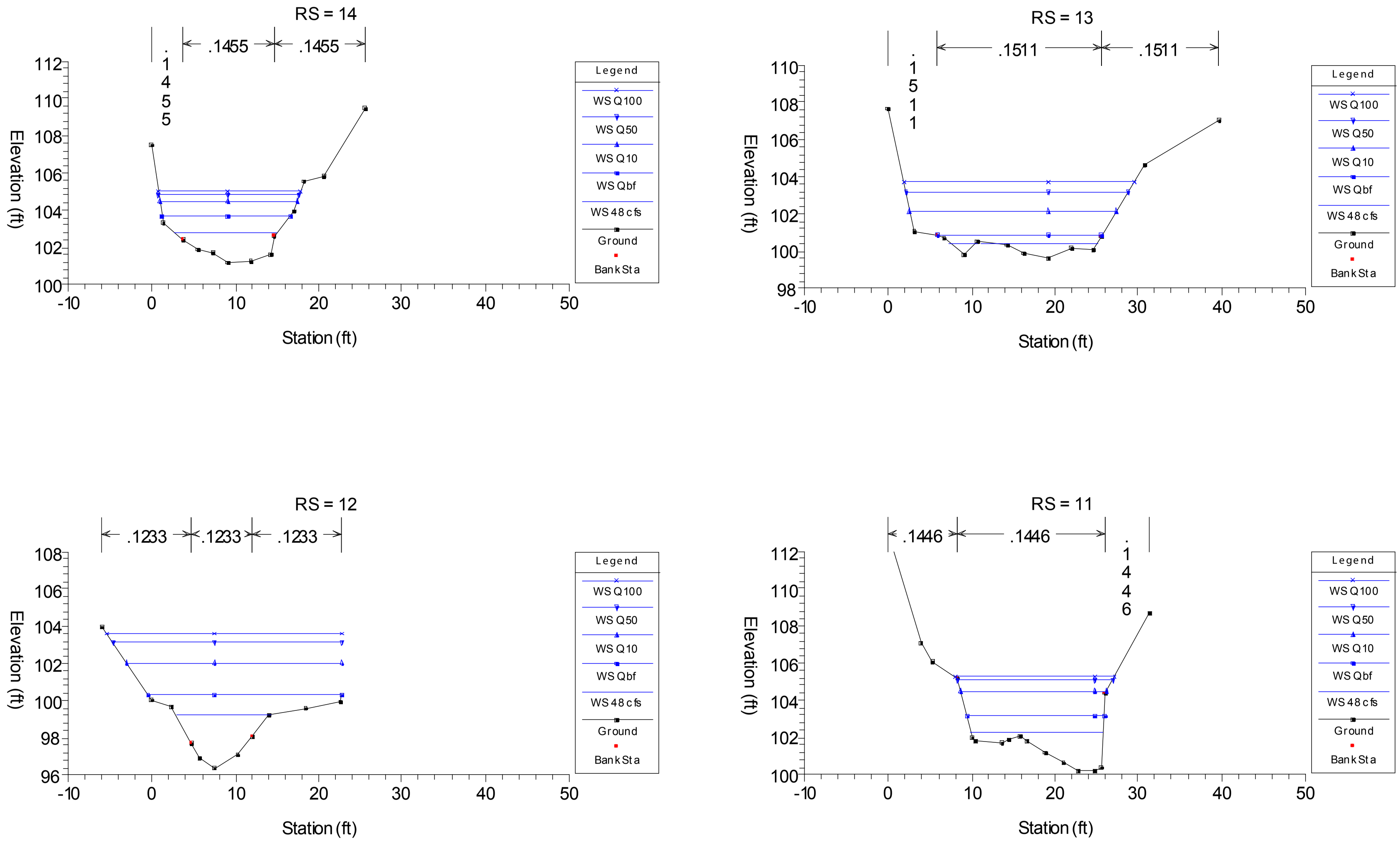


*Figure 4—Cross-section plots. Only measured cross sections are included. Manning's n values are included at the top of the cross section. The stationing (RS) corresponds to the stationing on the HEC-RAS profile. Green arrows define the ineffective flow areas. Black arrows represent points identified 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. *Sections 14-12 represent the left tributary and sections 11-9 represent the right tributary.*

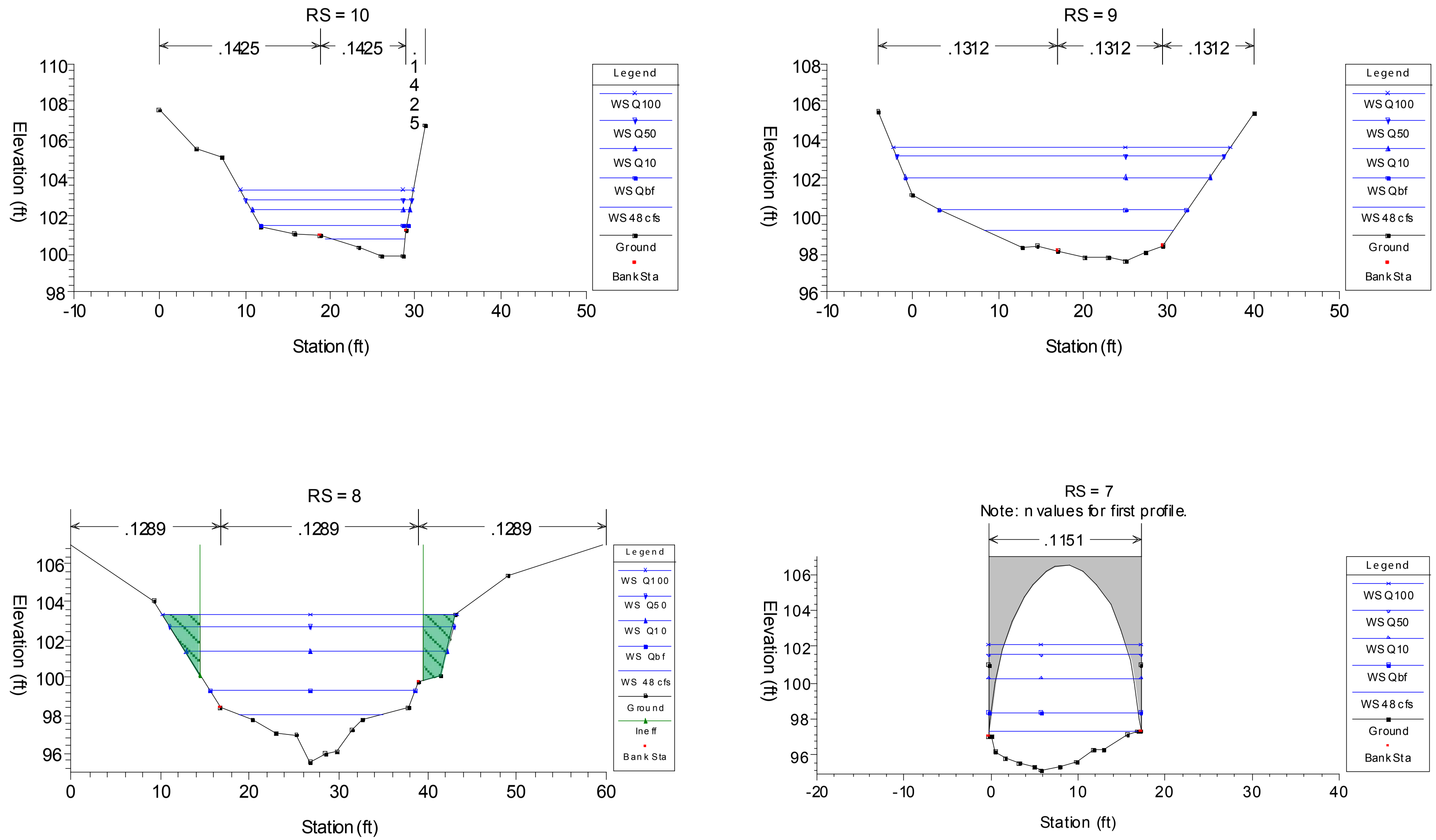


*Figure 4—Cross-section plots. Only measured cross sections are included. Manning's n values are included at the top of the cross section. The stationing (RS) corresponds to the stationing on the HEC-RAS profile. Green arrows define the ineffective flow areas. Black arrows represent points identified 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. *Sections 14-12 represent the left tributary and sections 11-9 represent the right tributary (continued).*

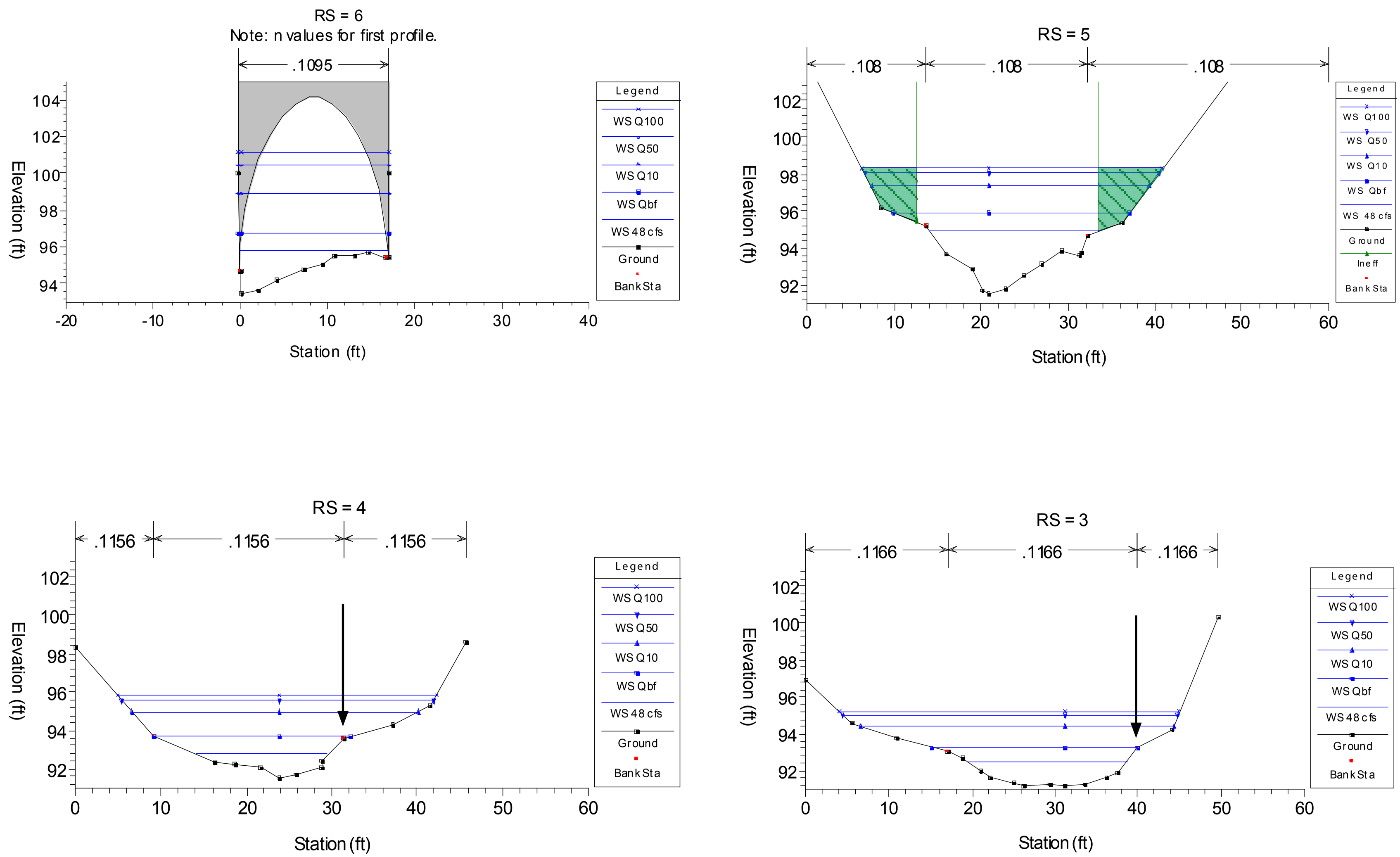


*Figure 4—Cross-section plots. Only measured cross sections are included. Manning's n values are included at the top of the cross section. The stationing (RS) corresponds to the stationing on the HEC-RAS profile. Green arrows define the ineffective flow areas. Black arrows represent points identified 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. *Sections 14-12 represent the left tributary and sections 11-9 represent the right tributary (continued).*

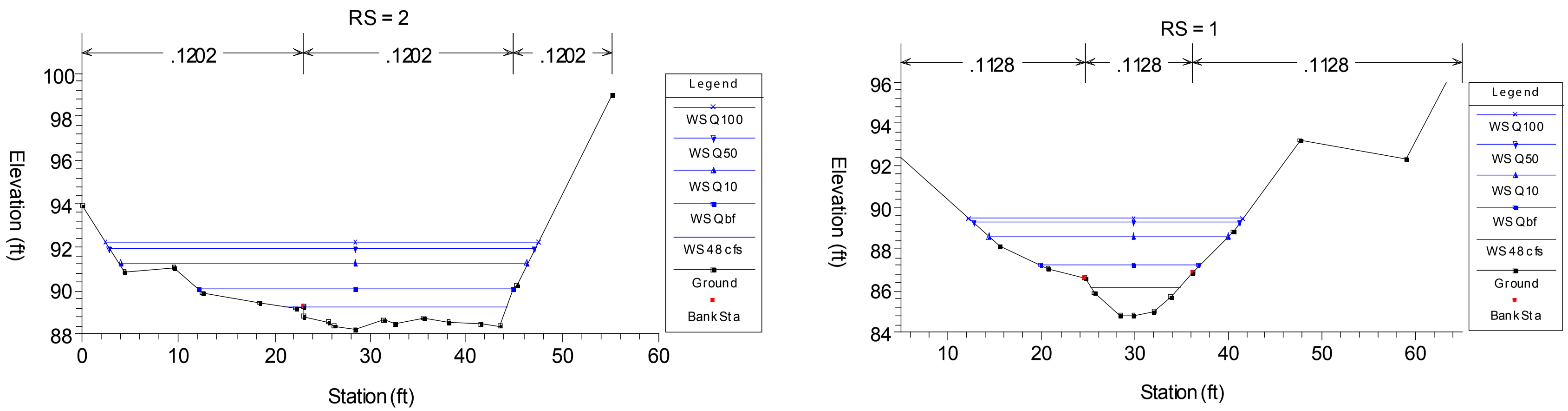


*Figure 4—Cross-section plots. Only measured cross sections are included. Manning's n values are included at the top of the cross section. The stationing (RS) corresponds to the stationing on the HEC-RAS profile. Green arrows define the ineffective flow areas. Black arrows represent points identified 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. *Sections 14-12 represent the left tributary and sections 11-9 represent the right tributary (continued).*

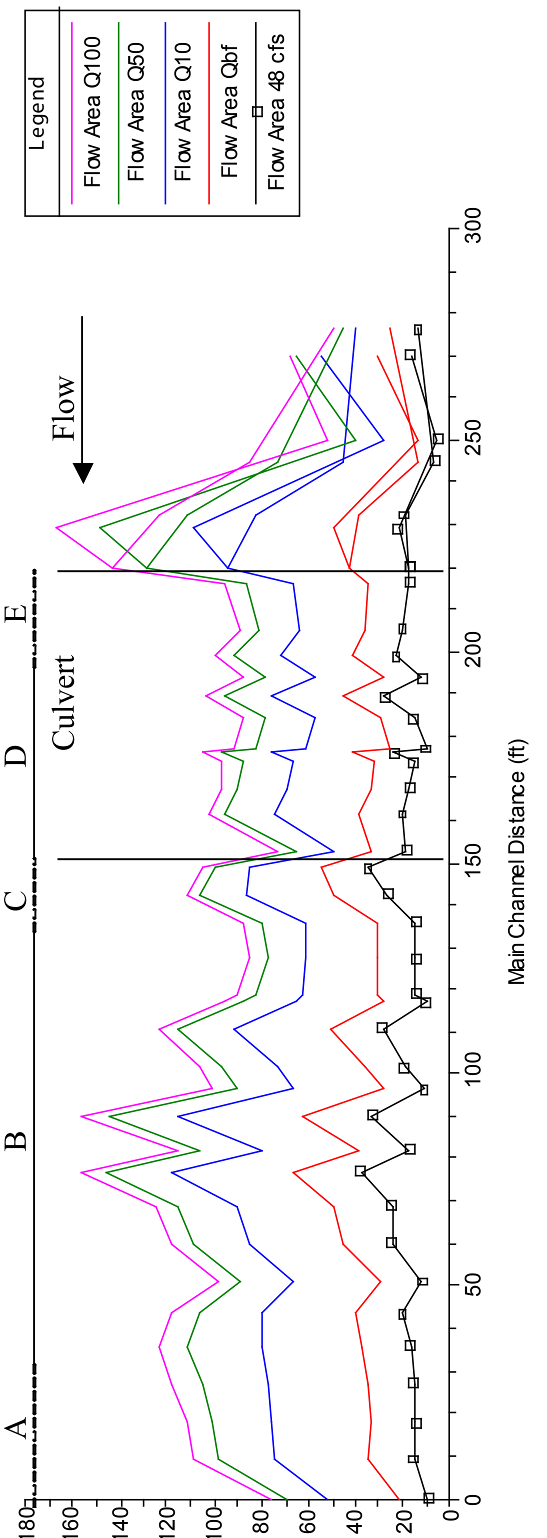


Figure 5—Flow area (total) profile plot.

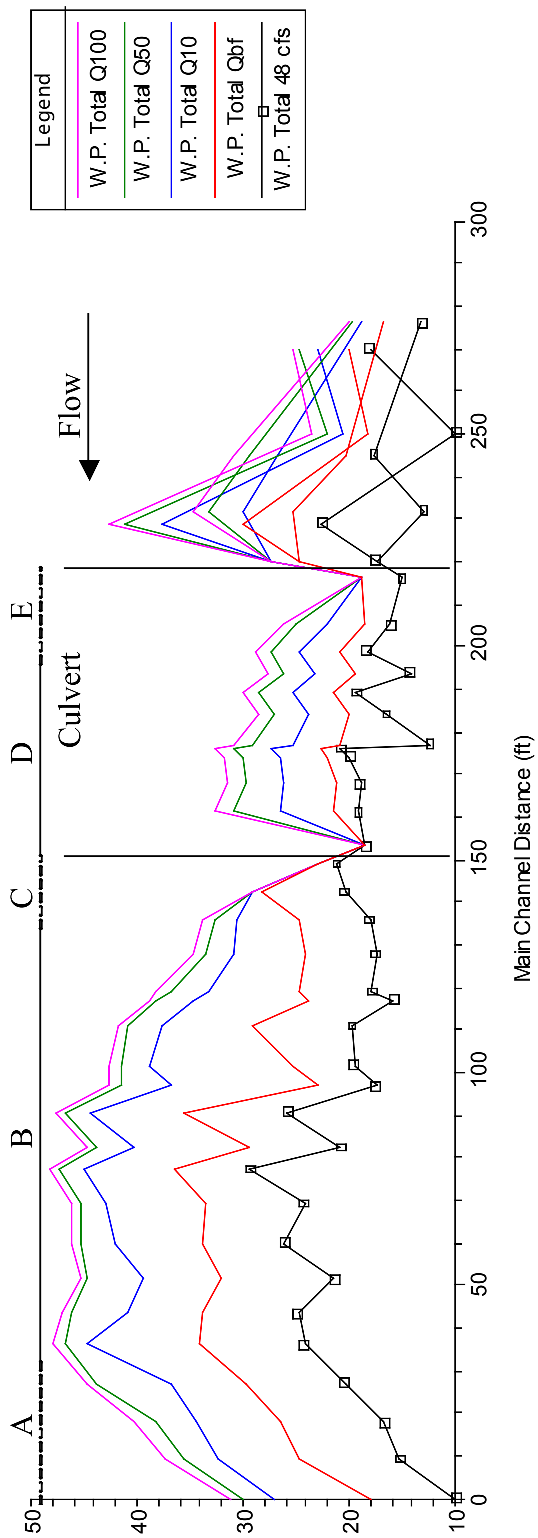


Figure 6—Wetted perimeter.

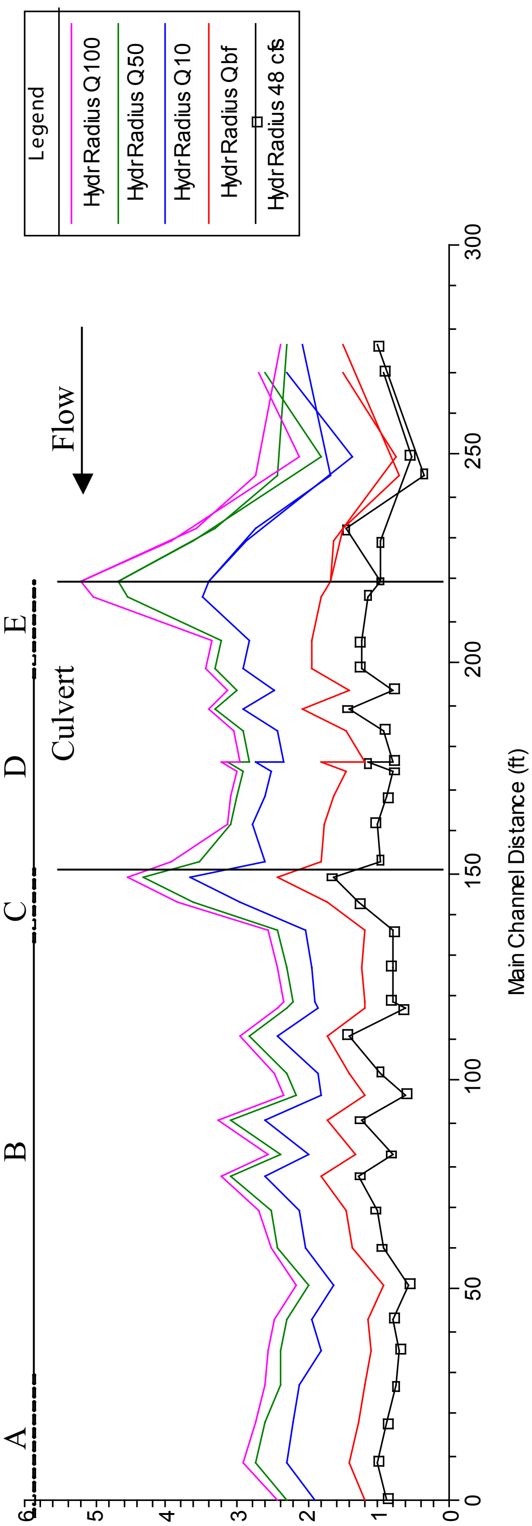


Figure 7—Hydraulic radius.

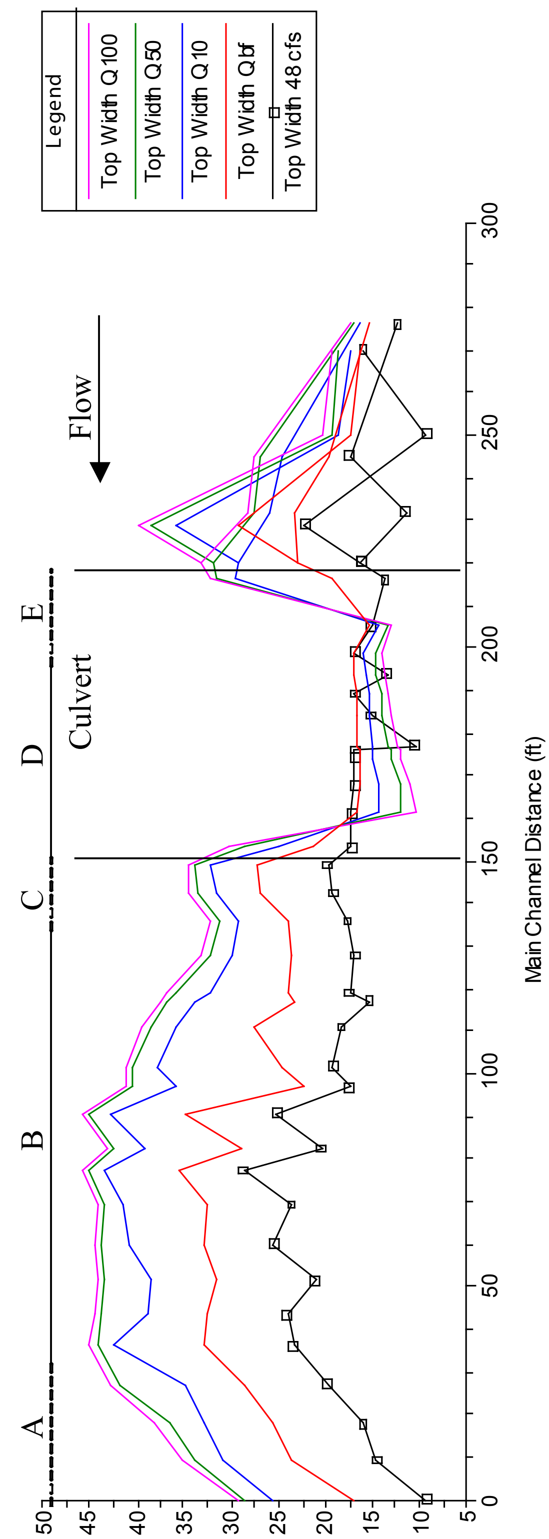


Figure 8—Top width.

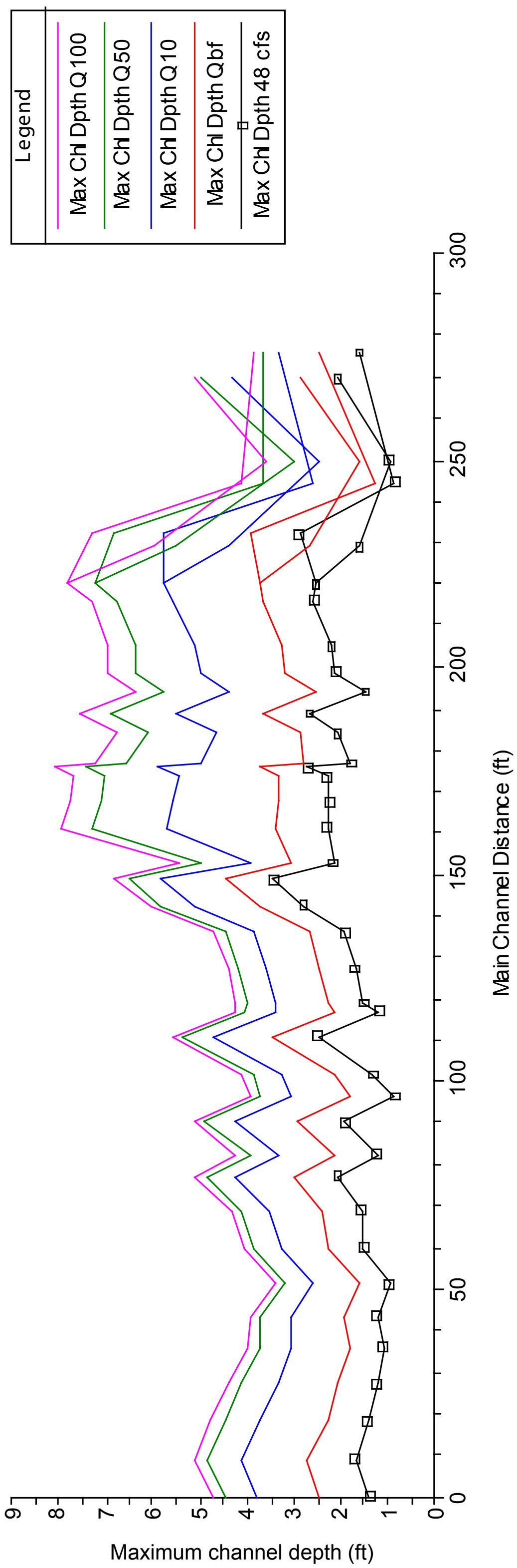


Figure 9—Maximum depth.

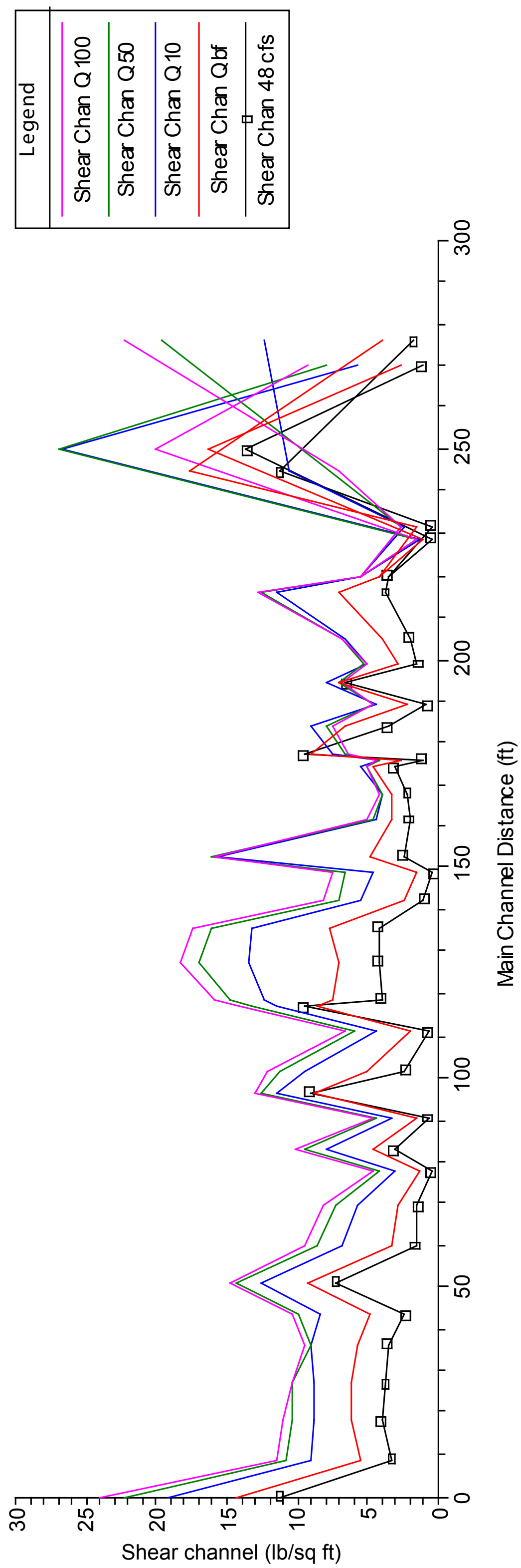


Figure 10—Shear stress (channel) profile.

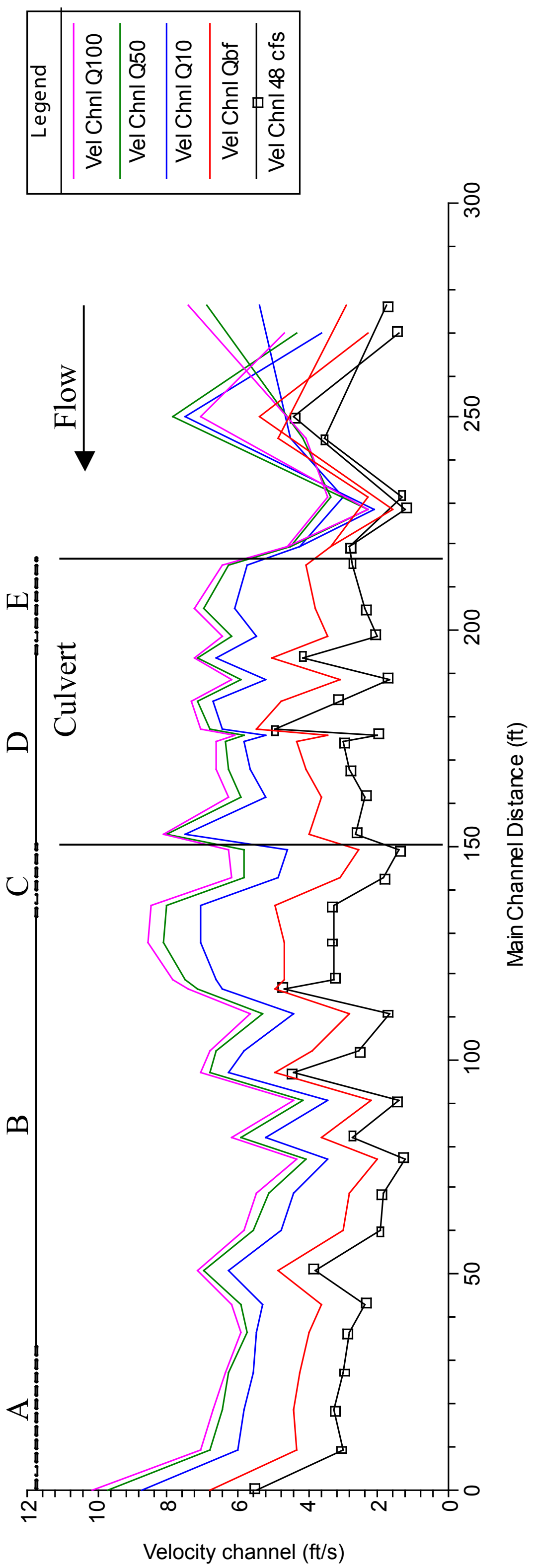
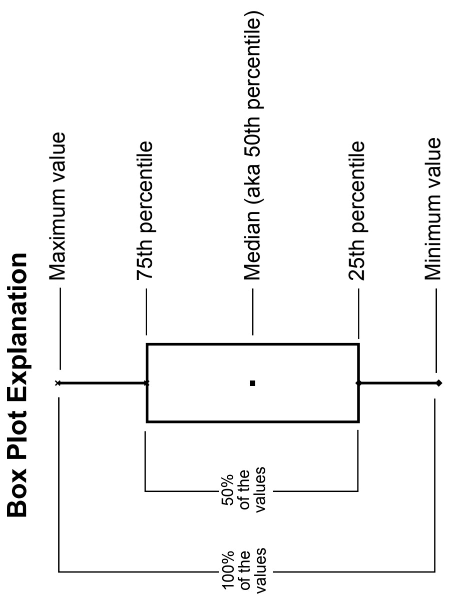


Figure 11—Velocity (channel) profile plot.



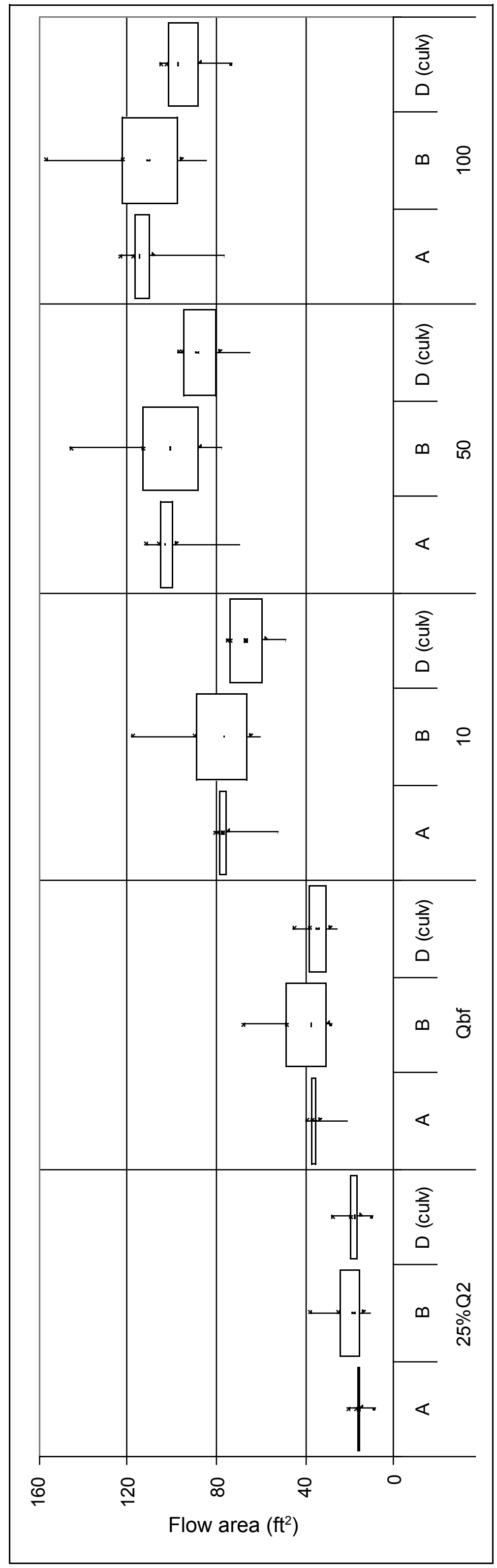


Figure 12—Flow area (total).

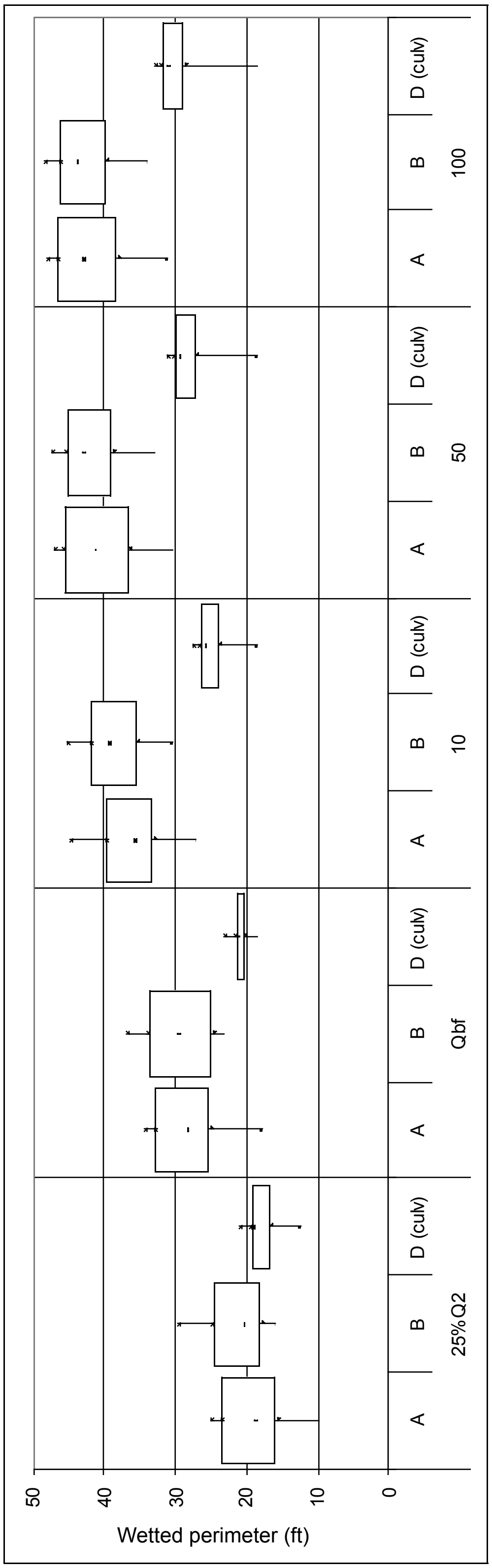


Figure 13—Wetted perimeter.

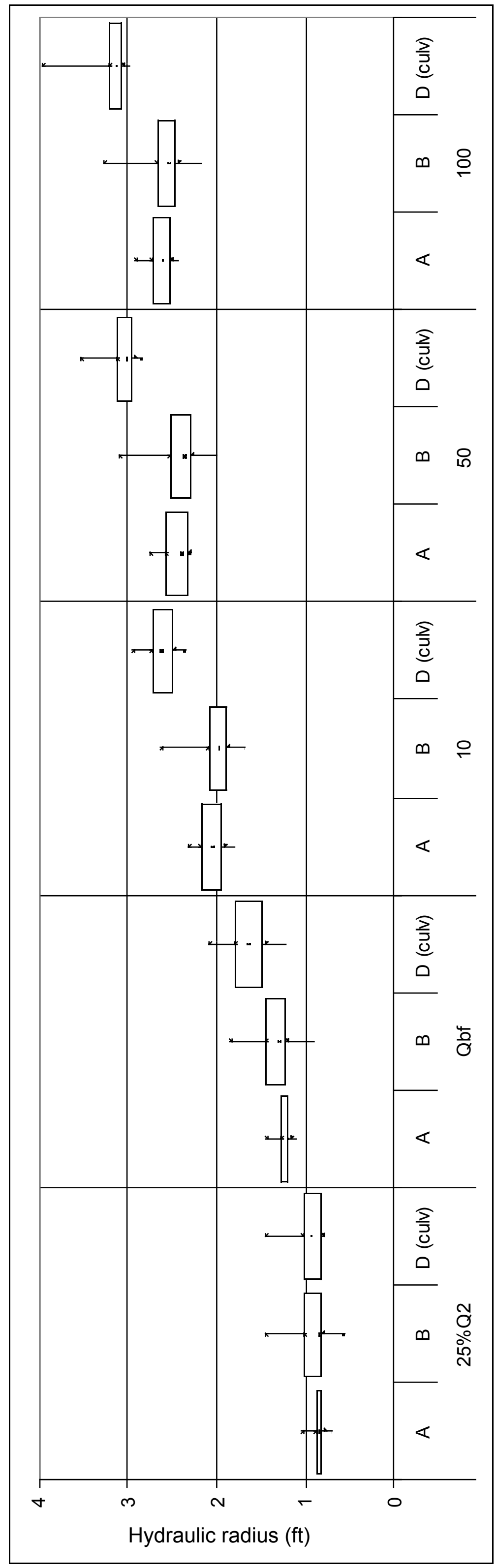


Figure 14—Hydraulic radius.

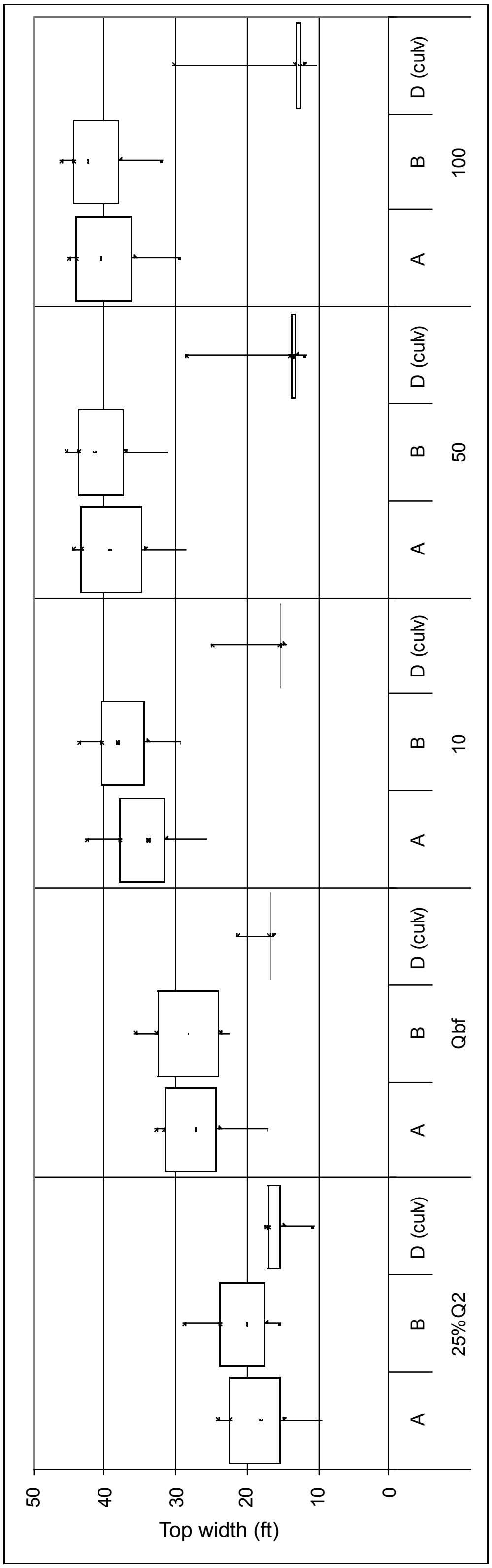


Figure 15—Top width.

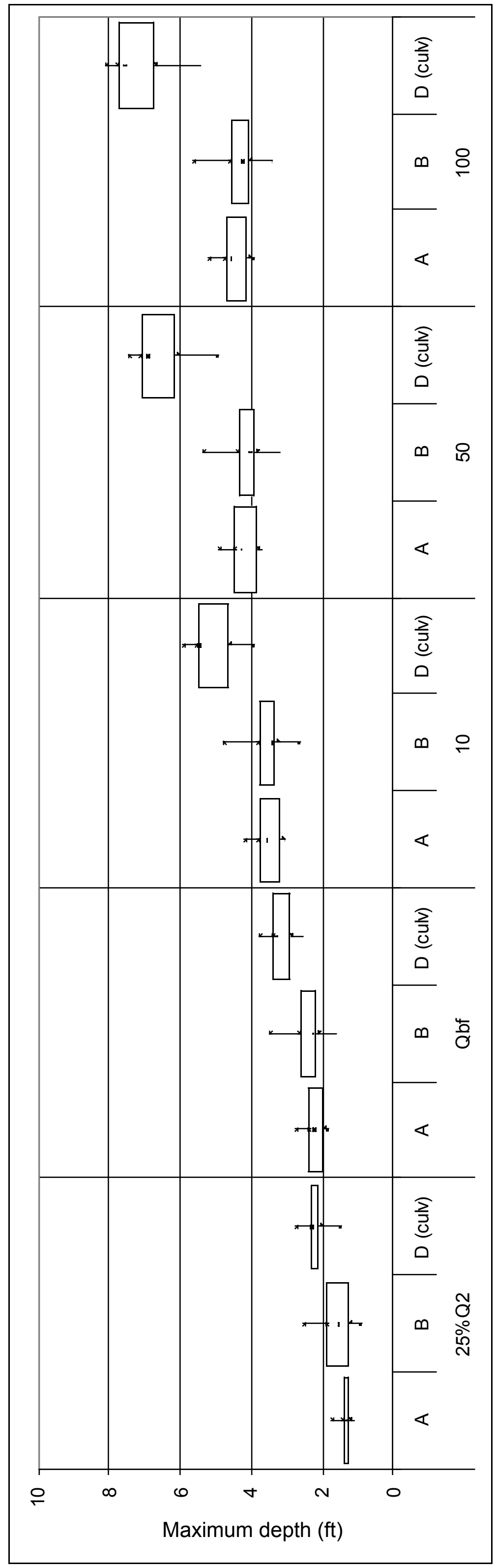


Figure 16—Maximum depth.

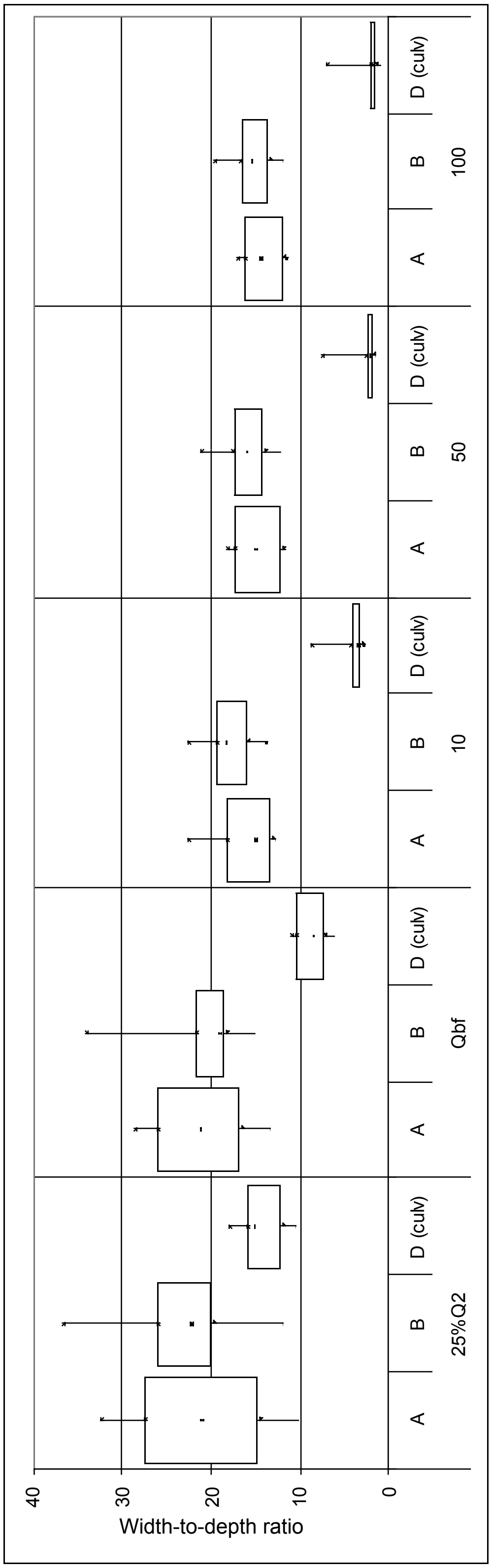


Figure 17—Width-to-depth ratio.

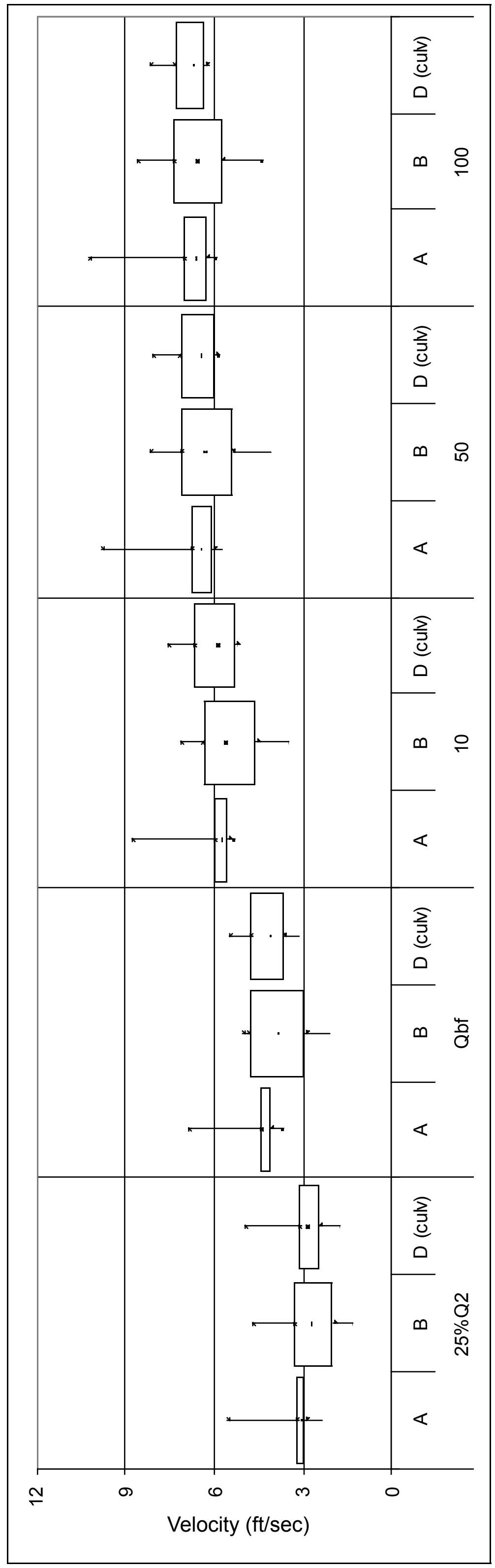


Figure 18—Velocity (channel).

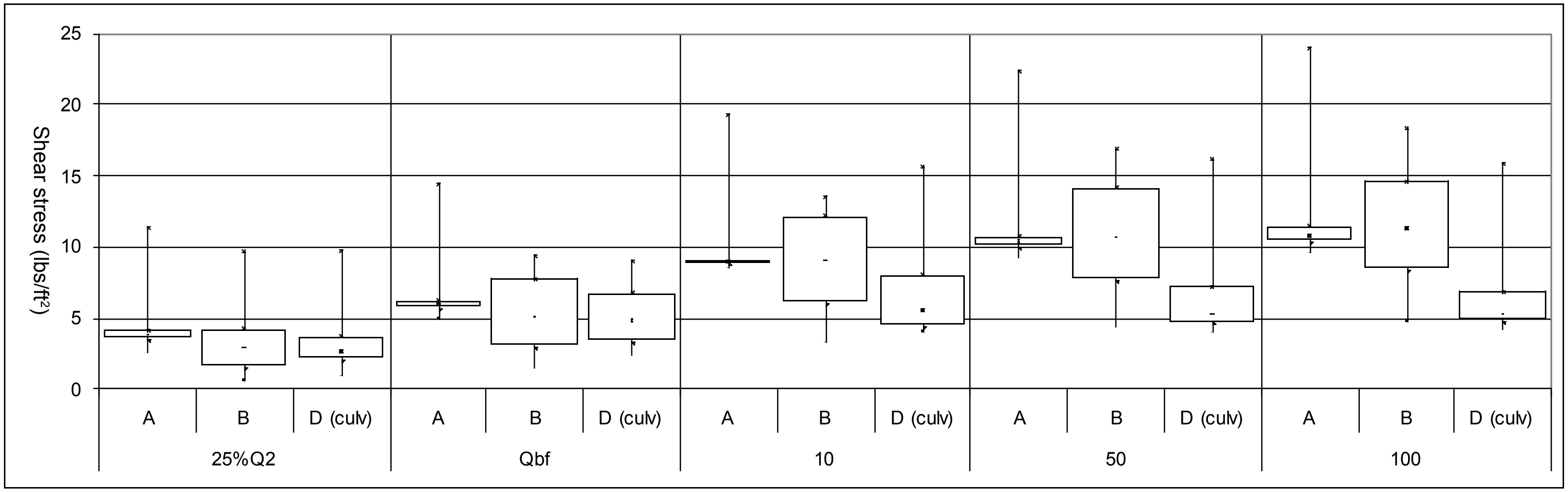
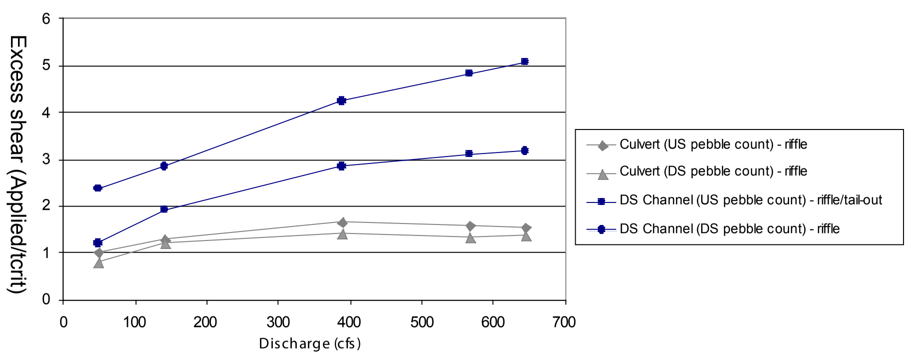


Figure 19—Shear stress (channel).



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	Riffle	0.07	No
	DS	Riffle	0.06	No
Downstream	US	Riffle/tail-out	0.02	
	DS	Riffle	0.02	

Table 4—Vertical sinuosity

Segment	Location	Vertical Sinuosity (ft/ft)
A	DS channel	1.007
B	DS channel	1.005
C	DS transition	1.005
D	Culvert	1.013
E	Culvert	1.008

Table 5—Depth distribution

Reach	XS Location	25% Q_2	Within range of channel conditions?
Culvert	US	4	No
	DS	11	No
Downstream	US	3	
	DS	3	

Table 6—Habitat unit composition

	Percent of surface area			
Reach	Pool	Glide	Riffle	Step
Culvert	65%	0%	32%	3%
Downstream Channel	51%	0%	41%	8%

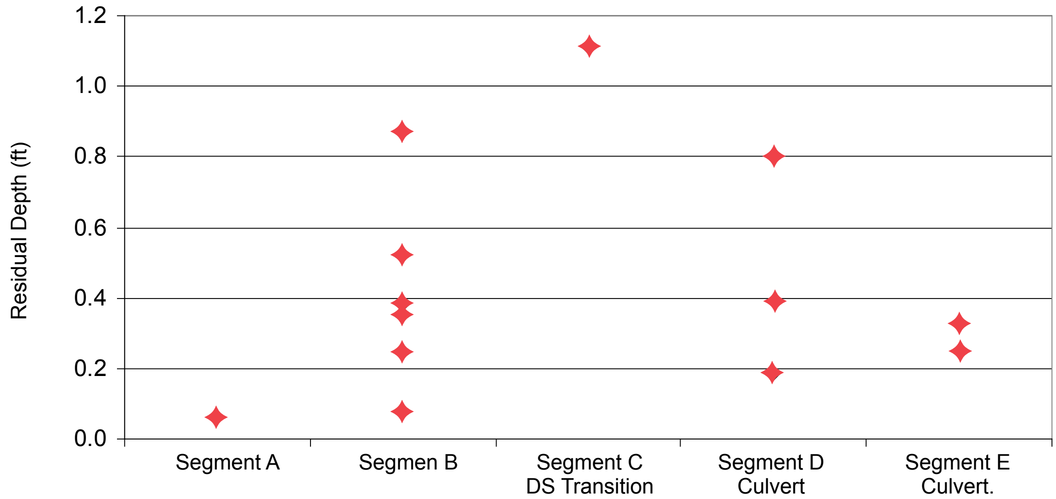


Figure 21—Residual depths.

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	Riffle	2.01	No	0.30	No
	DS	Riffle	1.29	No	0.00	No
Downstream	US	Riffle/tail-out	1.36		0.32	
	DS	Riffle	1.84		0.32	

Table 8—Large woody debris

Reach	Pieces/Channel Width
Culvert	0
Downstream	1.72

Terminology:

US = Upstream

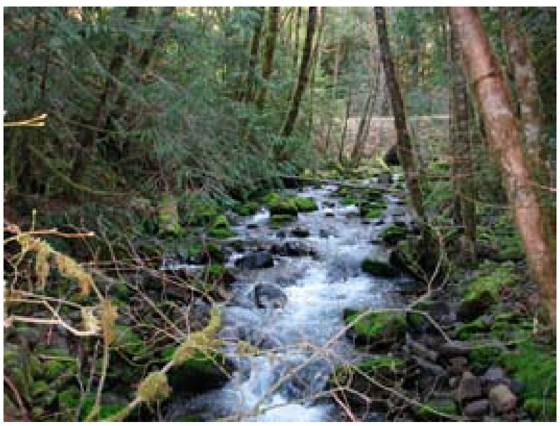
DS = Downstream

RR = Reference reach

XS = Cross section

View upstream towards culvert outlet.

View downstream towards culvert inlet.



Downstream reference reach.

Downstream reference reach – downstream pebble count, riffle.

Downstream reference reach – upstream pebble count, pool.

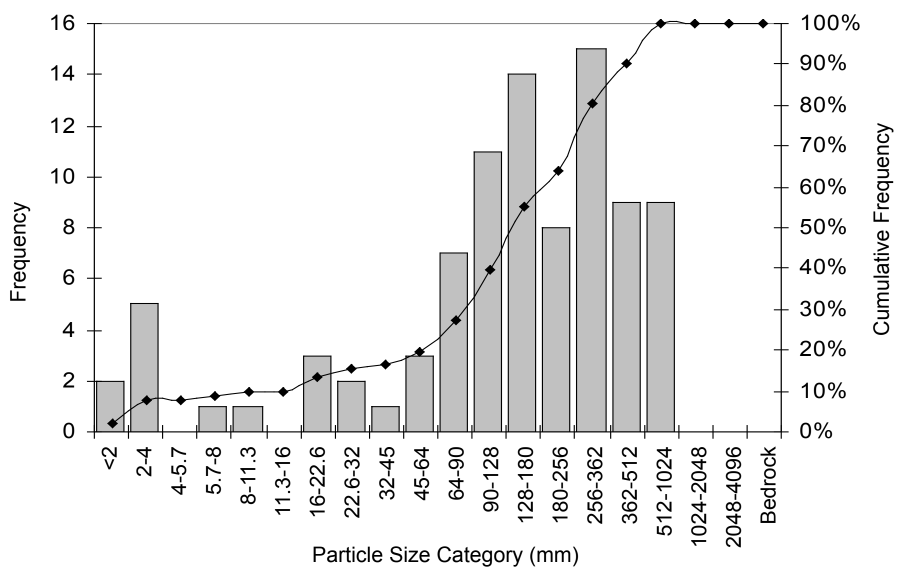
View upstream from roadway – confluence of tributaries.


Culvert – downstream pebble count, riffle/step.


Culvert – upstream pebble count, riffle.

Cross Section: Culvert – Upstream Pebble Count

Material	Size Class (mm)	Count	Item %	Cumulative %
sand	<2	2	2%	2%
very fine gravel	2 - 4	5	5%	8%
fine gravel	4 - 5.7	0	0%	8%
fine gravel	5.7 - 8	1	1%	9%
medium gravel	8 - 11.3	1	1%	10%
medium gravel	11.3 - 16	0	0%	10%
coarse gravel	16 - 22.6	3	3%	13%
coarse gravel	22.6 - 32	2	2%	15%
very coarse gravel	32 - 45	1	1%	16%
very coarse gravel	45 - 64	3	3%	20%
small cobble	64 - 90	7	8%	27%
medium cobble	90 - 128	11	12%	40%
large cobble	128 - 180	14	15%	55%
very large cobble	180 - 256	8	9%	64%
small boulder	256 - 362	15	16%	80%
small boulder	362 - 512	9	10%	90%
medium boulder	512 - 1024	9	10%	100%
large boulder	1024 - 2048	0	0%	100%
very large boulder	2048 - 4096	0	0%	100%
bedrock	Bedrock	0	0%	100%



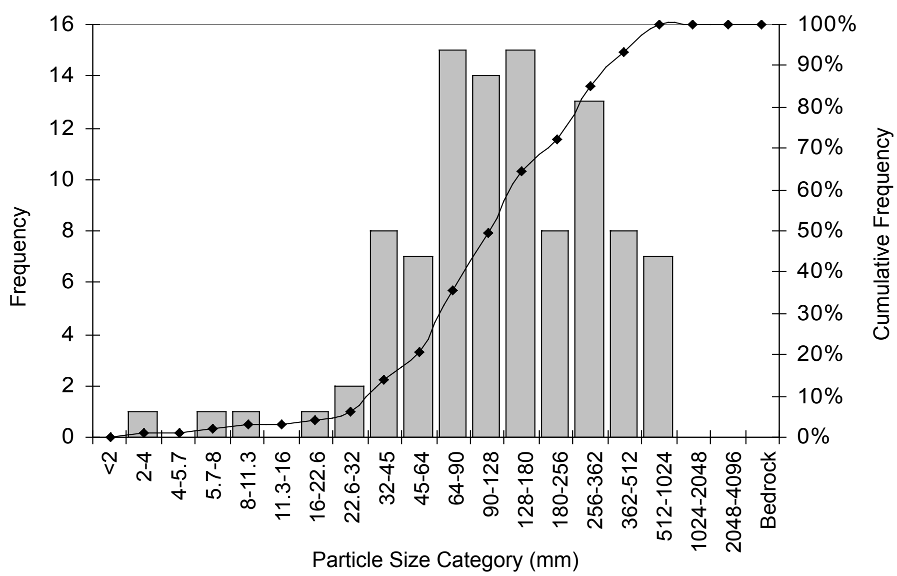
Size Class	Size percent finer than (mm)
D5	3
D16	44
D50	160
D84	430
D95	700
D100	900

Material	Percent Composition
Sand	2%
Gravel	18%
Cobble	44%
Boulder	36%
Bedrock	0%

Sorting Coefficient: 2.01
Skewness Coefficient: 0.30

Cross Section: Culvert – Downstream Pebble Count

Material	Size Class (mm)	Count	Item %	Cumulative %
sand	<2	0	0%	0%
very fine gravel	2 - 4	1	1%	1%
fine gravel	4 - 5.7	0	0%	1%
fine gravel	5.7 - 8	1	1%	2%
medium gravel	8 - 11.3	1	1%	3%
medium gravel	11.3 - 16	0	0%	3%
coarse gravel	16 - 22.6	1	1%	4%
coarse gravel	22.6 - 32	2	2%	6%
very coarse gravel	32 - 45	8	8%	14%
very coarse gravel	45 - 64	7	7%	21%
small cobble	64 - 90	15	15%	36%
medium cobble	90 - 128	14	14%	50%
large cobble	128 - 180	15	15%	64%
very large cobble	180 - 256	8	8%	72%
small boulder	256 - 362	13	13%	85%
small boulder	362 - 512	8	8%	93%
medium boulder	512 - 1024	7	7%	100%
large boulder	1024 - 2048	0	0%	100%
very large boulder	2048 - 4096	0	0%	100%
bedrock	Bedrock	0	0%	100%



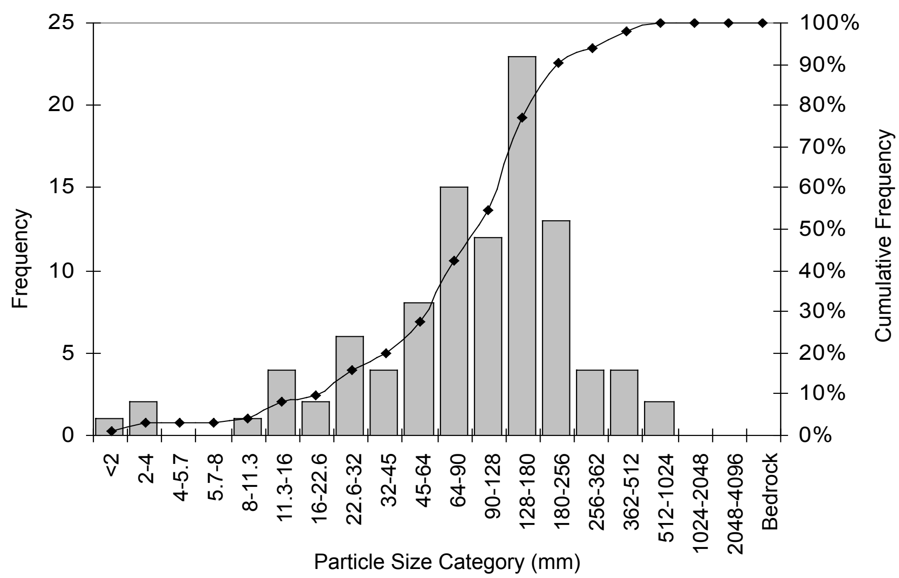
Size Class	Size percent finer than (mm)
D5	30
D16	60
D50	140
D84	360
D95	570
D100	830

Material	Percent Composition
Sand	0%
Gravel	21%
Cobble	51%
Boulder	28%
Bedrock	0%

Sorting Coefficient: 1.29
Skewness Coefficient: 0.00

Cross Section: Downstream Reference Reach – Upstream Pebble Count

Material	Size Class (mm)	Count	Item %	Cumulative %
sand	<2	1	1%	1%
very fine gravel	2 - 4	2	2%	3%
fine gravel	4 - 5.7	0	0%	3%
fine gravel	5.7 - 8	0	0%	3%
medium gravel	8 - 11.3	1	1%	4%
medium gravel	11.3 - 16	4	4%	8%
coarse gravel	16 - 22.6	2	2%	10%
coarse gravel	22.6 - 32	6	6%	16%
very coarse gravel	32 - 45	4	4%	20%
very coarse gravel	45 - 64	8	8%	28%
small cobble	64 - 90	15	15%	43%
medium cobble	90 - 128	12	12%	54%
large cobble	128 - 180	23	23%	77%
very large cobble	180 - 256	13	13%	90%
small boulder	256 - 362	4	4%	94%
small boulder	362 - 512	4	4%	98%
medium boulder	512 - 1024	2	2%	100%
large boulder	1024 - 2048	0	0%	100%
very large boulder	2048 - 4096	0	0%	100%
bedrock	Bedrock	0	0%	100%



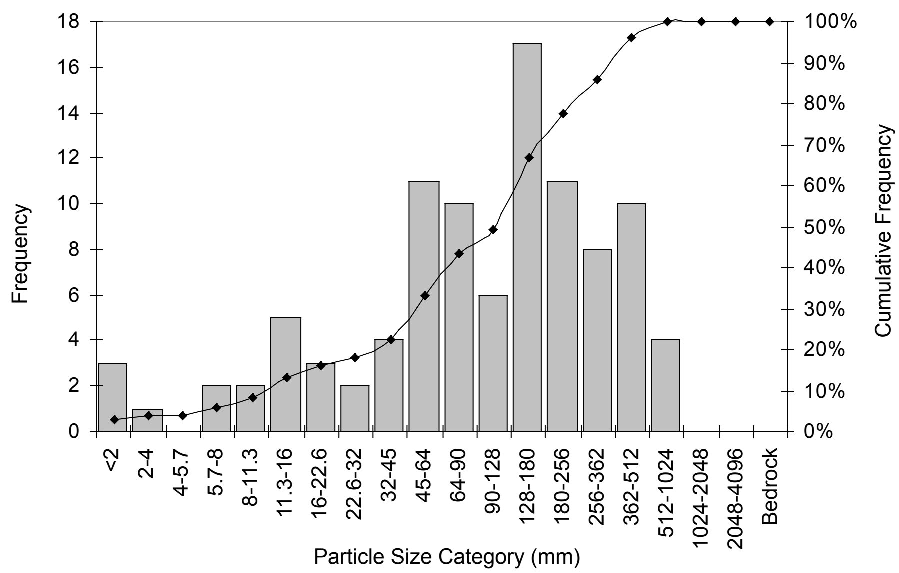
Size Class	Size percent finer than (mm)
D5	15
D16	35
D50	120
D84	210
D95	400
D100	600

Material	Percent Composition
Sand	1%
Gravel	27%
Cobble	62%
Boulder	10%
Bedrock	0%

Sorting Coefficient: 1.36
Skewness Coefficient: 0.32

Cross Section: Downstream Reference Reach – Downstream Pebble Count

Material	Size Range (mm)	Count	Item %	Cumulative %
sand	<2	3	3%	3%
very fine gravel	2 - 4	1	1%	4%
fine gravel	4 - 5.7	0	0%	4%
fine gravel	5.7 - 8	2	2%	6%
medium gravel	8 - 11.3	2	2%	8%
medium gravel	11.3 - 16	5	5%	13%
coarse gravel	16 - 22.6	3	3%	16%
coarse gravel	22.6 - 32	2	2%	18%
very coarse gravel	32 - 45	4	4%	22%
very coarse gravel	45 - 64	11	11%	33%
small cobble	64 - 90	10	10%	43%
medium cobble	90 - 128	6	6%	49%
large cobble	128 - 180	17	17%	67%
very large cobble	180 - 256	11	11%	78%
small boulder	256 - 362	8	8%	86%
small boulder	362 - 512	10	10%	96%
medium boulder	512 - 1024	4	4%	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	8
D16	24.04
D50	130
D84	336.4
D95	472
D100	700

Material	Percent Composition
Sand	3%
Gravel	30%
Cobble	44%
Boulder	22%
Bedrock	0%

Sorting Coefficient: 1.84
Skewness Coefficient: 0.32