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Technical Report SRH-2013-10

Beaverhead River Flushing Flow Study

Clark Canyon Dam, East Bench Unit, Montana
Montana Area Office
Billings, Montana

U.S. Department of the Interior
Bureau of Reclamation
Technical Service Center

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Sedimentation and River Hydraulics Group

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Introduction

The Montana Area Office requested that the Technical Service Center (TSC) perform an analysis to estimate the discharge necessary to mobilize fine sediment from the bed of the Beaverhead River below Clark Canyon Reservoir (Figure 1).

Clark Canyon Creek flows into the Beaverhead River below Clark Canyon Reservoir approximately 1.5 miles below the dam (Figure 1 and Figure 2). Each spring, Clark Canyon Creek delivers a great deal of fine sediment to the Beaverhead River. The Montana Area Office provided bed-material size data for the Beaverhead River. Locations of the pebble count data are shown in Figure 1. This report summarizes the results of the flushing flow analysis.

Fine sediment deposition from Clark Canyon Creek has affected fisheries in the Beaverhead River during years when peak flow releases from Clark Canyon Dam are insufficient to transport the additional tributary sediment. Limited releases during the spring have allowed fine sediment to deposit in the Beaverhead River, which has affected the trout fishery downstream from the dam. The purpose of this study was to investigate flow releases from Clark Canyon Dam that would help mobilize and transport fine sediment from the streambed. An annual program of short-duration, high-flow releases from Clark Canyon Dam are expected to flush fine sediments from the streambed and result in improved habitat conditions for trout.

Study Reach

The Beaverhead River is part of the Missouri headwaters within the Montana-Idaho Basin Range Province (Bartholomew et al, 1999). The Beaverhead River is formed at Clark Canyon Reservoir by the merger of the Red Rock River and the Horse Prairie River. The river then flows for 45 miles until it merges with the Ruby River near Twin Bridges, and then the Jefferson River is formed (Bartholomew et al, 1999). Pipe Organ Rock represents the end of the hydraulic model study and is located approximately 7 miles downstream of Clark Canyon Dam. Barretts Diversion Dam, which is part of the Reclamation project including Clark Canyon Dam is located approximately 15.5 miles downstream of the dam. USGS gaging station 06016000 (Beaverhead River at Barretts) is the main gaging station used in the study.

The Beaverhead river flows through a straight, narrow canyon for 12 miles, where it then moves into a wider valley. For the first 12 miles, the river has a slope of .0024, which decreases slightly as it enters the wider valley. Downstream of Barretts Diversion Dam, the slope decrease slightly to 0.0023. Major tributary streams are Grasshopper Creek, Blacktail Deer Creek, and Rattlesnake Creek (Bartholomew et al, 1999).

Clark Canyon Dam was constructed in 1964 to allow the irrigation of the bench east of Dillon, MT. Operation of the Clark Canyon Reservoir influences the flow regime in the Beaverhead River. The peak of the hydrograph is shifted later in the year, reflecting controlled release of

stored water. The low flow regime is fairly stable, reflecting average low-flow discharge from the reservoir. Diversion of river water to the East Bench Unit irrigation system is reflected at gaging stations further downstream, such as USGS gage # 06017000 (Beaverhead River at Dillon). Reduced flows are distinct between April and November, resulting in an inverted hydrograph.

Pipe Organ Rock is situated at a ridge of volcanic rocks (Bartholomew et al, 1999). The Beaverhead River canyon is divided into an upper and lower section with different characteristics but similar gradients. Just below Clark Canyon Creek, the Beaverhead River cuts through a narrow half mile long gorge composed of a narrow intrusive volcanic complex (Bartholomew et al, 1999). With the exception of this location, the upper Beaverhead River has a wide floodplain of 240 to 1000 feet (Bartholomew et al, 1999). The river is flanked by wide terraces at different elevations. The river channel consists of meander loops with wave lengths that are shorter than amplitudes. The broad floodplain contains numerous cutoff meander loops that are representative of a meander patter upstream of resistant bedrock. Downstream of Pipe Organ and below the Grasshopper tributary, the river becomes a confined straight or braided channel with a sinuous course (Bartholomew et al, 1999).

Clark Canyon Creek enters the Beaverhead River approximately 1.5 miles downstream of the dam. The creek is approximately 8 miles long and drains an area of 11,000 acres (Boyd, 2011). The main stem has woody riparian vegetation. The sediments in the valley bottom are coarse grained. Field observations provided by Boyd (2011) indicate that the Clark Canyon Creek watershed produces high sedimentation rates because of highly erodible source area and slope instability. Sediment is most pronounced from ash-laden Tertiary volcanics, which are also prone to landslides and debris formation (Boyd, 2011). The geology of Clark Canyon Creek is believed to play an important role in sediment production. The lower portion of the creek is capped by erosion-resistant volcanic rocks (Boyd, 2011). However further upstream, erodible layers of volcanic rocks are exposed as the valley widens in the headwaters (Boyd, 2011). Large portions of the rock formations have been remobilized as landslides (Boyd, 2011).

Montana State agencies (Fish, Wildlife and Parks) are in the process of evaluating methods to reduce the sediment yield from Clark Canyon Creek (Boyd, 2011).
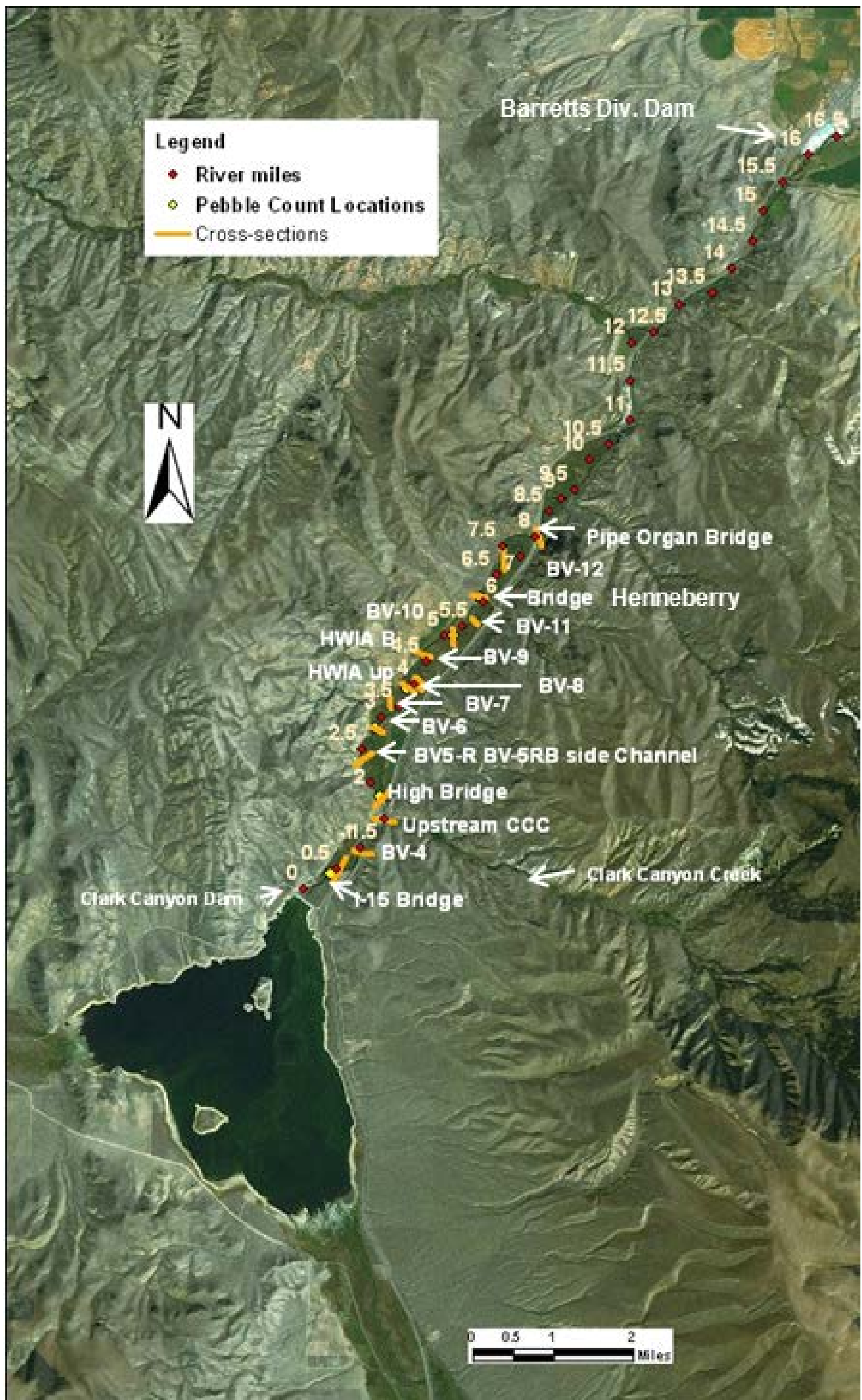
Figure 1-Location Map of the Beaverhead River downstream from Clark Canyon Dam. The Beaverhead River flows northeast from Clark Canyon Dam.

Figure 2- Confluence of the Beaverhead River and Clark Canyon Creek.

Hydraulic Model

Channel Surveys

The Montana Area Office collected cross-section data at selected locations on the Beaverhead River on May 1, 2011 and May 1, 2012. The horizontal datum was NAD83 State Plane, Montana (International Feet), and the vertical datum is NAVD88 (U.S. Survey Feet). The survey was requested by the Sedimentation and River Hydraulic Group. Budget limitations restricted the number of cross-sections to no more than one or two per mile. The Sedimentation Group identified locations for cross-sections, and the data were collected by the area office. The data were organized and sent to the Sedimentation and River Hydraulics Group in August 2012. These cross-section data were used as input to the HEC-RAS, one-dimensional model (HEC-RAS, 2010) to simulate the channel hydraulics (velocity, flow depth, and water surface elevation) for a range of river flows.

A longitudinal profile survey of the water surface and channel thalweg was not conducted, but would have documented all the hydraulic controls (e.g., riffle crests, weirs, etc.) along the river

channel. Cross section surveys at each of these hydraulic controls would have allowed for a more accurate hydraulics model.

Model Geometry and Boundary Conditions

The model cross sections extended from just below Clark Canyon Dam downstream to the Pipe Organ bridge (Figure 1). A total of 15 cross sections were used to represent the channel geometry over the 7-mile reach. The HEC-RAS model linearly interpolates cross sections between the measured cross sections. A weir just downstream of Clark Canyon Dam was omitted from the survey. This feature is visible in aerial photography. Using the horizontal location of the weir and assumptions regarding its elevation, a weir cross section was added to the HEC-RAS model. In addition, three cross sections were added, as part of the model calibration, to represent two riffles and one pool. The actual existence of the these riffles and pools had to be assumed for model calibration, but could not be verified with the existing information (survey data, ground photographs, or Google Earth aerial photography).

Manning's *n* roughness coefficients are specified for each cross section. For this study, the same roughness coefficient was specified at each cross section based on professional judgment and model calibration (see next section).

The upstream model boundary condition is the specified river flow or discharge. Discharge was observed to increase in the downstream direction based on flow information provided in the 2011 survey. Discharge between the I-15 Bridge and cross section HWIA-B was 87 percent of the mean-daily discharge of the downstream gage. Discharge between cross sections HWIA-B and Pipe Organ were 94 percent of the mean-daily discharge of the downstream gage. Based on the gage at Barretts Diversion Dam, the flow was 379 cfs during collection of the cross-section data on May 1, 2012. The 2011 discharge data and the percentage of flow used in the calibration model is shown in Table 1.

Exceedance values for daily flows at the USGS gage 06016000, Beaverhead River at Barretts Diversion Dam are summarized in Table 2. A discharge of 423 cfs is exceeded 50 percent of the time, and a discharge of 1000 cfs is only exceeded 6.6 percent of the time. Flows used in the hydraulic model are summarized in Table 3. The water surface profile of the calibration and measured data are shown in Figure 3.

The downstream model boundary was specified using the normal depth equation that utilizes the discharge, channel roughness coefficient, and the longitudinal channel bottom slope to calculate the depth at the downstream most cross section.

Table 1-Discharge data used in model calibration

Name	Sta No.	Discharge (cfs)	Fracton of Gage Discharge	Fracton of Gage	Discharge (cfs)
I-15 Bridge	17	370	86%		
BV-4	16	375	87%		
U/S CCC	15	380	88%		
High Bridge	14	370	86%		
BV-5	13	333	77%		
BV-6	12	386	90%		
BV-7	11	370	86%		
BV-8	10	416	97%		
HWIA-B	9.5	375	87%	87%	330
BV-9	9	415	96%		
BV-10	8	412	96%		
BV-11	7	385	89%		
Henneberry Bridge	6	415	96%		
BV-12	5	390	90%		
Pipe Organ	4	410	95%	94%	356
Barretts Diversion Dam		431	100%		379

Table 2-Exceedance values for daily discharge for Beaverhead River flows at the Barretts Diversion Dam

Exceedance	Discharge (cfs)
90%	119
75%	215
50%	423
25%	713
10%	927
6.6%	1,000
3.5%	1,170
1%	1,770

Table 3-Different Discharges used in model study

| Profile	I-15 Bridge River Sta 17 Q Total (cfs)	BV-9 River Sta 9 Q Total (cfs)
PF 1	87	94
PF 2	131	141
PF 3	174	188
PF 4	218	235
PF 5	261	282
PF 6	305	329
PF 7	348	376
PF 8	392	423
PF 9	435	470
PF 10	522	564
PF 11	609	658
PF 12	696	752
PF 13	783	846
PF 14	870	940
PF 15	957	1034
PF 16	1044	1128
PF 17	1131	1222
PF 18	1218	1316
PF 19	1305	1410
PF 20	1392	1504
PF 21	1479	1598
PF 22	1566	1692
PF 23	1653	1740
PF 24	1786	1880
PF 25	1827	1974
PF 26	1914	2068
PF 27	2001	2162
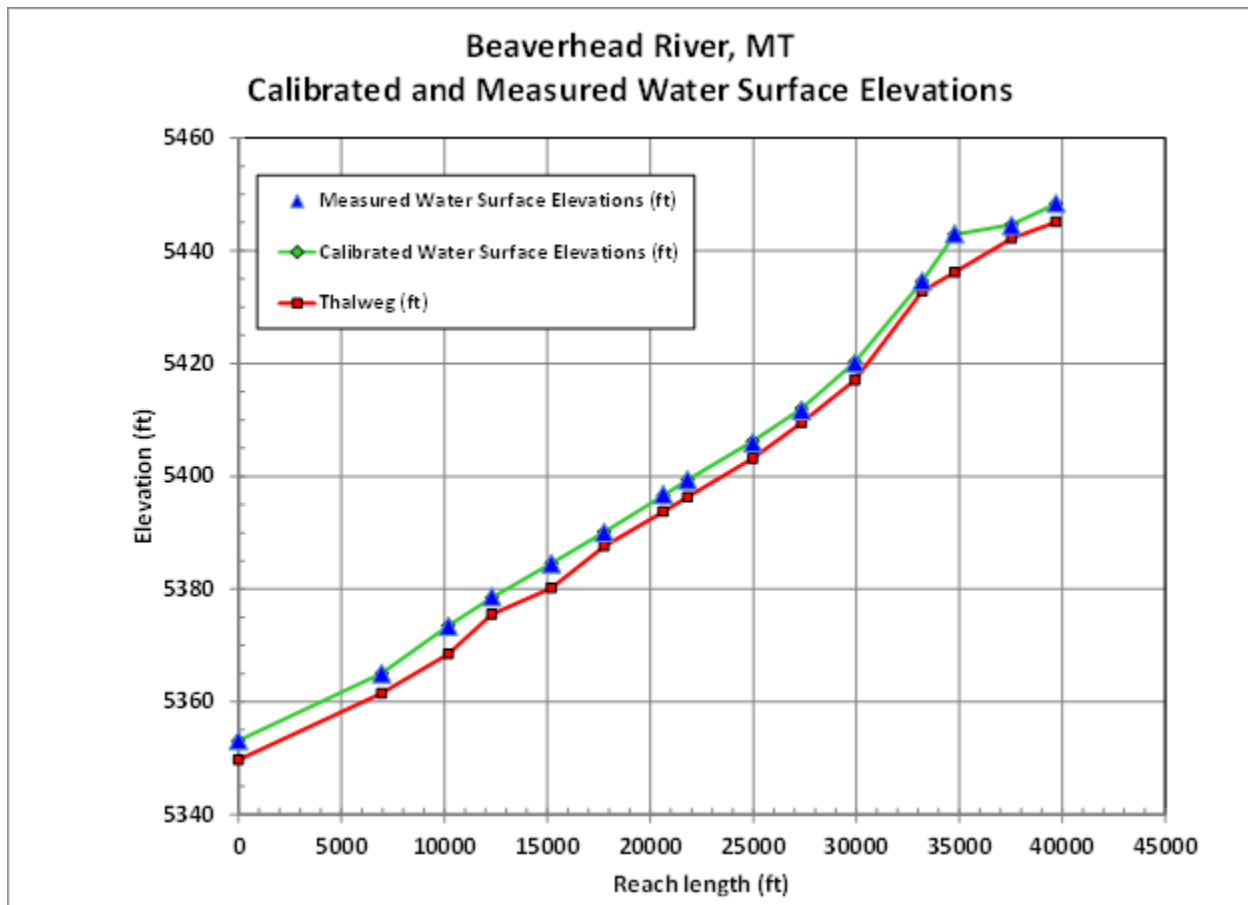
Figure 3. Comparison of computed and measured water surface profiles along with the channel thalweg profile. Stationing begins at Barrett's Diversion Dam.

Hydraulic Model Calibration

The HEC-RAS model was calibrated so that computed water surface elevations closely matched measured water surface elevations. Model calibration included the adjustment of channel roughness, inclusion of four additional cross sections (the weir discussed earlier, a pool, and two riffles not included in the survey), interpolated cross sections between measured cross sections, and accounting for an increase in discharge downstream of BV-9 (Sta. 9). The final calibration produced root mean squared (RMS) error (the difference between the measured and computed water surface elevation) of 0.16 feet (Table 4). The longitudinal profiles of computed and measured water surface elevation, along with the channel thalweg, are presented in Figure 3. The maximum difference between measured and computed water surface was 0.3 feet. The final model calibration was accomplished using the following procedure.

- The same Manning's n roughness coefficient of 0.040 was used at each cross section. Roughness values of 0.0375 and 0.0425 both produced higher RMS error values.

- A pool cross section was inserted in the model 300 feet downstream of cross section BV4 by duplicating this cross section and lowering the channel bottom elevations by 1.1 feet.

- A weir cross section was inserted in the model 1290 feet downstream of cross section U/S CCC (Clark Canyon Creek) with a crest elevation of 5441 feet and a crest length of 40 feet. The presence of a weir could be identified in the aerial photography.

- A riffle was inserted in the model 290 feet downstream of BV10 by duplicating this cross section and raising the channel bottom elevations by 0.7 feet.

- A riffle was also inserted in the model 350 feet downstream of the Henneberry Bridge by duplicating this cross section and raising the channel bottom elevations by 0.8 feet.

Table 4-Final Calibration Data

				Increasing discharge with distance downstream and cross-section adjustments, Mannings *n* of 0.040		
		Cross Section Information		computed water surface elevation (feet)	Difference (feet)	Error squared
Name	Sta No.	Measured Water Surface Elevation	Cross Section Adjustments			
I-15 Bridge	17	5448.4		5448.4	0.0	0.002
BV-4	16	5444.5	a pool was created 300 feet downstream and the bed was lowered 1.1 ft	5444.6	0.1	0.014
U/S CCC	15	5443.0	added weir 1290 feet downstream from Clark Canyon Creek Cross-section	5442.9	-0.1	0.012
High Bridge	14	5434.6		5434.6	0.0	0.000
BV5	13	5420.1		5420.3	0.2	0.036
BV6	12	5411.7		5412.0	0.3	0.084
BV7	11	5405.9		5406.2	0.3	0.096
BV8	10	5399.4		5399.3	-0.1	0.005
HWIA-B	9.5	5396.8		5396.6	-0.2	0.053
BV-9	9	5390.0		5390.1	0.1	0.014
BV-10	8	5384.5	a riffle was created 290 feet downstream and the bed was raised 0.7 ft	5384.6	0.1	0.004
BV-11	7	5378.6		5378.5	-0.1	0.020
Bridge	6	5373.4	a riffle was created 350 feet downstream and the bed was raised 0.8 ft	5373.5	0.1	0.008
BV-12	5	5365.0		5365.0	0.0	0.001
Pipe Organ	4	5353.1		5353.1	0.0	0.000
				RMS Error =		**0.158**

Hydraulic Model Results

The HEC-RAS model was utilized to simulate a series of flows from the I-15 Bridge to Pipe Organ. A few of the profiles and model results are shown in Table 5. The table shows the range of the flows from 216 cfs up to 1,692 cfs. Top widths varied from 47 feet at BV-5 to 181 feet at HWIA-B. Velocities ranged from 1.28 ft/s, at the cross section known as upstream of Clark Canyon Creek (U/S CCC) station to 7 ft/s, at BV-5.

Hydraulic Model Limitations

The model was able to produce a longitudinal water surface profile that matched measured water surface elevations at field cross sections very well (RMS error of 0.16 feet). The model is expected to provide reasonable estimates of water surface elevations for discharges lower than the calibrated discharge up to the bankfull discharge. The model cross section geometry does not extend beyond the channel, so the model would over estimate water surface and velocity for discharges greater than the bankfull discharge.

Channel roughness coefficients are likely greater at lower discharge and less at higher discharge. This means that model predictions of water surface may be somewhat high at higher discharge (within the bankfull discharge) and somewhat low at lower discharge.

Since the channel geometry is not know well known between the 15 measured cross sections, model results should only be used at cross sections measured in the field rather than at any of the interpolated cross sections. Therefore, model results are only presented for cross sections measured in the field.

Table 5-Hydraulic Model Results for a range of flows

River mile (from upstream to downstream)	Station (total distance from upstream to downstream	Q	Thalweg	Water surface elevation	Velocity	Top Width
(mi)	(ft)	(cfs)	(ft)	(ft)	(ft/s)	(ft)
0	39,705	218	5445.1	5447.8	2.53	66.7
0	39,705	392	5445.1	5448.6	3.06	81.0
0	39,705	696	5445.1	5449.5	3.6	87.9
0	39,705	1044	5445.1	5450.4	4.03	87.9
0	39,705	1392	5445.1	5451.1	4.38	87.9
0	39,705	1566	5445.1	5451.5	4.53	87.9
0.4	37,538	218	5442.2	5444.1	3.03	57.7
0.4	37,538	392	5442.2	5444.9	3.38	68.7
0.4	37,538	696	5442.2	5446.0	3.73	73.0
0.4	37,538	1044	5442.2	5447.1	4.08	75.7
0.4	37,538	1392	5442.2	5448.0	4.39	76.9
0.4	37,538	1566	5442.2	5448.4	4.53	76.9
0.9	34781	218	5436.2	5442.5	1.28	53.1
0.9	34781	392	5436.2	5443.1	1.97	57.8
0.9	34781	696	5436.2	5443.9	2.89	61.0
0.9	34781	1044	5436.2	5444.7	3.71	63.4
0.9	34781	1392	5436.2	5445.3	4.38	63.4
0.9	34781	1566	5436.2	5445.7	4.67	63.4
1.2	33,205	218	5432.8	5434.3	2.97	63.5
1.2	33,205	392	5432.8	5434.8	3.71	68.2
1.2	33,205	696	5432.8	5435.5	4.59	73.6
1.2	33,205	1044	5432.8	5436.1	5.33	78.7
1.2	33,205	1392	5432.8	5436.7	5.9	80.4
1.2	33,205	1566	5432.8	5436.9	6.16	80.7
1.8	29943	218	5417.1	5419.8	3.51	47.3
1.8	29943	392	5417.1	5420.5	4.3	54.2
1.8	29943	696	5417.1	5421.4	5.23	58.8
1.8	29943	1044	5417.1	5422.2	6.04	61.9
1.8	29943	1392	5417.1	5422.8	6.72	63.7
1.8	29943	1566	5417.1	5423.1	7.02	64.2

Table 3-Hydraulic Model Results for a range of flows continued

Sta name	River mile (from upstream to downstream m)	(total distance from upstream to downstream m	Q	Thalweg	Water surface elevation	Velocity	Top Width
	(mi)	(ft)	(cfs)	(ft)	(ft)	(ft/s)	(ft)
BV-6	2.3	27,343	218	5409.5	5411.6	2.81	76.2
BV-6	2.3	27,343	392	5409.5	5412.2	3.37	91.4
BV-6	2.3	27,343	696	5409.5	5412.9	4.05	108.9
BV-6	2.3	27,343	1044	5409.5	5413.6	4.51	110.5
BV-6	2.3	27,343	1392	5409.5	5414.1	4.88	110.6
BV-6	2.3	27,343	1566	5409.5	5414.4	5.03	110.6
BV-7	2.8	24,980	218	5403.2	5405.8	2.48	64.5
BV-7	2.8	24,980	392	5403.2	5406.4	3.07	69.0
BV-7	2.8	24,980	696	5403.2	5407.3	3.77	70.8
BV-7	2.8	24,980	1044	5403.2	5408.1	4.38	71.4
BV-7	2.8	24,980	1392	5403.2	5408.9	4.88	71.4
BV-7	2.8	24,980	1566	5403.2	5409.2	5.11	71.4
BV-8	3.4	21,804	218	5396.3	5398.8	2.37	50.3
BV-8	3.4	21,804	392	5396.3	5399.6	3.05	57.5
BV-8	3.4	21,804	696	5396.3	5400.4	3.98	73.7
BV-8	3.4	21,804	1044	5396.3	5401.1	4.81	74.3
BV-8	3.4	21,804	1392	5396.3	5401.6	5.51	74.3
BV-8	3.4	21,804	1566	5396.3	5401.9	5.84	74.3
HWIA-B	3.6	20,633	218	5393.7	5396.2	2.53	91.5
HWIA-B	3.6	20,633	392	5393.7	5396.8	2.95	93.6
HWIA-B	3.6	20,633	696	5393.7	5397.6	3.66	138.4
HWIA-B	3.6	20,633	1044	5393.7	5398.2	4.34	179.9
HWIA-B	3.6	20,633	1392	5393.7	5398.6	4.58	180.6
HWIA-B	3.6	20,633	1566	5393.7	5398.8	4.68	180.8
BV-9	4.2	17,760	235	5387.6	5389.7	2.82	59.5
BV-9	4.2	17,760	423	5387.6	5390.4	3.49	68.8
BV-9	4.2	17,760	752	5387.6	5391.2	4.25	73.4
BV-9	4.2	17,760	1128	5387.6	5392.0	4.91	73.5
BV-9	4.2	17,760	1504	5387.6	5392.7	5.44	73.5
BV-9	4.2	17,760	1692	5387.6	5393.0	5.68	73.5

Table 3-Hydraulic Model Results for a range of flows continued

Sta name	River mile (from upstream to downstream)	Station (total distance from upstream to downstream	Q	Thalweg	Water surface elevation	Velocity	Top Width
	(mi)	(ft)	(cfs)	(ft)	(ft)	(ft/s)	(ft)
BV-10	4.6	15,200	235	5380.2	5384.0	1.56	72.9
BV-10	4.6	15,200	423	5380.2	5384.8	2.1	81.1
BV-10	4.6	15,200	752	5380.2	5385.8	2.73	84.6
BV-10	4.6	15,200	1128	5380.2	5386.7	3.3	84.8
BV-10	4.6	15,200	1504	5380.2	5387.4	3.78	84.8
BV-10	4.6	15,200	1692	5380.2	5387.8	3.99	84.8
BV-11	5.2	12,302	235	5375.5	5378.0	2.87	58.3
BV-11	5.2	12,302	423	5375.5	5378.7	3.58	60.8
BV-11	5.2	12,302	752	5375.5	5379.6	4.46	63.7
BV-11	5.2	12,302	1128	5375.5	5380.4	5.22	65.6
BV-11	5.2	12,302	1504	5375.5	5381.0	5.83	66.3
BV-11	5.2	12,302	1692	5375.5	5381.4	6.1	66.3
Henneberry Bridge	5.6	10,198	235	5368.5	5373.0	1.51	67.7
Henneberry Bridge	5.6	10,198	423	5368.5	5373.7	2.06	72.3
Henneberry Bridge	5.6	10,198	752	5368.5	5374.7	2.78	76.5
Henneberry Bridge	5.6	10,198	1128	5368.5	5375.6	3.41	81.2
Henneberry Bridge	5.6	10,198	1504	5368.5	5376.4	3.91	82.7
Henneberry Bridge	5.6	10,198	1692	5368.5	5376.7	4.13	82.7
BV-12	6.2	6,953	235	5361.5	5364.5	2.6	56.8
BV-12	6.2	6,953	423	5361.5	5365.3	3.22	58.7
BV-12	6.2	6,953	752	5361.5	5366.4	3.98	63.4
BV-12	6.2	6,953	1128	5361.5	5367.3	4.62	63.6
BV-12	6.2	6,953	1504	5361.5	5368.2	5.15	63.6
BV-12	6.2	6,953	1692	5361.5	5368.6	5.39	63.6
Pipe Organ	7.5	0	235	5349.7	5352.6	2.68	63.3
Pipe Organ	7.5	0	423	5349.7	5353.3	3.28	76.2
Pipe Organ	7.5	0	752	5349.7	5354.2	3.96	79.5
Pipe Organ	7.5	0	1128	5349.7	5355.1	4.53	80.1
Pipe Organ	7.5	0	1504	5349.7	5355.8	5	80.6
Pipe Organ	7.5	0	1692	5349.7	5356.1	5.2	80.7

Sediment Transport

Pebble Count Data

The pebble count technique (Wolman, 1954) is used to measure the bed-material grain size distribution for rivers that flow over gravel and cobble-sized sediment. Matt Jaeger of Montana Fish Wildlife and Parks measured bed material using pebble counts along the Beaverhead River at seven sites during May 2011 and May 2012. Riffle, pool, and composite data were measured at all seven sites. Composite data represented a combination of pool and riffle data. Riffle, pool and composite particle size gradation data were used in the bed-material transport capacity calculations (computed sediment transport rate for sand and gravel). River flows on the Beaverhead River were higher than normal between the 2011 and 2012 measurements. It was hypothesized that fine sediment would be eroded and transported downstream during high flows, and the pebble count data would be coarser in 2012. Bed-material size gradation plots from riffles and pools are presented in Appendix A for measurements in 2011 and 2012 (Figure 6 through Figure 13).

Discharges at the Barretts gauge were in excess of 1,000 cfs from July 20, 2011through August 16, 2011 with a maximum discharge of 1,170 cfs. The D_{15} and median sediment particle size (D_{50}) were calculated for the pool and riffle data for 2011 and 2012 to compare changes. In most instances, the pool and riffle bed material are coarser in 2012 than in 2011, indicating that finer sediments of the bed material were eroded and transported downstream (Figure 4 and Figure 5). Montana Fish, Wildlife and Parks did not make any observations about embeddedness between the two surveys.

For both 2011 and 2012, the median grain size of the riffles was generally coarser than in the pools, which is to be expected because stream-flow velocities through riffles are generally faster than through pools. Therefore, more sediment is likely to deposit in pools than in riffles, so there was more change in the sediment grain size in pools than in riffles between 2011 and 2012.
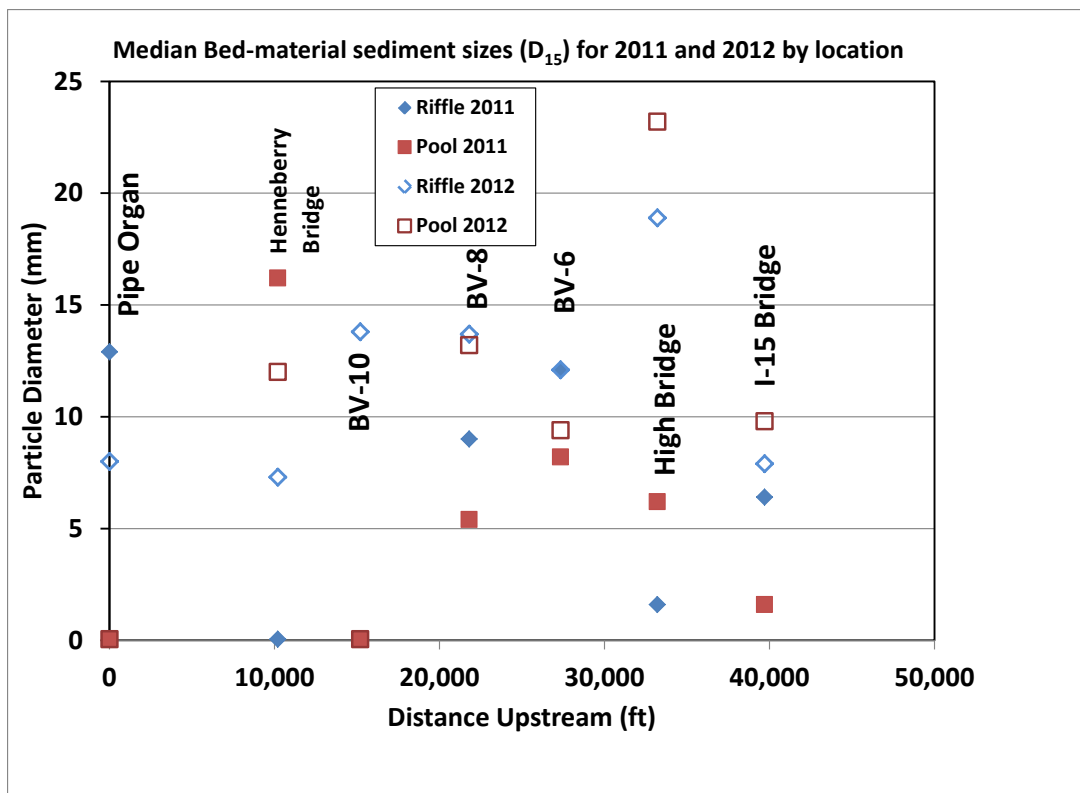
Figure 4. Median Bed-material sediment sizes (D_{15}) for 2011 and 2012 by location.
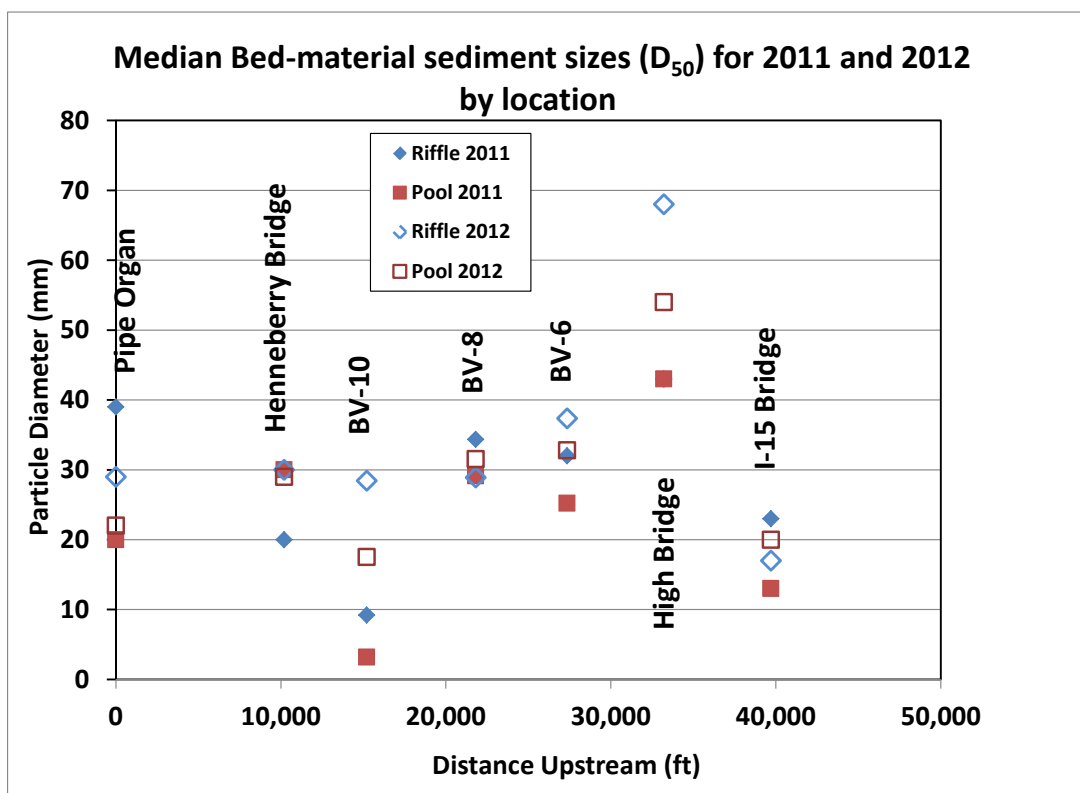

Figure 5. Median Bed-material sediment sizes (D_{50}) for 2011 and 2012 by location.

Bed-material Transport Capacity

Bed-material transport capacity was computed for the Beaverhead River reach with the SRH-1D Capacity model. SRH-1D Capacity is a sediment transport model developed to calculate the hydraulic capacity to transport sediment for a given set of channel hydraulics and bed-material grain size. The input needed to run the model are listed below:

- HEC-RAS hydraulics model output for each cross-section where sediment transport capacity is to be computed.
- Bed-material particle size gradation data.

The 2012 pebble count data documented the bed-material size gradation of seven riffles and pools. A composite size gradation was also provided for each of the seven cross sections. HEC-RAS hydraulic output data include discharge, velocity, wetted top width, hydraulic radius, friction slope, and channel bed slope (Table 5).

The Parker (1990) sediment transport equation was used for computing bed-material transport capacity. The equation was developed based on surface grain-size distribution for Oak Creek, excluding grain sizes smaller than 2 mm (Wilcock et.al, 2009). This sediment transport equation is often used for gravel-bed rivers. In order to flush fine sediment (less than 1 mm) from the interstitial spaces of a gravel bed river, it was assumed that the discharge needs to be high enough to just mobilize the largest gravel or cobble size (Kondolf et. al., 1996). For this analysis, the discharge that can just mobilize the bed material size that is larger than 90 percent of the bed (D_{90}) was determined.

Results of Sediment Transport Analysis

The SRH-1D Capacity model provides results for the bed-material capacity for each size fraction. Bed-material transport capacity was computed at the seven measured cross sections where pebble count data were provided. For each cross section, the discharge that will just begin to mobilize the D_{90} sediment particle size was identified. For the selected transport equation (Parker, 1990), the results indicate that a discharge of about 600 cfs would mobilize the D_{90} bed-material size, and thus flush the fine sediment from the gravel from all the cross sections except for Henneberry Bridge and BV-10. These results are different that the observations made based on pebble count data. For these two cross sections, a discharge of about 1,800 cfs would be required to mobilize the D_{90} bed-material size (Figure 6). The bed-material sizes at Henneberry Bridge and BV-10 are similar to other locations, but the flow velocities are smaller, so a larger discharge is needed to mobilize the sediment. Bed-material transport capacity is presented in Appendix B (Figure 14 through Figure 20).
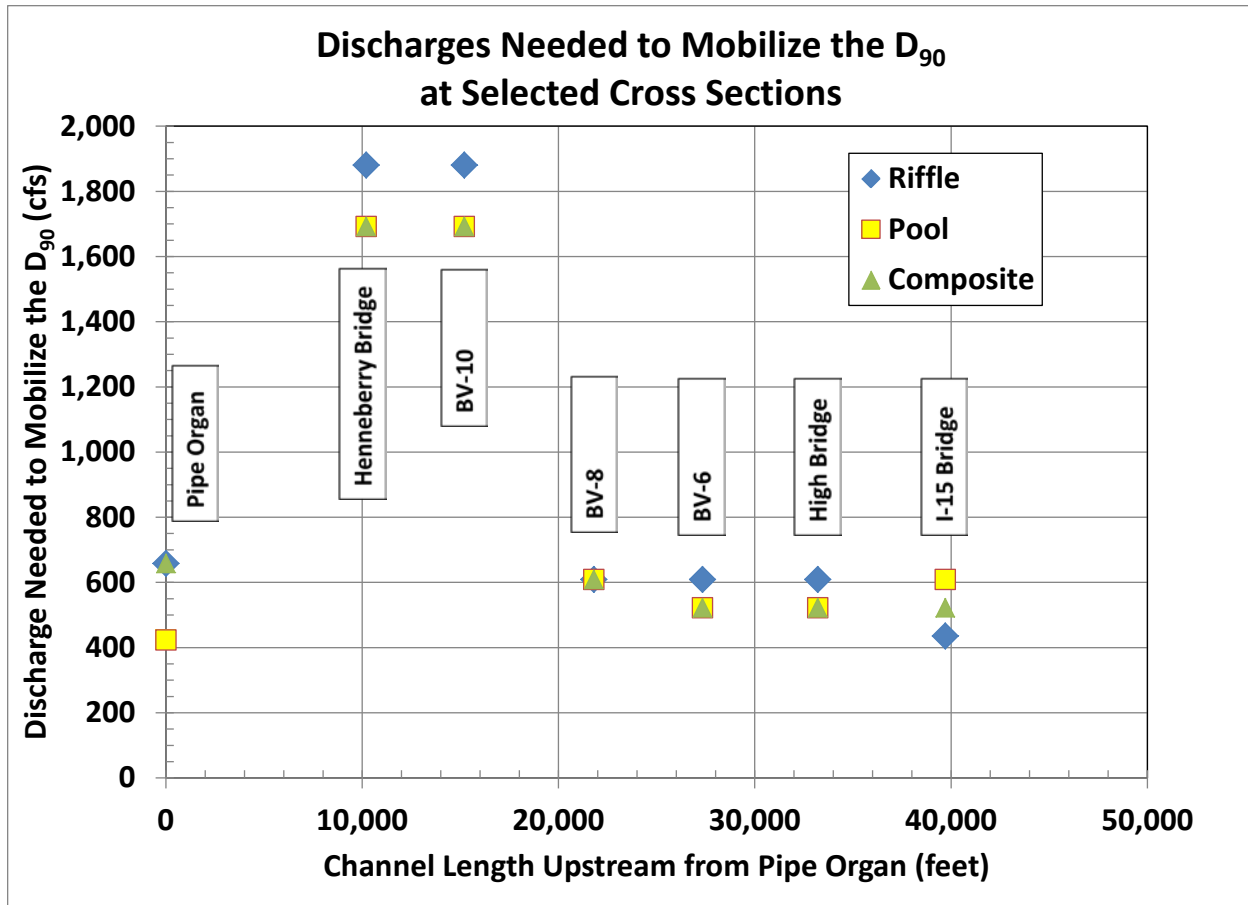
Figure 6. Discharges needed to mobilize the D90 at selected cross sections.

Sediment Transport Model Limitations

The bed-material transport capacity results were based on the Parker sediment transport equation. Measured bedload (sand and gravel) transport rates were not available to calibrate this transport equation. Computed sediment transport rates can vary by a factor of 2 from measured sediment transport rates. Therefore, the discharge estimated by this study to flush fine sediments from the channel bed should be treated as approximate and need to be field verified. Comparisons of pebble count data between 2011 and 2012 do provide an upper bound on the discharge required to flush fine sediments from the channel bed.

Future observations of the bed including pebble counts, bulk sediment samples, and photographs should help verify the study results.

Conclusions and Recommendations

Discharges at the Barretts gauge were in excess of 1,000 cfs from July 20, 2011through August 16, 2011 with a maximum discharge of 1,170 cfs. A discharge of 1,000 cfs is exceeded during 7 percent of the non-winter days. In most instances, the pool and riffle bed material became coarser in 2012 than in 2011, indicating that finer sediments of the bed material were eroded and transported downstream during high and sustained flows. This data does not indicate the lowest discharge that would have flushed fine sediment from the stream bed.

The sediment model results indicate that a discharge of 600 cfs would mobilize the largest gravel and cobble sizes and flush fine sediment at every section, except BV-10 and Henneberry Bridge. A discharge of about 1,800 cfs would be needed to flush fine sediments at those two sections. A comparison of pebble count data between 2011 and 2012 indicates that, at Henneberry Bridge, median grain size of the pool did not significantly change, but the riffle became somewhat coarser. At BV-10 both the riffle and pool became coarser between 2011 and 2012. This data suggests that a discharge of about 1,000 cfs is sufficient to flush fine sediment from the pool and riffle at BV-10 and the riffle at Henneberry Bridge.

The sediment transport analysis is based on a theoretical sediment transport equation (Parker). However, measured rates of gravel transport (bed load) were not available from the Beaverhead River to calibrate the sediment transport equation. Therefore, the discharges estimated in the analysis to flush fine sediment from the gravel bed should be considered as a starting point for experimental high-flow releases from Clark Canyon Dam. Monitoring data would be needed to verify if the actual peak discharge and duration are successful in flushing fine sediments from the gravel bed. For future monitoring, collection of bulk sediment samples from the streambed would provide more accurate information on particle size distribution than pebble counts, especially when fine sediments are present. Photographs should be taken of each sample in the field.

For the purposes of flushing fine sediment from the streambed, the peak discharge of the flushing flow is more important than the duration of the peak discharge. However, the duration of the peak discharge needs to be long enough (6 hours) so that the peak discharge does not significantly attenuate at Barretts Diversion Dam. The rate of discharge rise and fall is not expected to influence the flushing of sediment. Therefore, the rate of rise and fall should be short enough to conserve water, but not so short as to cause safety problems for recreationist (rising discharge) or stranding problems for fish (falling discharge).

Fine sediments that are flushed from the gravel bed are likely to deposit along the Beaverhead River downstream from Pipe Organ because the longitudinal channel slope is not as steep and because water is diverted from the river at the Barretts Diversion Dam farther downstream.

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Appendix A – Bed-material Data
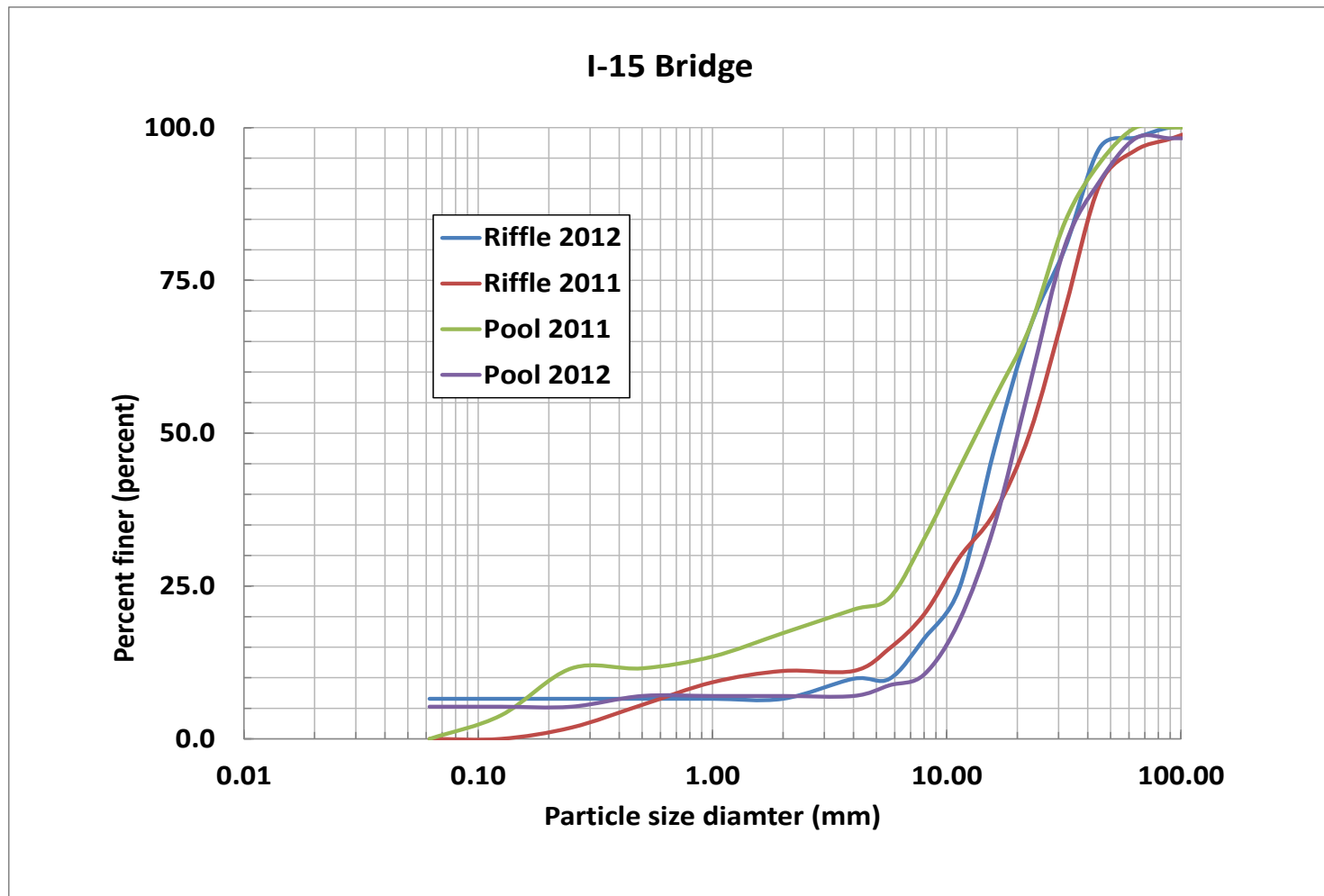
Figure 7-Bed material size data for I-15 Bridge
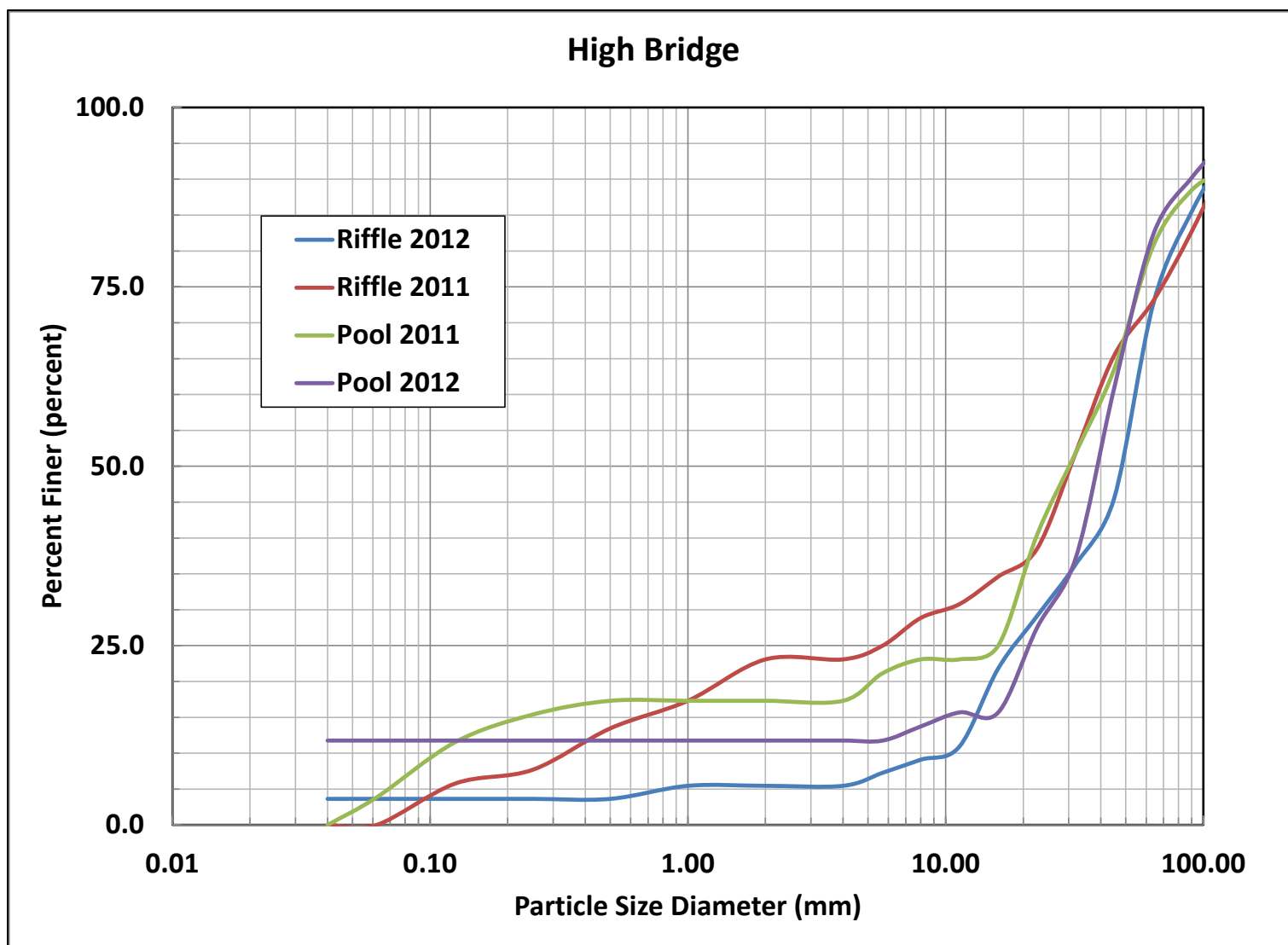
Figure 8- Bed material size data for High Bridge.
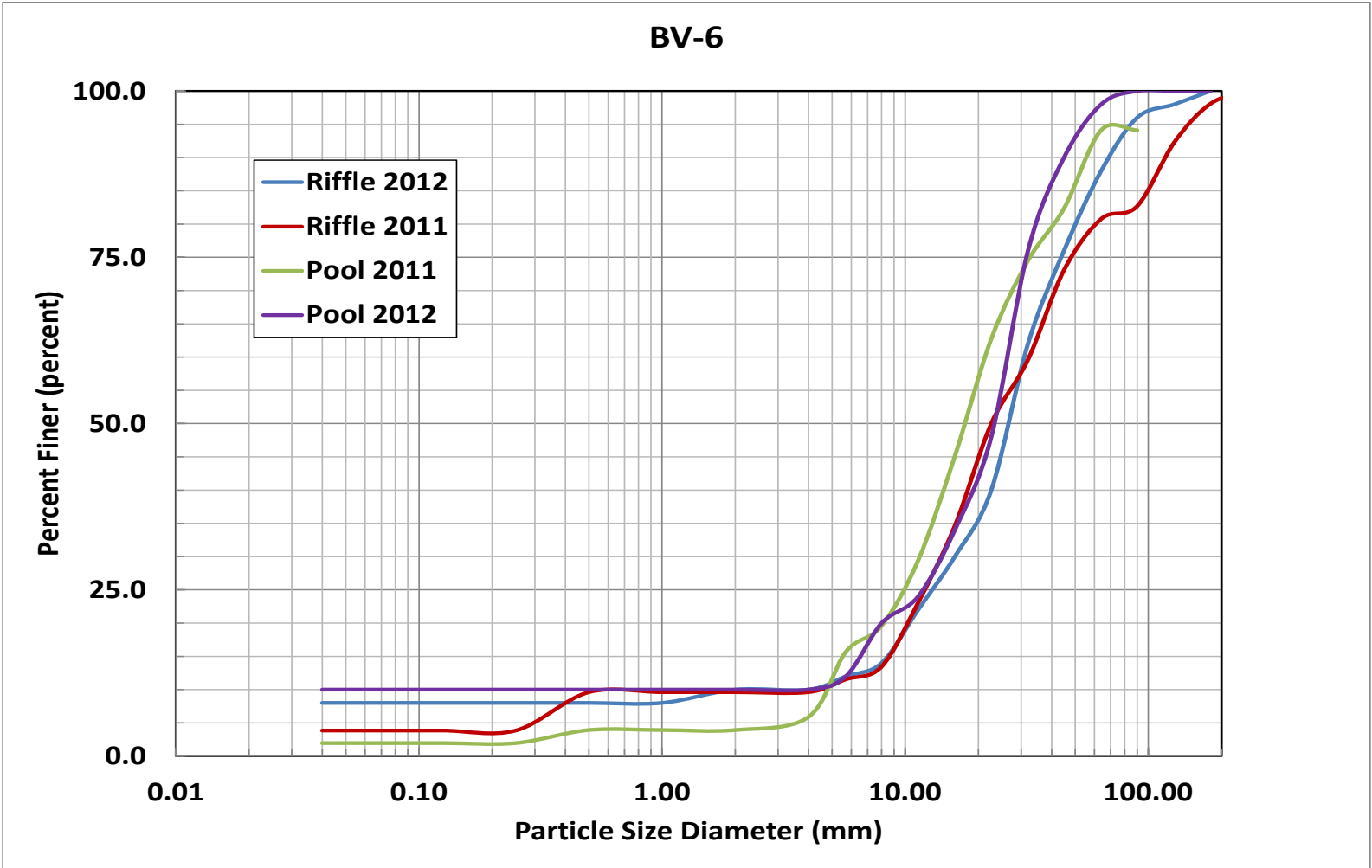
Figure 9- Bed material size data for BV-6.
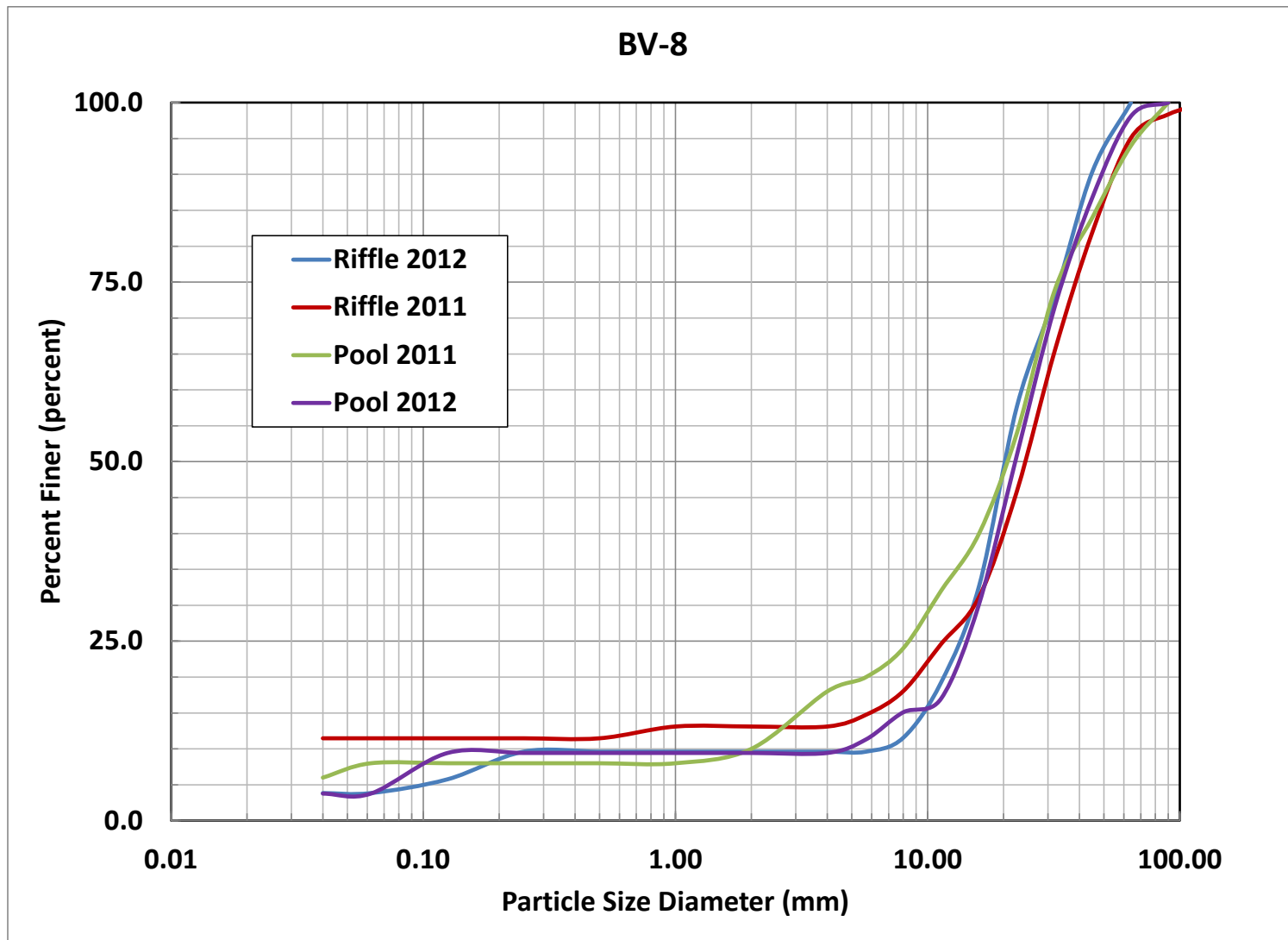
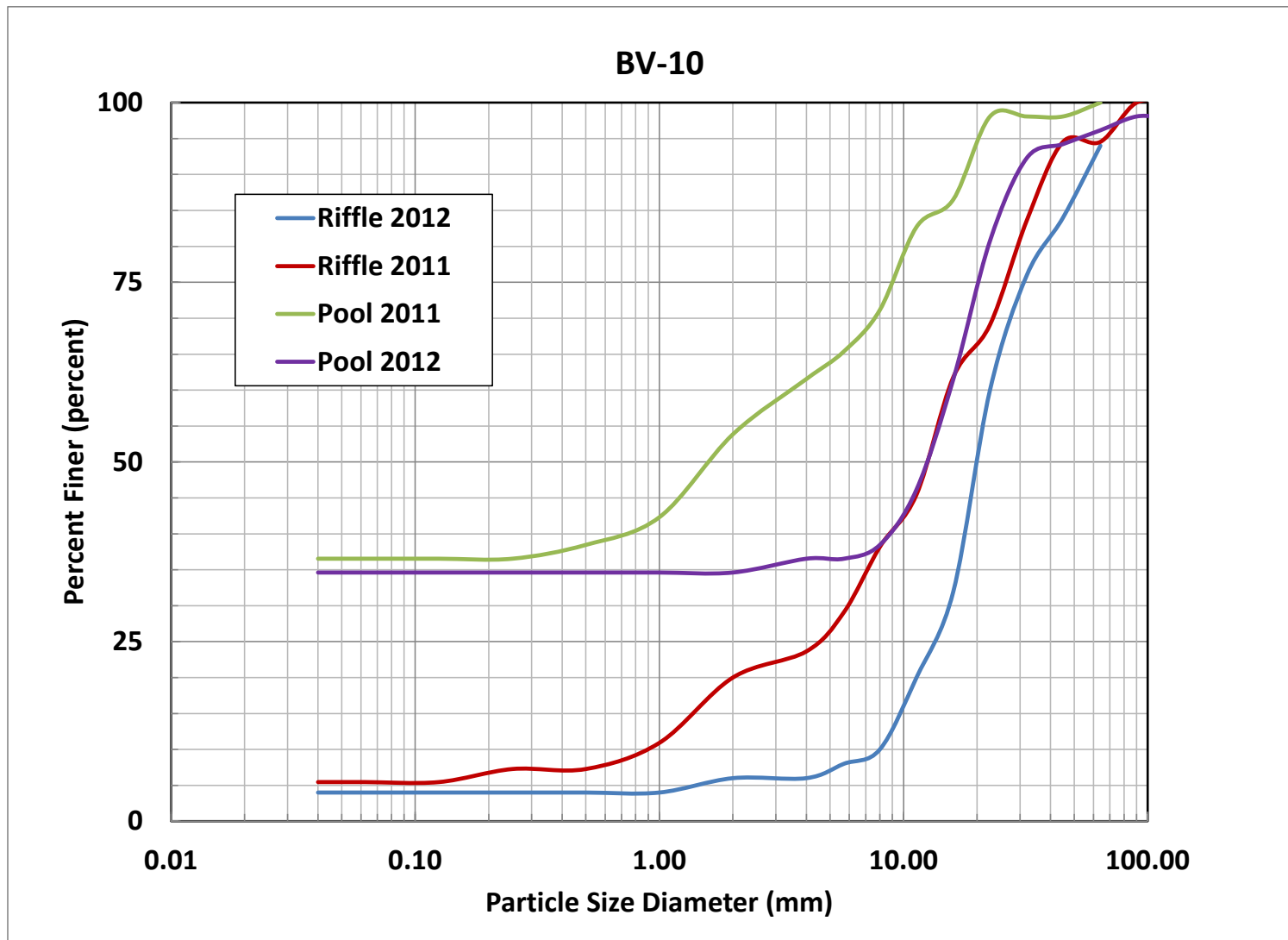**Figure 10- Bed material size data for BV-8.**

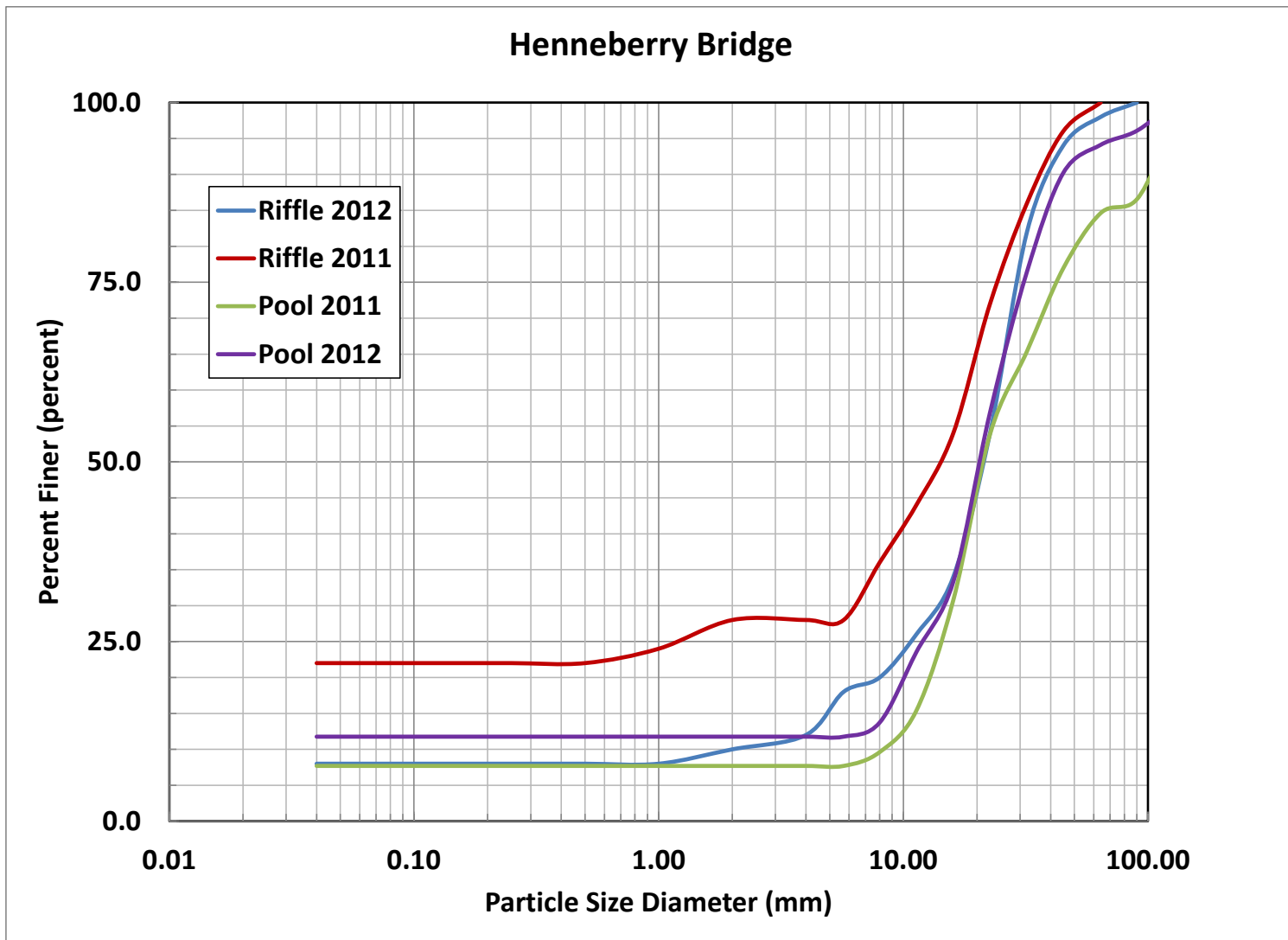**Figure 11- Bed material size data for BV-10.**

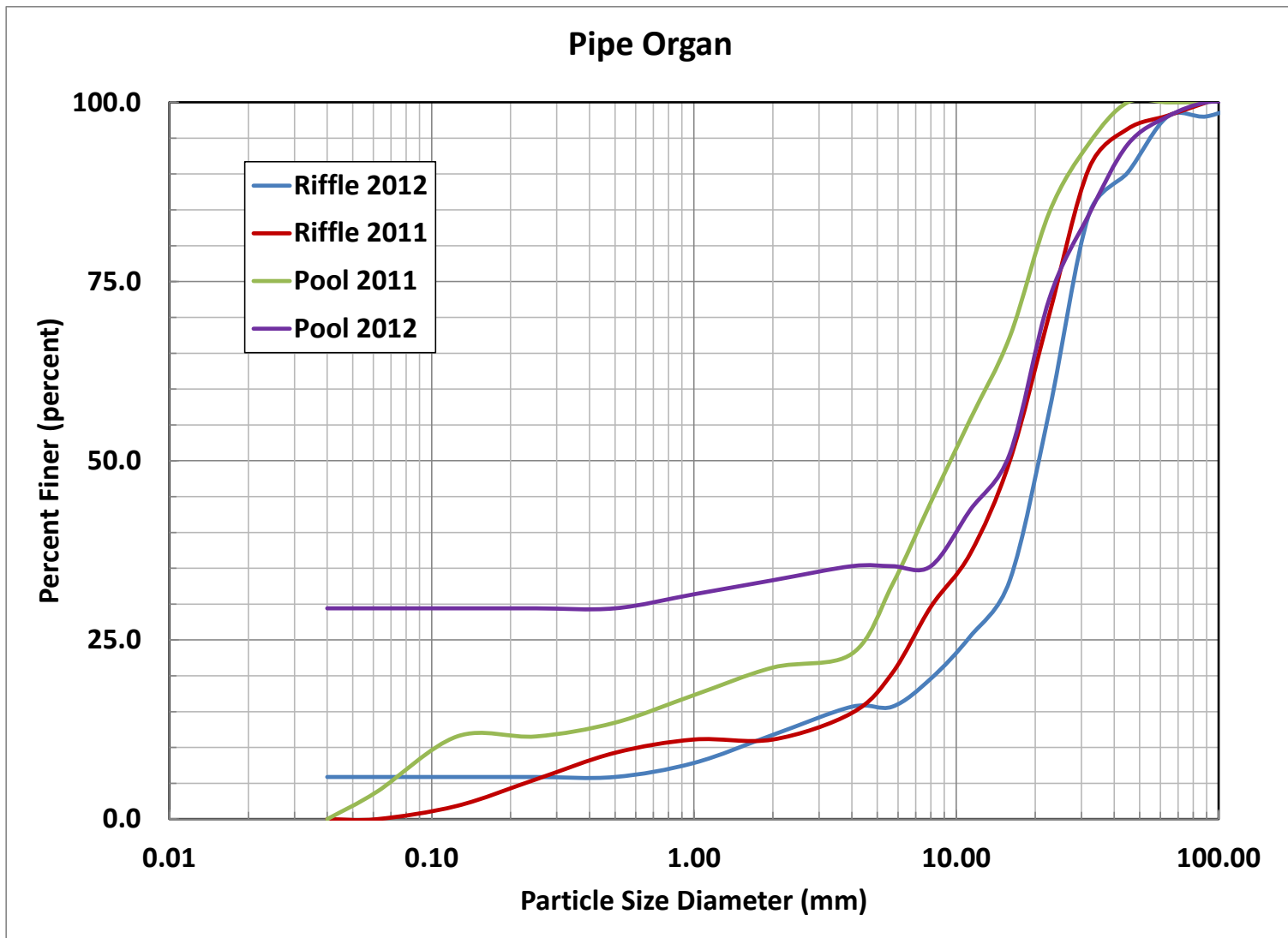**Figure 12- Bed material size data for Henneberry Bridge.**

Figure 13- Bed material size data for Pipe Organ.
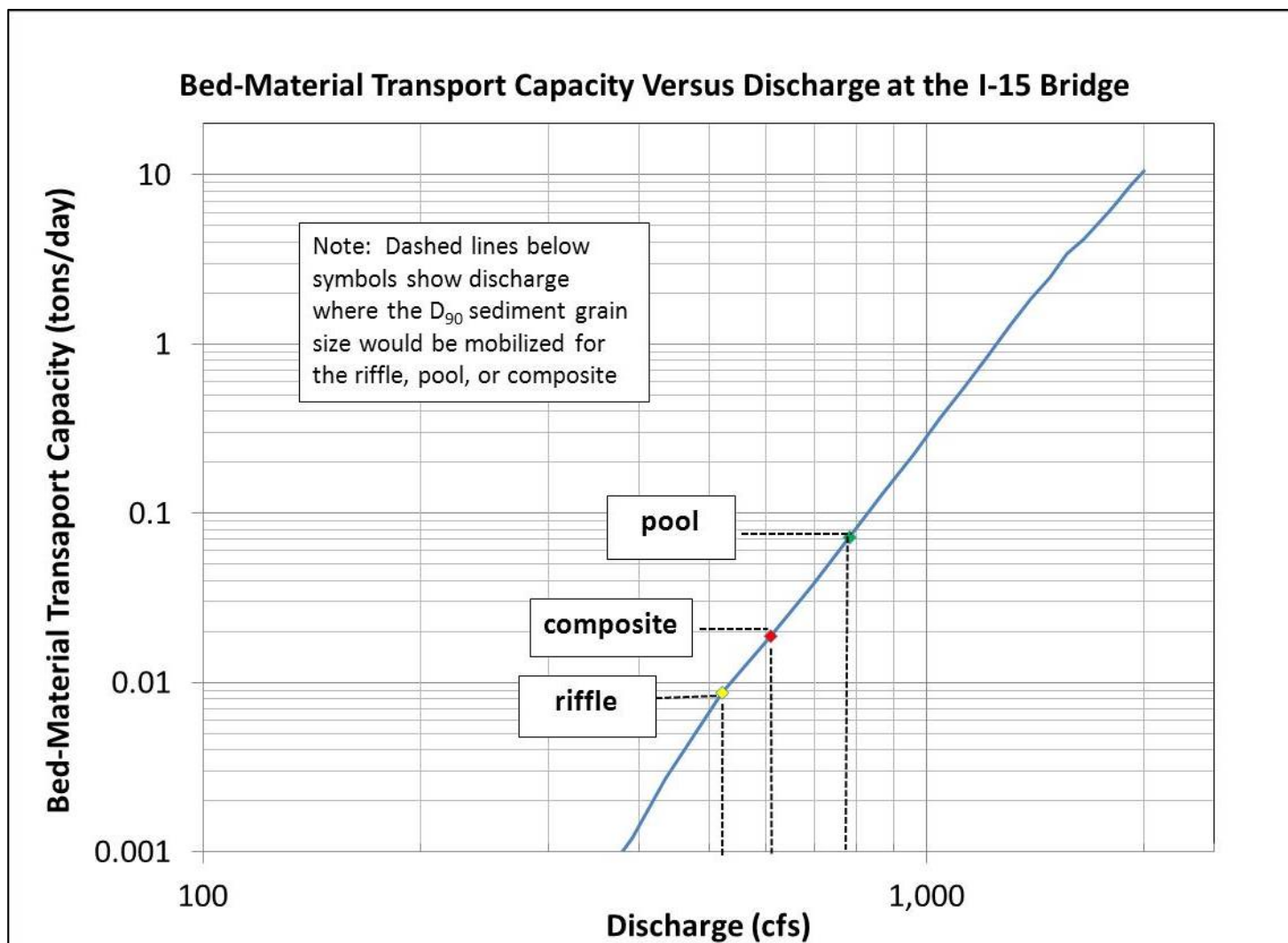
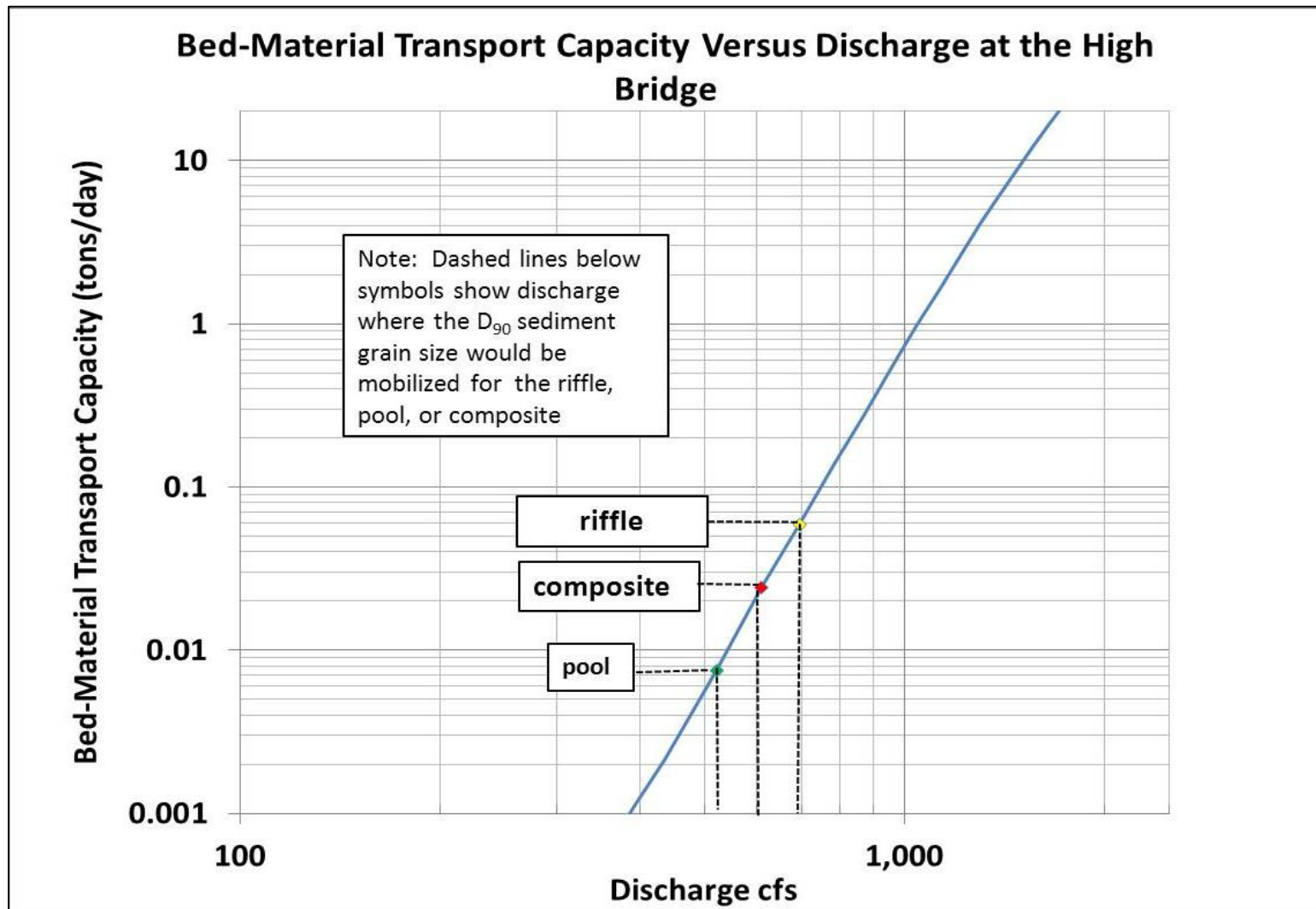# Appendix B – Bed-material Capacity Data

Figure 14-Bed material transport capacity at the I-15 Bridge.

Figure 15- Bed material transport capacity at the High Bridge.
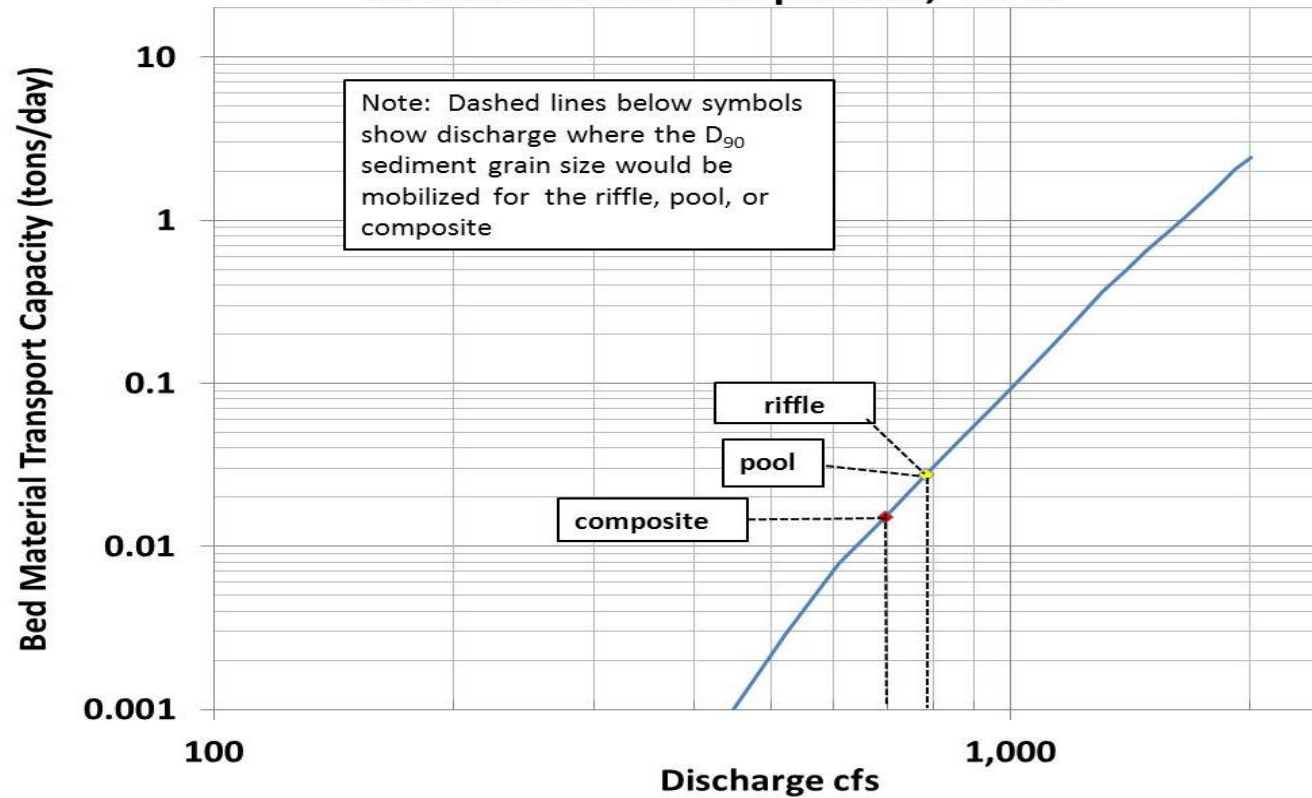
Figure 16- Bed material transport capacity at BV-6.
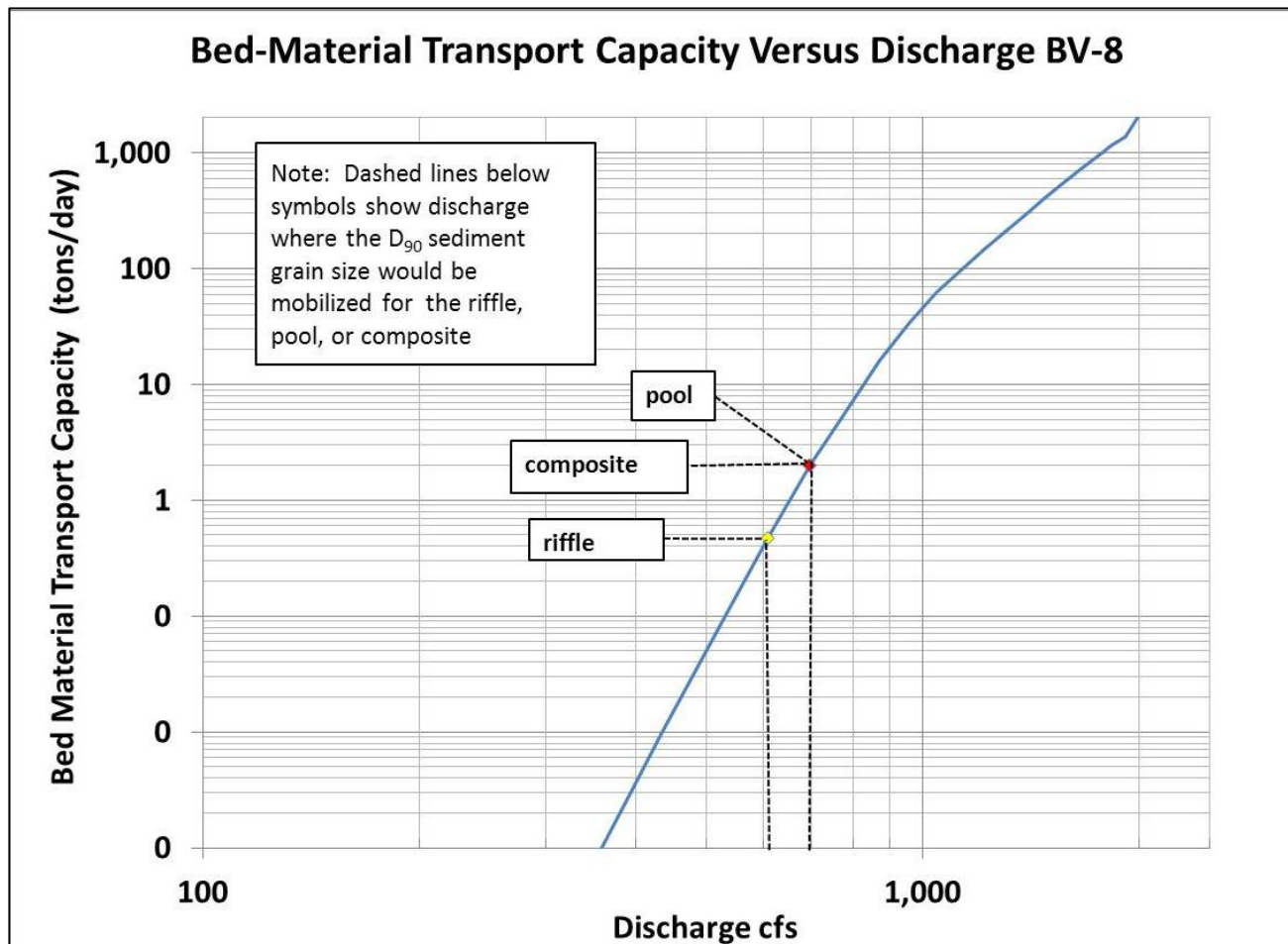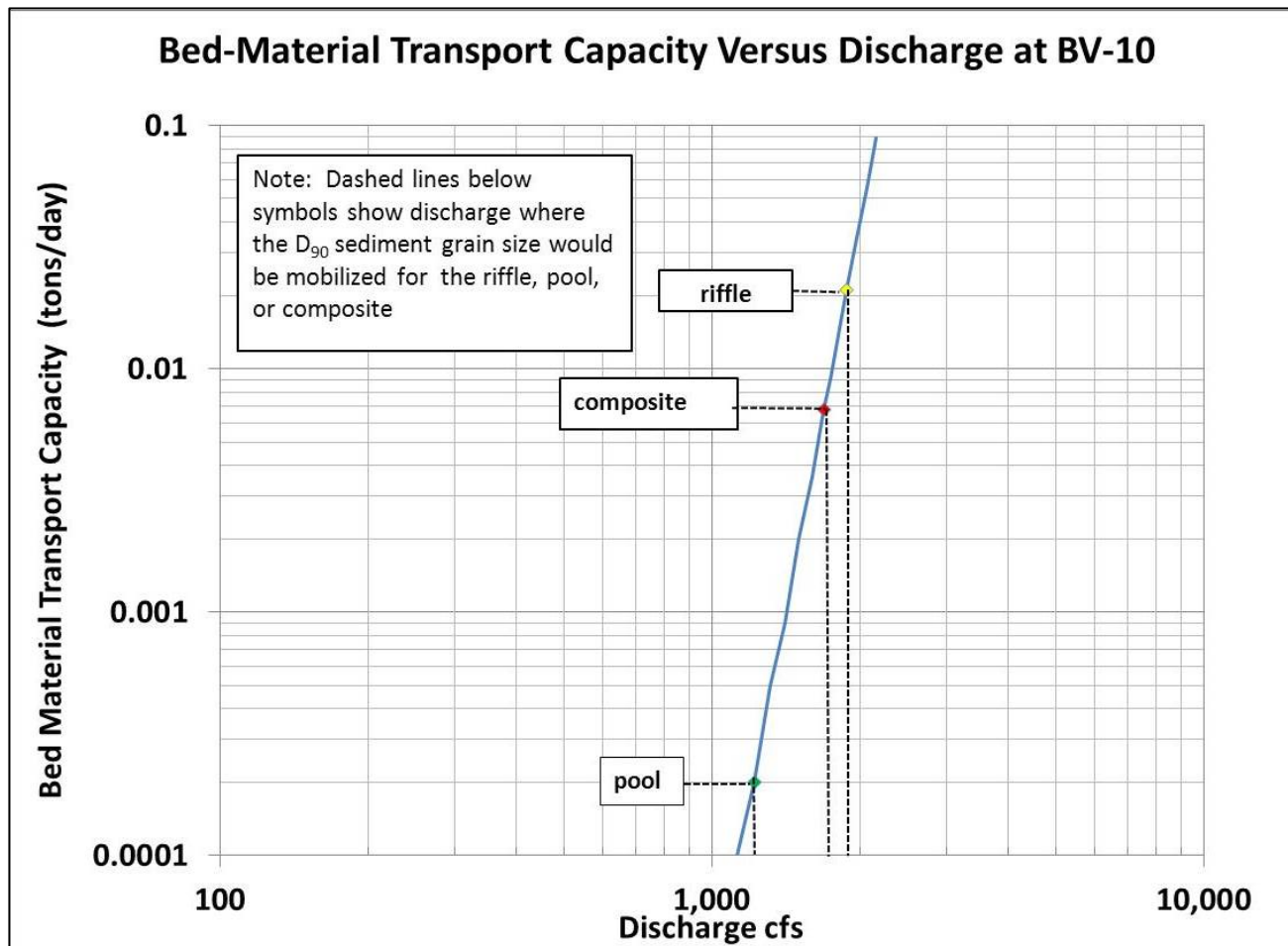
Figure 17- Bed material transport capacity at BV-8.

Figure 18- Bed material transport capacity at BV-10.
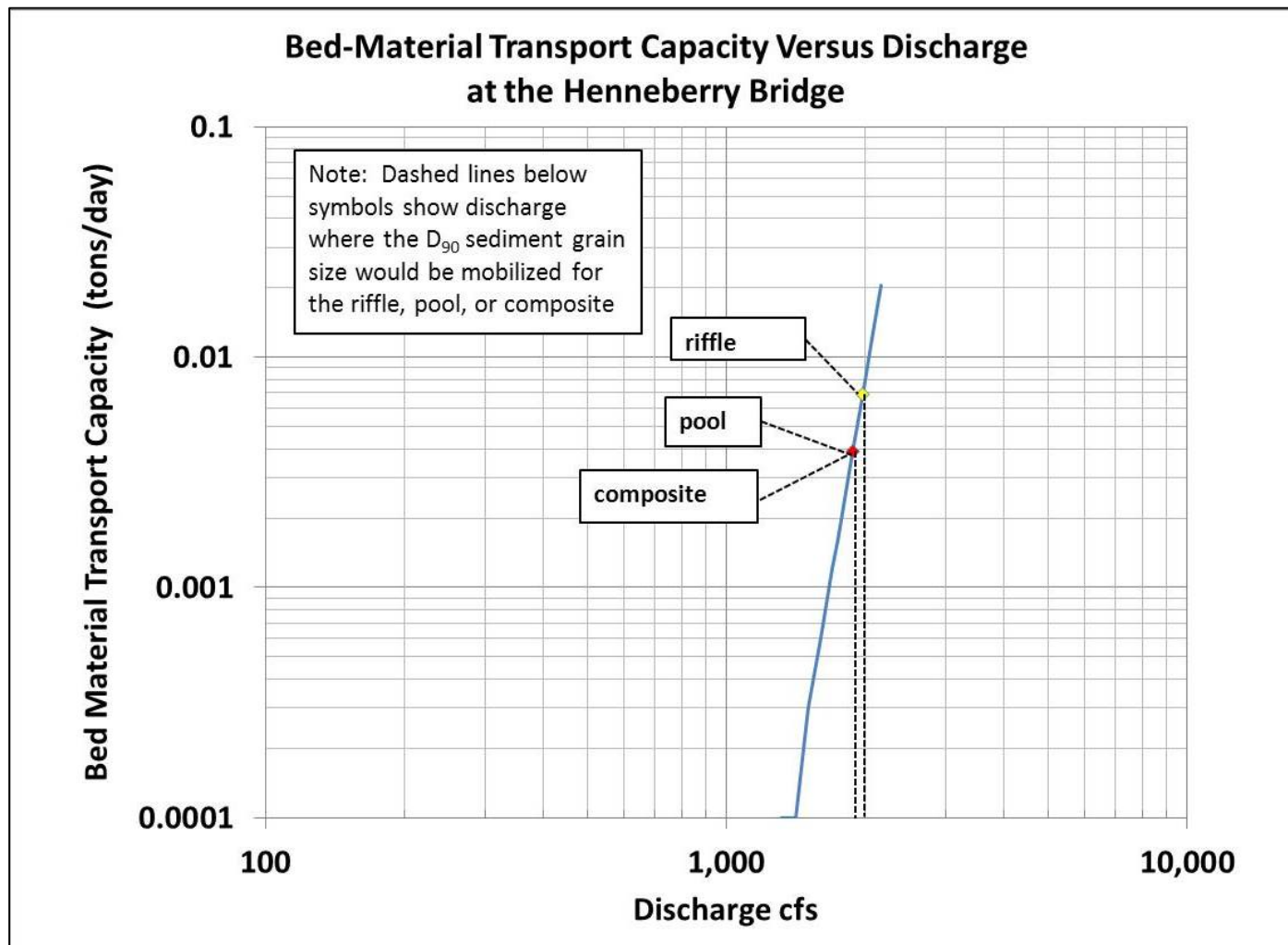
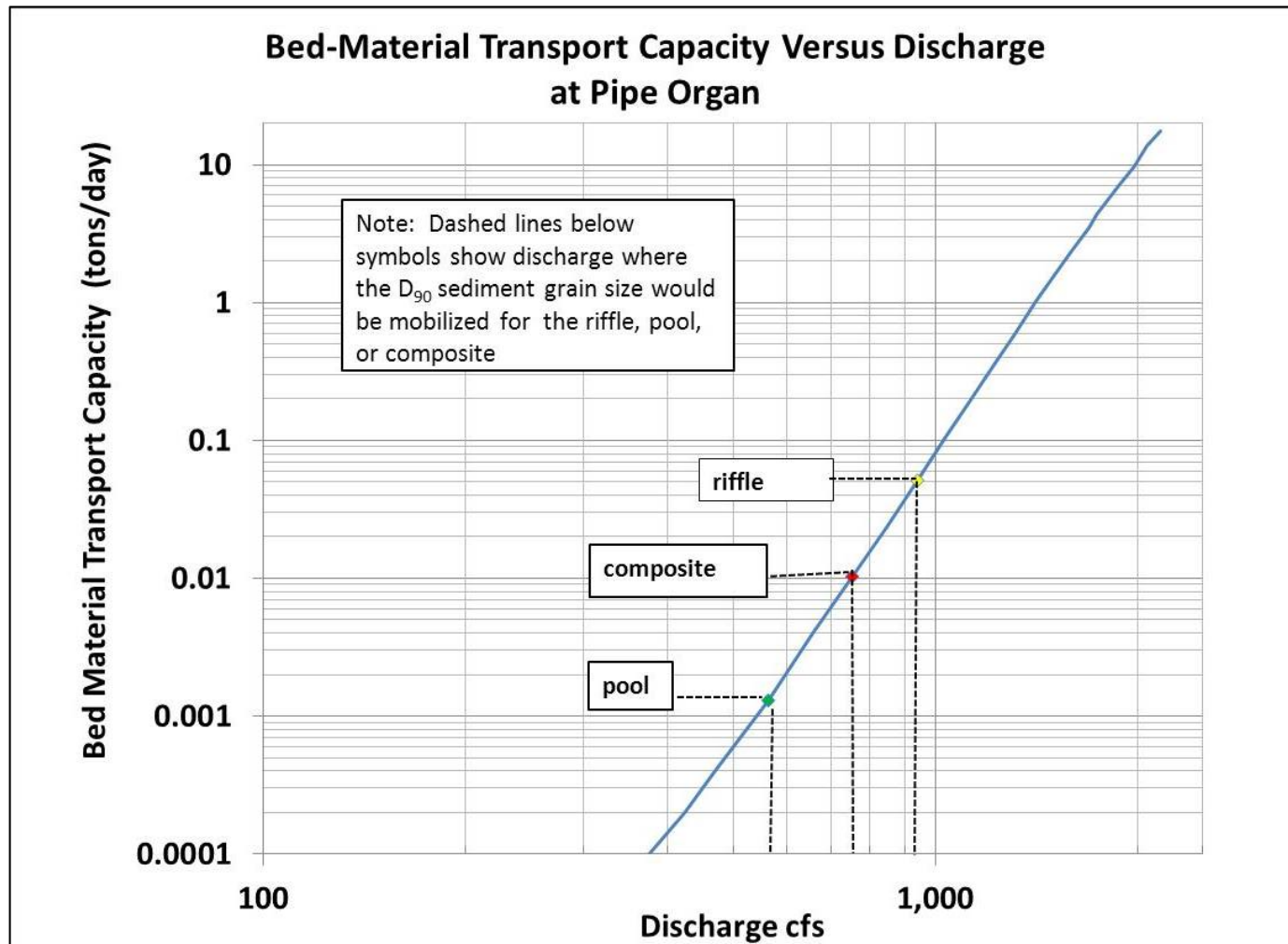**Figure 19- Bed material transport capacity at the Henneberry Bridge.**

Figure 20- Bed material transport capacity at Pipe Organ.