Knife River Assessment Fall 2015

J15Y133600

Prepared for
Environmental Troubleshooters

March 11, 2016

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1 Introduction

The Lake Superior Steelheaders Association (LSSA) seeks to improve habitat conditions for both spawning adult steelhead and juvenile fish in the Knife River system. The Knife River watershed is 83.6 square miles (Nieber et al. 2008) with the main branch containing approximately 25 river miles (SStLSWCD 2011).

Cardno was contracted to Environmental Troubleshooters (ET) to assess 12 stream reaches in the upper Knife River watershed (ten reaches on the Knife River main stem and two reaches on McCarthy Creek; Figure 1). Reaches were previously selected by another contractor hired by ET. Field work was initiated on November 23, 2015 and was completed on December 17, 2015. During this period, we were limited by frozen stream conditions and high water to twelve days of adequate work conditions in the stream. The two reaches on McCarthy were the only two reaches where no data were collected and there are three reaches were one or more components of data are missing due to site conditions and available time. The remaining data gaps will be completed in spring 2016 when conditions allow.

Stream reach characterization through the natural channel classification system developed by Rosgen (1996) is important because it provides information on the reach's stability, state, and stream restoration options. The basic stream assessment completed for each reach allows for the assigning a reach into one (or more) Rosgen classification system stream types.

2 Methods

For each stream reach, the following parameters were collected in the field:

- A longitudinal profile collecting relative elevations for stream thalweg (stream bed), water surface, bankfull, and low bank height
- Three cross sections (two at riffles and one at a pool)
- Two pebble counts (one at an active riffle and one composite count throughout the assessment reach)
- Rosgen stream assessment Level III worksheets (Rosgen 2008)- Worksheet 3-4 (Meander Patterns), Worksheet 3-5 (Depositional Patterns), Worksheet 3-6 (Channel Blockages), and Worksheet 3-10 (Pfankuch)

At least one temporary control point was established at each reach and assigned the relative elevation of 100 feet. Temporary control points were either an 18-inch piece of rebar or 24-inch wooden stake driven flush to the ground. Each control point was flagged at ground level and overhead on adjacent trees. A brief description of each control point is provided for each reach summary below.

Survey data were entered into a Microsoft Excel spreadsheet for initial data quality and visual inspection before being copied into RIVERMorph, a computer program developed to analyze stream survey data and summarize stream metrics developed by Rosgen and others (Rosgen 1996). To allow for a reach comparison, 100 feet relative elevations for each reach were converted to estimated real elevation by interpreting the location of the control point on a contour map generated from LiDAR or USGS topographical maps.

For each reach, the following parameters were estimated either in RiverMorph or through map/GIS analysis:

- Bankfull area, width, depth, and maximum depth
- Channel slope
- Width/depth ratio
- Flood-prone area width
- Entrenchment ratio
- Sinuosity
- Dominant bed material

3 Results and Discussion

Below is a summary of the stream classification parameters. Figures of surveyed cross sections, the longitudinal profile, and Rosgen Level III worksheets along with a map of the survey reach are included Appendices A through C. An electronic copy of assessment data in spreadsheet/database format is also included with this report.

3.1 Reach 1

Figure 3-1 Example of stream characteristics along Reach 1

Table 3-1 Summary of stream classification parameters for Reach 1

Parameter	Value	Range
Watershed size	7.12 mi^2	N/A
Assessment reach length	607 ft	N/A
Channel slope	0.008	N/A
Bankfull cross sectional area	26.5 ft^2	25.0 – 27.9 ft^2
Bankfull cross sectional width	16.3 ft	15.5 – 17.2 ft
Bankfull cross sectional depth	1.6 ft	1.5 – 1.8 ft
Bankfull cross sectional maximum depth	2.1 ft	1.7 – 2.5 ft
Width/depth ratio	10.2	8.6 – 11.8
Flood-prone area width	415.4 ft	408.7 – 422.1 ft
Entrenchment ratio	25.5	23.8 – 27.3
Sinuosity	1.0	N/A
Dominant bed material (D_{50})	174.8 mm (Large cobble)	N/A
Dominant bed material (D_{84})	504.6 mm (Small boulder)	N/A
Rosgen stream type	E	N/A

3.2 Reach 2

Figure 3-2 Example of stream characteristics along Reach 2

Table 3-2 Summary of stream classification parameters for Reach 2

Parameter	Value	Range
Watershed size	8.01 mi^2	N/A
Assessment reach length	890 ft	N/A
Channel slope	0.008	N/A
Bankfull cross sectional area	25.4 ft^2	20.2 – 30.5 ft^2
Bankfull cross sectional width	20.3 ft	15.9 – 24.6 ft
Bankfull cross sectional depth	1.3 ft	1.2 – 1.3 ft
Bankfull cross sectional maximum depth	1.7 ft	1.5 – 1.8 ft
Width/depth ratio	16.2	12.5 – 19.8
Flood-prone area width	119.4 ft	115.5 – 123.2 ft
Entrenchment ratio	6.2	4.7 – 7.7
Sinuosity	1.1	N/A
Dominant bed material (D_{50})	77.0 mm (Small cobble)	N/A
Dominant bed material (D_{84})	235.8 mm (Large cobble)	N/A
Rosgen stream type	C	N/A

3.3 Reach 3

Figure 3-3 Example of stream characteristics along Reach 3

Table 3-3 Summary of stream classification parameters for Reach 3

Parameter	Value	Range
Watershed size	13.7 mi^2	N/A
Assessment reach length	759 ft	N/A
Channel slope	0.014	N/A
Bankfull cross sectional area	35.5 ft^2	33.6 – 37.5 ft^2
Bankfull cross sectional width	29.4 ft	26.0 – 32.8 ft
Bankfull cross sectional depth	1.2 ft	1.0 – 1.4 ft
Bankfull cross sectional maximum depth	2.0 ft	1.9 – 2.0 ft
Width/depth ratio	25.1	18.1 – 32.2
Flood-prone area width	52.4 ft	37.8 – 66.9 ft
Entrenchment ratio	1.7	1.5 – 2.0
Sinuosity	1.1	N/A
Dominant bed material (D_{50})	Incomplete	N/A
Dominant bed material (D_{84})	Incomplete	N/A
Rosgen stream type	B	N/A

3.4 Reach 4

Figure 3-4 Example of stream characteristics along Reach 4

Table 3-4 Summary of stream classification parameters for Reach 4

Parameter	Value	Range
Watershed size	14.3 mi^2	N/A
Assessment reach length	785 ft	N/A
Channel slope	0.012	N/A
Bankfull cross sectional area	38.3 ft^2	36.0 – 40.6 ft^2
Bankfull cross sectional width	31.4 ft	27.7 – 35.1 ft
Bankfull cross sectional depth	1.2 ft	1.2 – 1.3 ft
Bankfull cross sectional maximum depth	2.0 ft	1.9 – 2.1 ft
Width/depth ratio	25.8	21.3 – 30.2
Flood-prone area width	119.4 ft	107.8 – 130.9 ft
Entrenchment ratio	3.9	3.1 – 4.7
Sinuosity	1.2	N/A
Dominant bed material (D_{50})	39.4 mm (V.Coarse Gravel)	N/A
Dominant bed material (D_{84})	114.8 mm (Small cobble)	N/A
Rosgen stream type	B/C	N/A

3.5 Reach 5

Figure 3-5 Example of stream characteristics along Reach 5

Table 3-5 Summary of stream classification parameters for Reach 5

Parameter	Value	Range
Watershed size	14.8 mi^2	N/A
Assessment reach length	923 ft	N/A
Channel slope	0.011	N/A
Bankfull cross sectional area	39.3 ft^2	38.6 – 39.9 ft^2
Bankfull cross sectional width	24.2 ft	22.6 – 25.8 ft
Bankfull cross sectional depth	1.6 ft	1.5 – 1.8 ft
Bankfull cross sectional maximum depth	2.0 ft	1.9 – 2.0 ft
Width/depth ratio	15.1	12.9 – 17.3
Flood-prone area width	68.7 ft	52.3 – 84.7 ft
Entrenchment ratio	1.7	1.5 – 2.0
Sinuosity	1.1	N/A
Dominant bed material (D_{50})	58.2 mm (V.Coarse Gravel)	N/A
Dominant bed material (D_{84})	195.2 mm (Large cobble)	N/A
Rosgen stream type	B/C	N/A

3.6 Reach 6

Figure 3-6 Example of stream characteristics along Reach 6

Table 3-6 Summary of stream classification parameters for Reach 6

Parameter	Value	Range
Watershed size	15.2 mi^2	N/A
Assessment reach length	850 ft	N/A
Channel slope	0.007	N/A
Bankfull cross sectional area	42.6 ft^2	41.2 – 43.4 ft^2
Bankfull cross sectional width	24.2 ft	22.3 – 26.1 ft
Bankfull cross sectional depth	1.8 ft	1.7 – 1.9 ft
Bankfull cross sectional maximum depth	2.5 ft	2.5 – 2.5 ft^2
Width/depth ratio	13.8	11.9 – 15.7
Flood-prone area width	125.3 ft	116.5 – 134.1 ft
Entrenchment ratio	5.2	4.5 – 6.0
Sinuosity	1.1	N/A
Dominant bed material (D_{50})	Incomplete	N/A
Dominant bed material (D_{84})	Incomplete	N/A
Rosgen stream type	C/E	N/A

3.7 Reach 7

Figure 3-7 Example of stream characteristics along Reach 7

Table 3-7 Summary of stream classification parameters for Reach 7

Parameter	Value	Range
Watershed size	18.6 mi^2	N/A
Assessment reach length	722 ft	N/A
Channel slope	0.007	N/A
Bankfull cross sectional area	45.6 ft^2	45.1 – 46.1 ft^2
Bankfull cross sectional width	28.3 ft	26.3 – 30.4 ft
Bankfull cross sectional depth	1.6 ft	1.5 – 1.7 ft
Bankfull cross sectional maximum depth	2.2 ft	2.1 – 2.2 ft
Width/depth ratio	17.7	15.4 – 20.0
Flood-prone area width	114.7 ft	104.3 – 125.1 ft
Entrenchment ratio	4.1	3.4 – 4.8
Sinuosity	1.5	N/A
Dominant bed material (D_{50})	35.9 mm (V.Coarse Gravel)	N/A
Dominant bed material (D_{84})	89.9 mm (Small Cobble)	N/A
Rosgen stream type	C	N/A

3.8 Reach 8

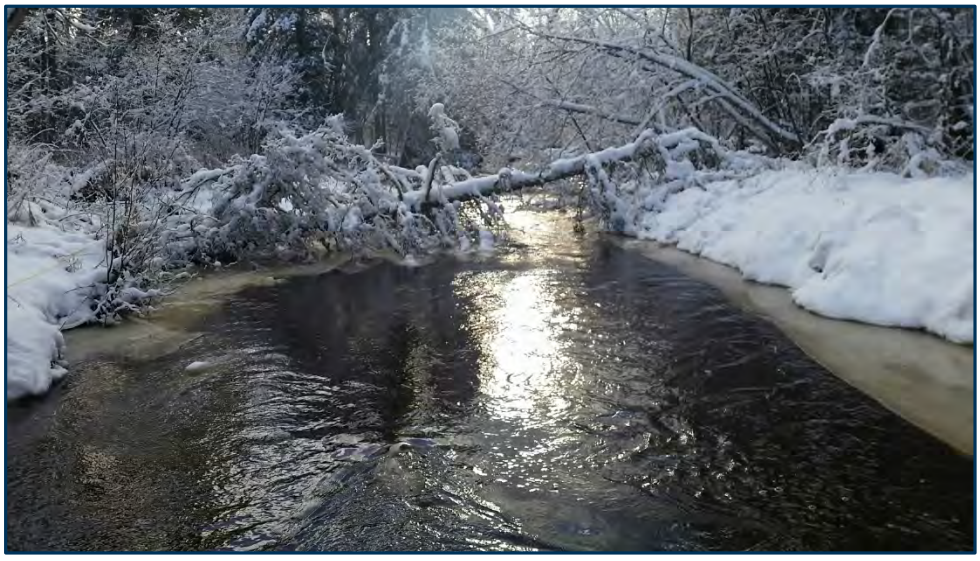

Figure 3-8 Example of stream characteristics along Reach 8

Table 3-8 Summary of stream classification parameters for Reach 8

Parameter	Value	Range
Watershed size	18.9 mi^2	N/A
Assessment reach length	552 ft	N/A
Channel slope	0.004	N/A
Bankfull cross sectional area	49.9 ft^2	Incomplete
Bankfull cross sectional width	27.6 ft	Incomplete
Bankfull cross sectional depth	1.8 ft	Incomplete
Bankfull cross sectional maximum depth	2.4 ft	Incomplete
Width/depth ratio	15.2	Incomplete
Flood-prone area width	392.7 ft	Incomplete
Entrenchment ratio	4.8	Incomplete
Sinuosity	2.1	N/A
Dominant bed material (D_{50})	Incomplete	N/A
Dominant bed material (D_{84})	Incomplete	N/A
Rosgen stream type	C	N/A

3.9 Reach 9

Figure 3-9 Example of stream characteristics along Reach 9

Table 3-9 Summary of stream classification parameters for Reach 9

Parameter	Value	Range
Watershed size	19.2 mi^2	N/A
Assessment reach length	813 ft	N/A
Channel slope	0.006	N/A
Bankfull cross sectional area	49.1 ft^2	48.7 – 49.6 ft^2
Bankfull cross sectional width	27.6 ft	26.7 – 28.5 ft
Bankfull cross sectional depth	1.8 ft	1.7 – 1.8 ft
Bankfull cross sectional maximum depth	2.3 ft	2.2 – 2.4 ft
Width/depth ratio	15.5	14.6 – 16.4
Flood-prone area width	42.4 ft	38.5 – 46.2 ft
Entrenchment ratio	1.5	1.4 – 1.7
Sinuosity	1.3	N/A
Dominant bed material (D_{50})	38.6 mm (V.Coarse Gravel)	N/A
Dominant bed material (D_{84})	74.2 mm (Small Cobble)	N/A
Rosgen stream type	C	N/A

3.10 Reach 12

Figure 3-10 Example of stream characteristics along Reach 12

Table 3-10 Summary of stream classification parameters for Reach 12

Parameter	Value	Range
Watershed size	19.3 mi^2	N/A
Assessment reach length	584 ft	N/A
Channel slope	0.008	N/A
Bankfull cross sectional area	49.9 ft^2	44.9 – 54.9 ft^2
Bankfull cross sectional width	30.3 ft	28.4 – 32.2 ft
Bankfull cross sectional depth	1.7 ft	1.4 – 1.9 ft
Bankfull cross sectional maximum depth	2.5 ft	2.1 – 2.9 ft
Width/depth ratio	18.9 ft	14.7 – 23.0 ft
Flood-prone area width	273.5 ft	185.0 – 262.0 ft
Entrenchment ratio	9.2	5.8 – 12.4
Sinuosity	1.3	N/A
Dominant bed material (D_{50})	51.7 mm (V.Coarse Gravel)	N/A
Dominant bed material (D_{84})	131.2 mm (Large Cobble)	N/A
Rosgen stream type	B/C	N/A

4 Reach Priorities

Prioritizing where to work within the watershed will be important to LSSA so funds can be used effectively and so projects can start to build upon each other for achieving the desired results without working against each other. For example, installing habitat structures in one reach shouldn't result in the de-stabilization of an adjacent reach. Improving spawning habitat while holding structure is unavailable. Based on the work completed through December 2015, the ten reaches that were evaluated can be prioritized:

High – Direct benefit to Knife River habitat and watershed, can be accomplished with existing grant funds available.

Medium – Direct benefit to Knife River habitat and watershed, needs additional funds or resources such as more data or detailed design to determine feasibility or course of action. May have overall greater benefit to the Knife River, but has a greater cost (time, resources, effort...i.e. lower cost:benefit ratio).

Low – Limited potential project scope. Importance may increase as other work in the watershed is done. Unknown if project will be successful.

Table 4-1 Preliminary prioritization for reaches assessed fall 2016 along the Knife River.

Reach	Rank	Rationale
Reach 1	Low	Stable reach with big substrate. Difficult access.
Reach 2	Low/Med	Stable reach. Has good substrate. Would need bigger distance to accomplish a major project.
Reach 3	Low	Stable reach. Limited to small scale project.
Reach 4	High	3 area of severely eroding banks. Opportunity to stabilize and create great habitat.
Reach 5	Low	Stable reach. Limited to small scale project.
Reach 6	Medium	Major logs, but doesn't appear to be fish passage issue. Evaluate annually.
Reach 7	Medium	Major logs, but doesn't appear to be fish passage issue. Evaluate annually.
Reach 8	High	Unstable reach. Major log jams. Several eroding banks. Opportunity to stabilize and create great habitat.
Reach 9	High	Unstable portions of reach with eroding banks. Opportunity to stabilize and create great habitat.
Reach 12	High	Eroding high bank. Opportunity to stabilize and create great habitat.

5 Literature Cited

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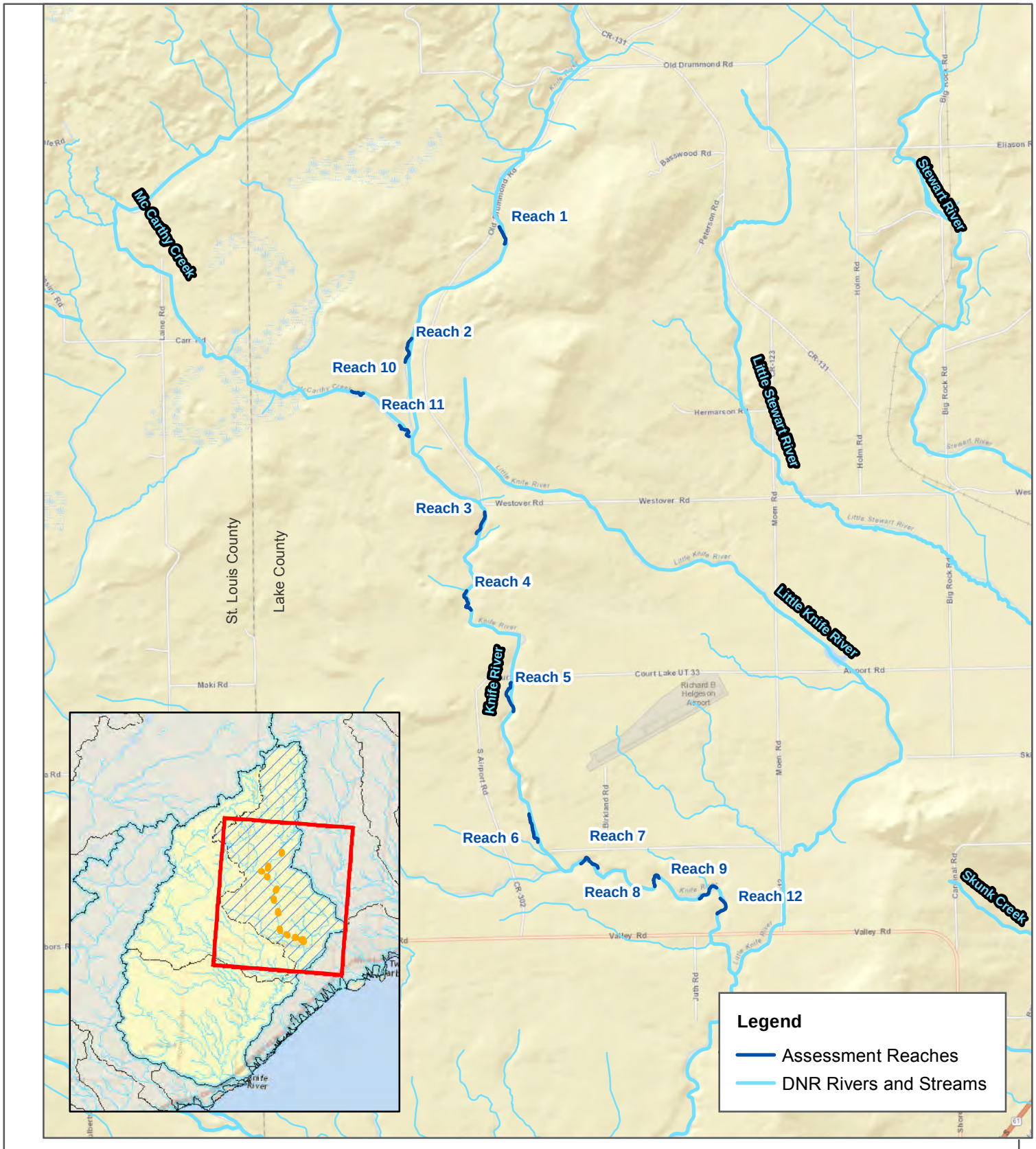
Knife River Assessment Fall 2015

APPENDIX A

REACH MAPS



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Lake County, Minnesota

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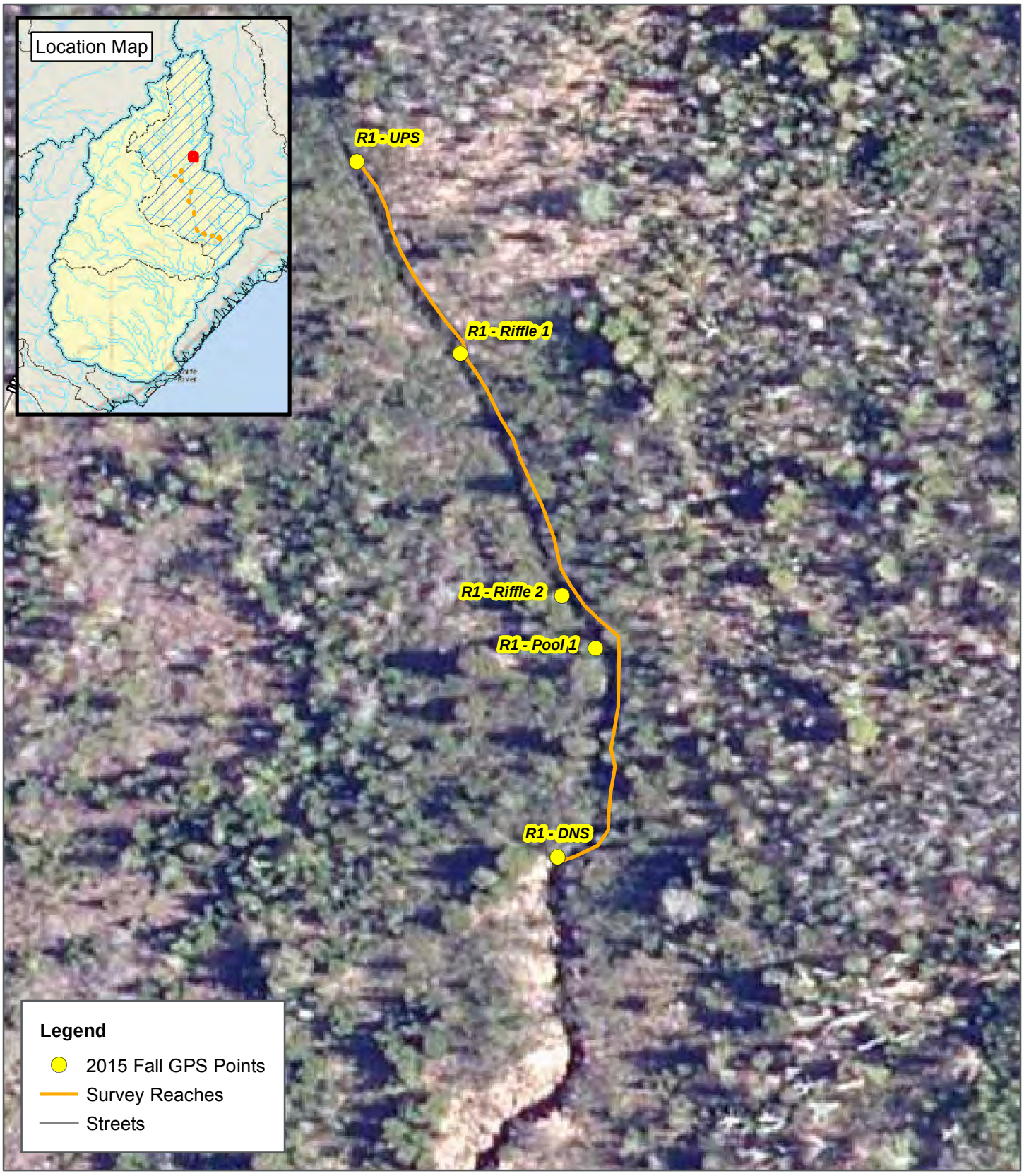

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Reach 1

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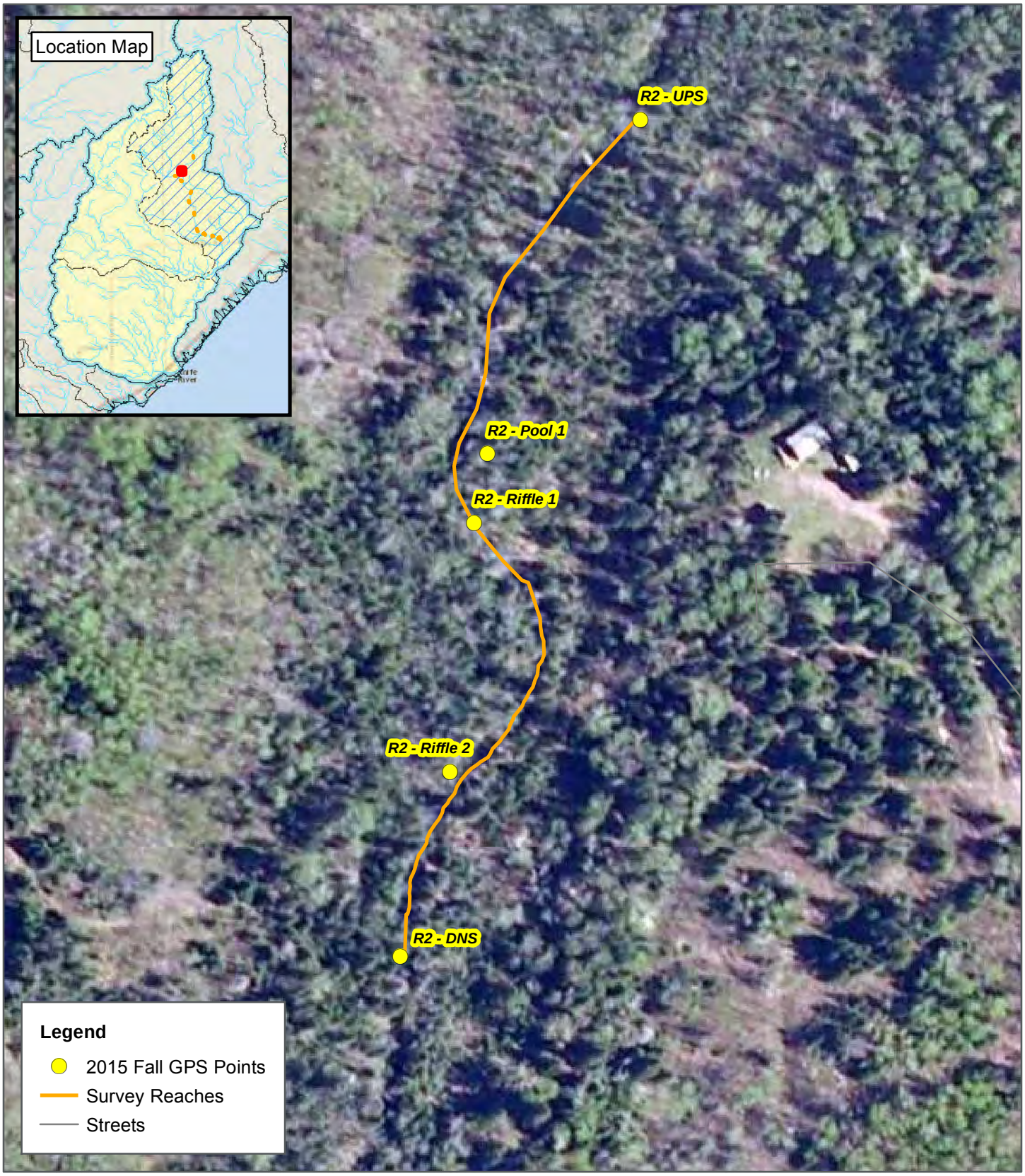

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Reach 2

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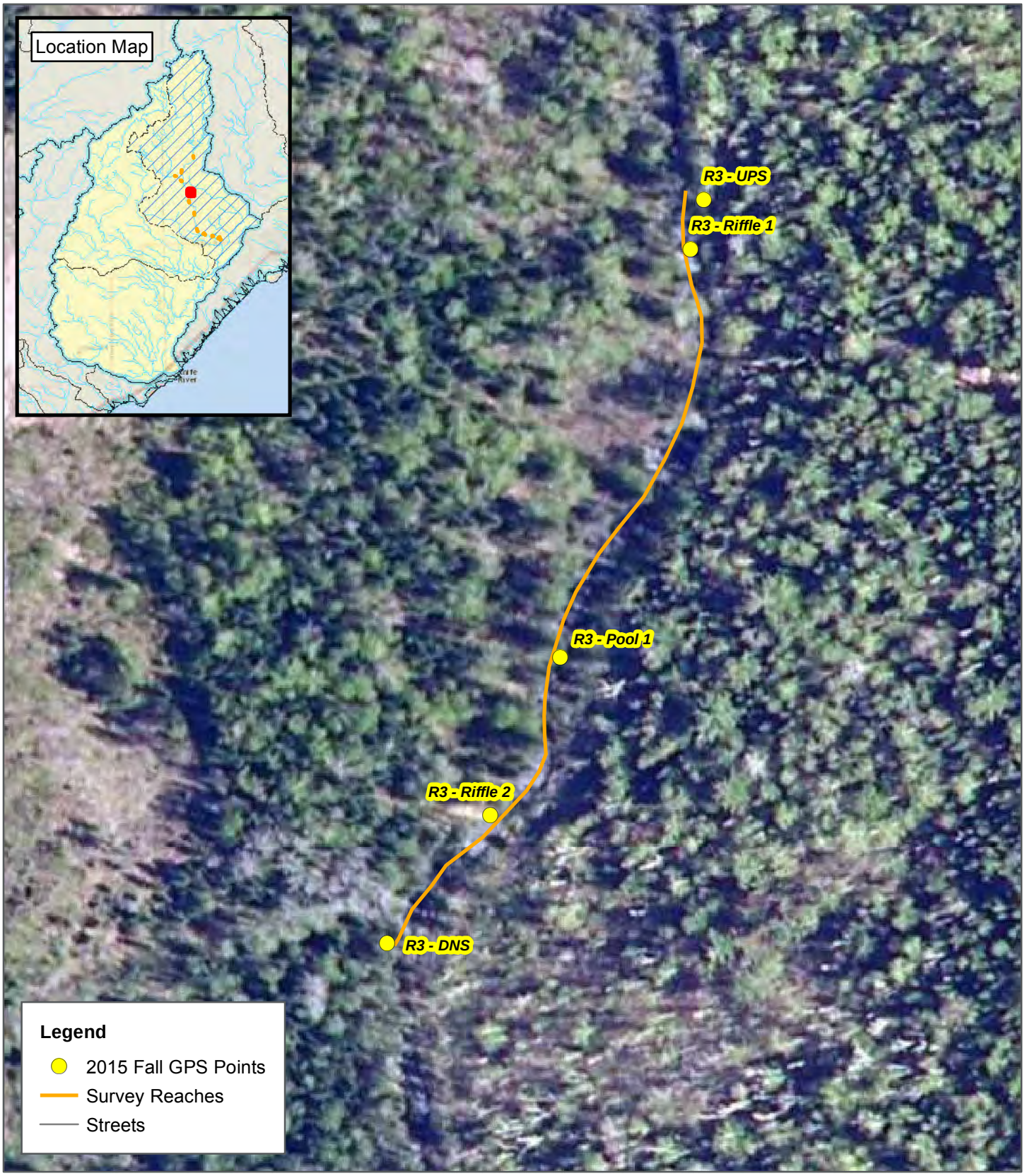

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Reach 3

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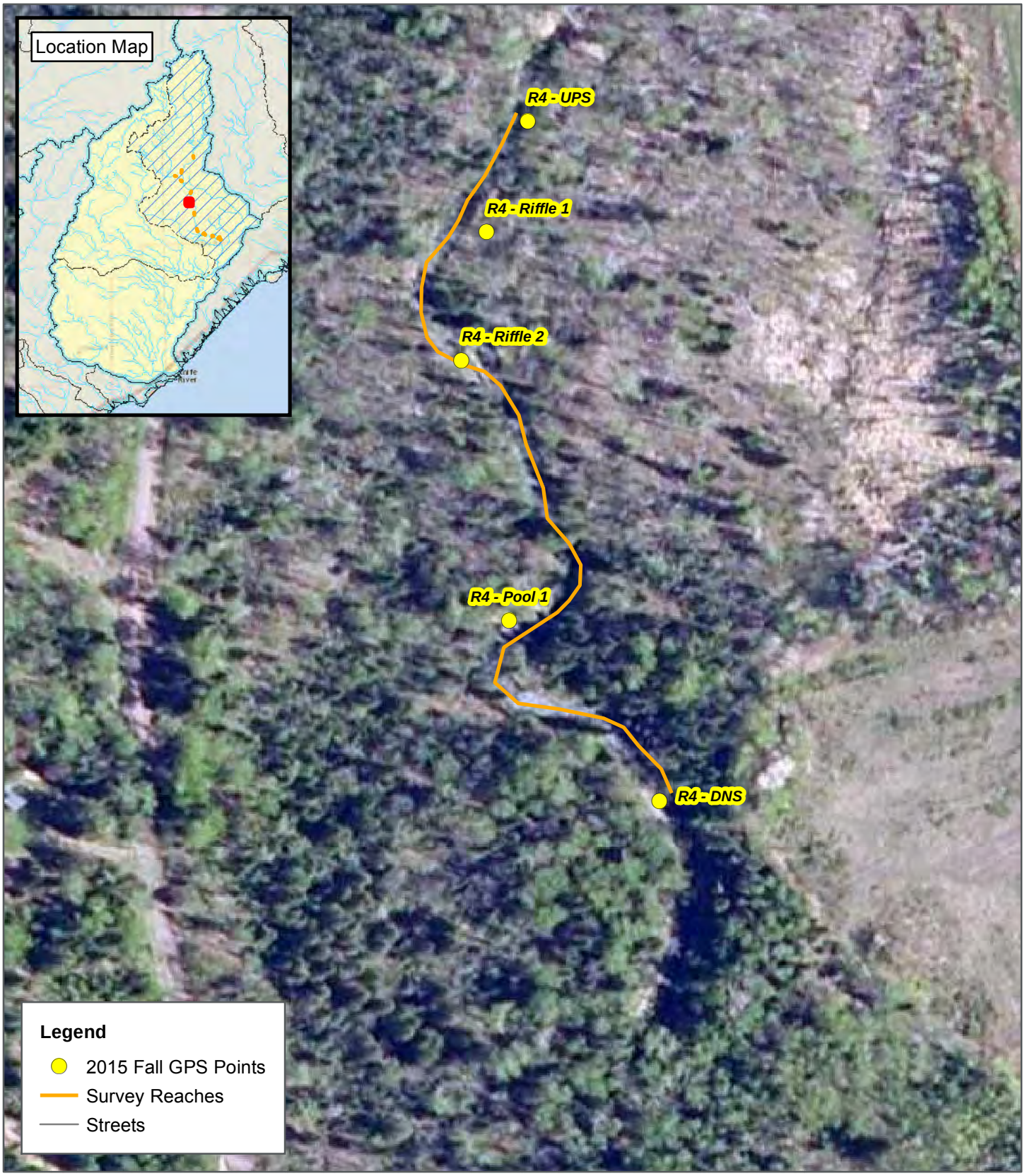

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Reach 4

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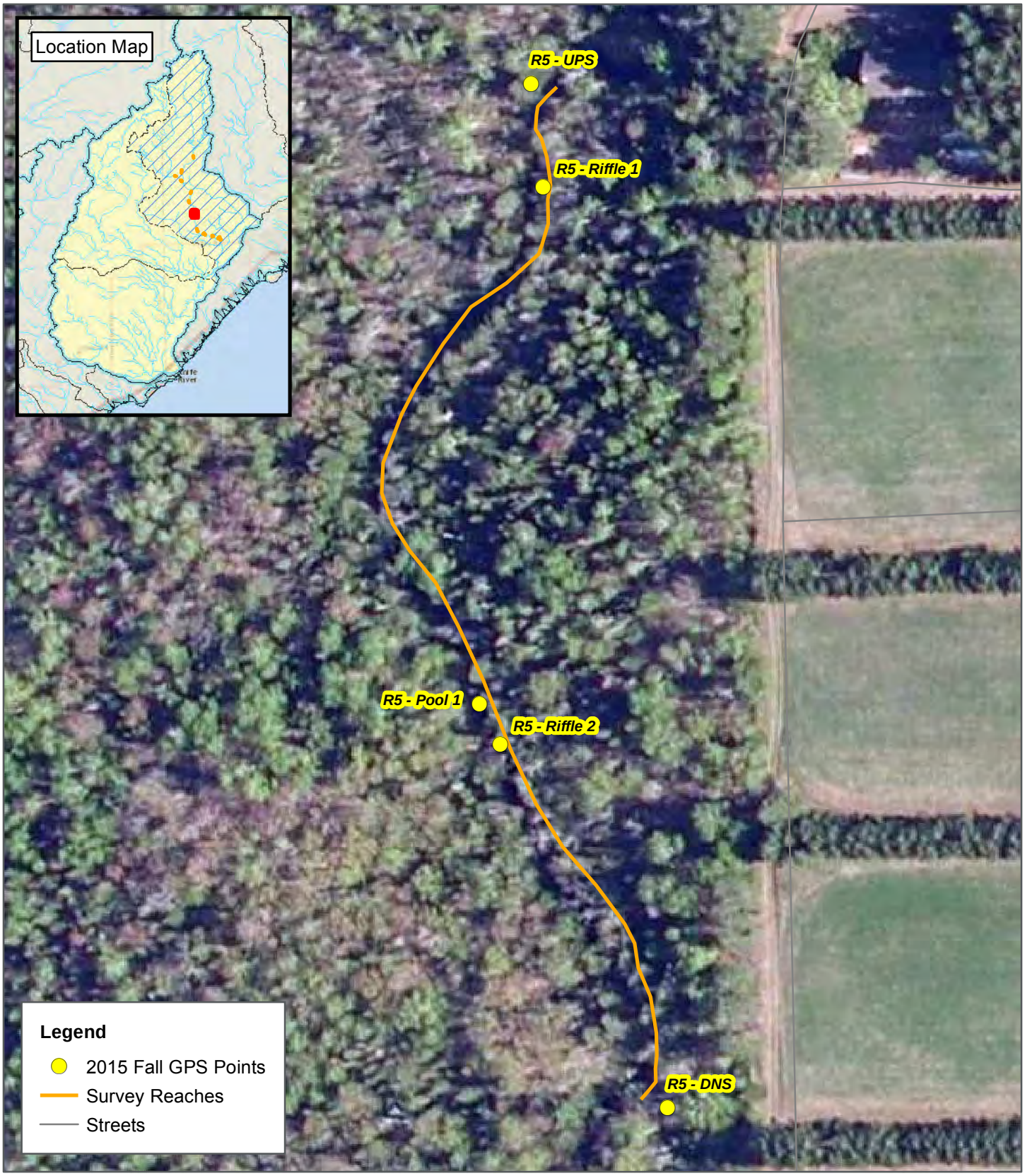

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Reach 5

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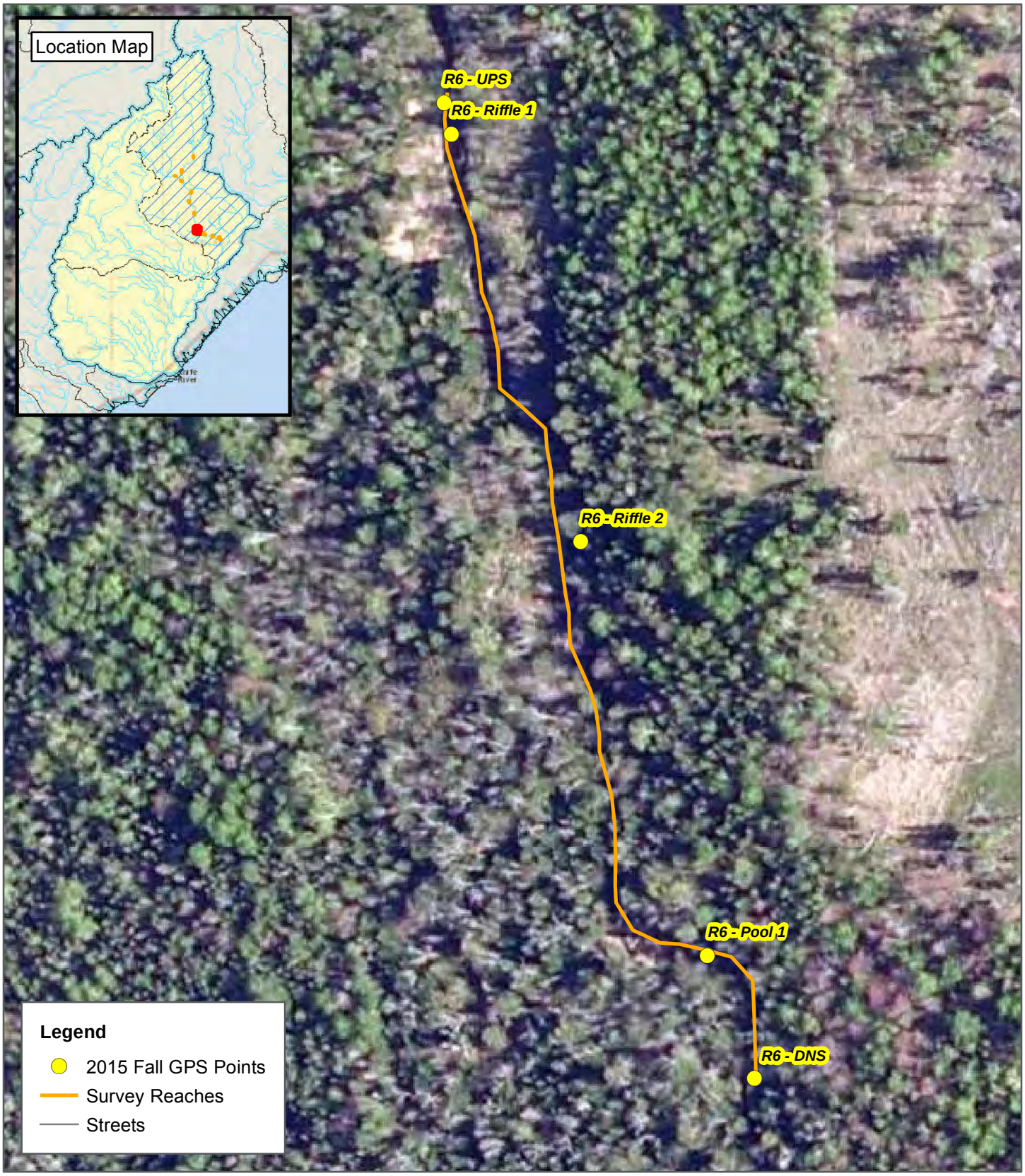

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Reach 6

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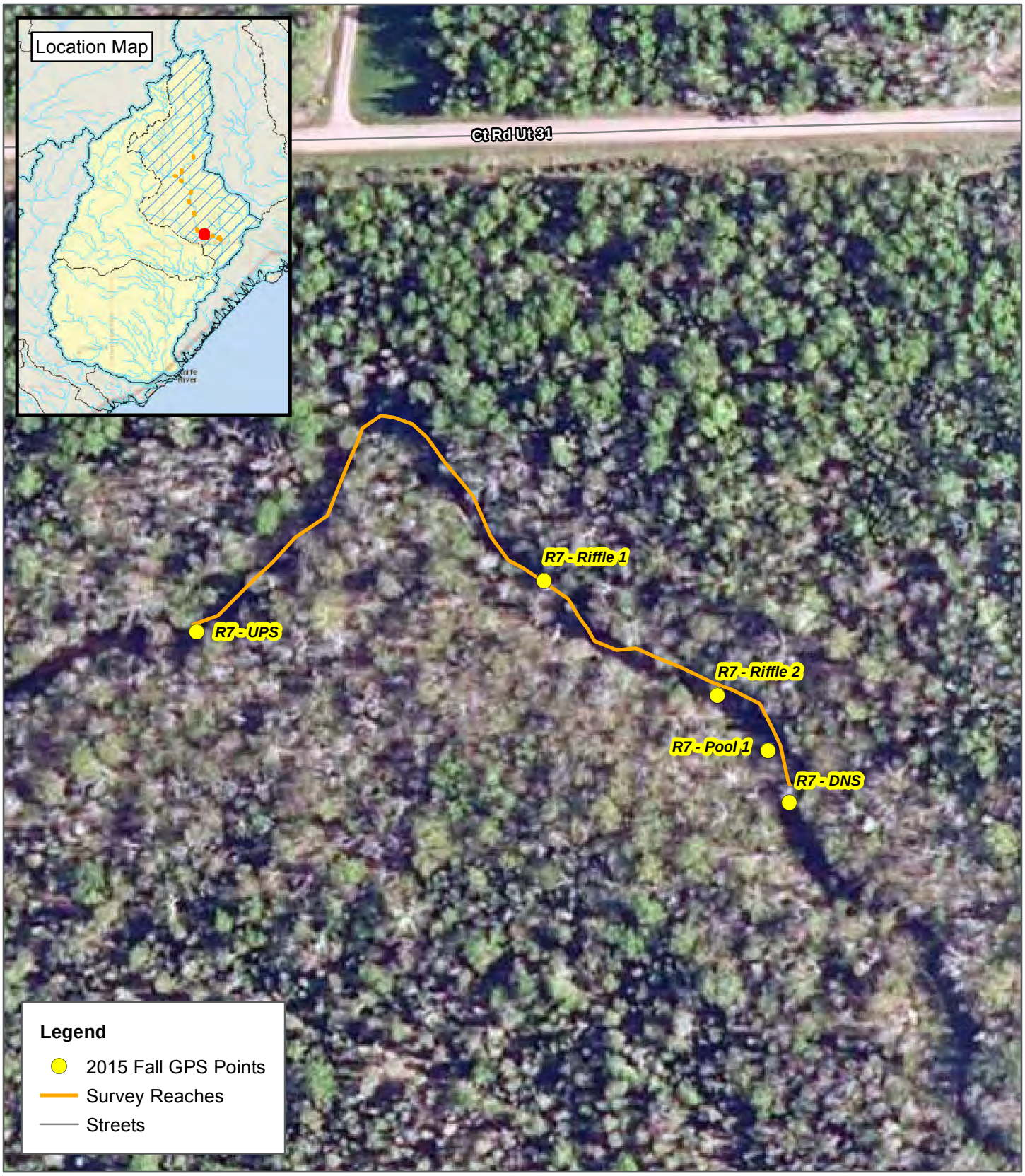

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Reach 7

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0 100 200 Feet

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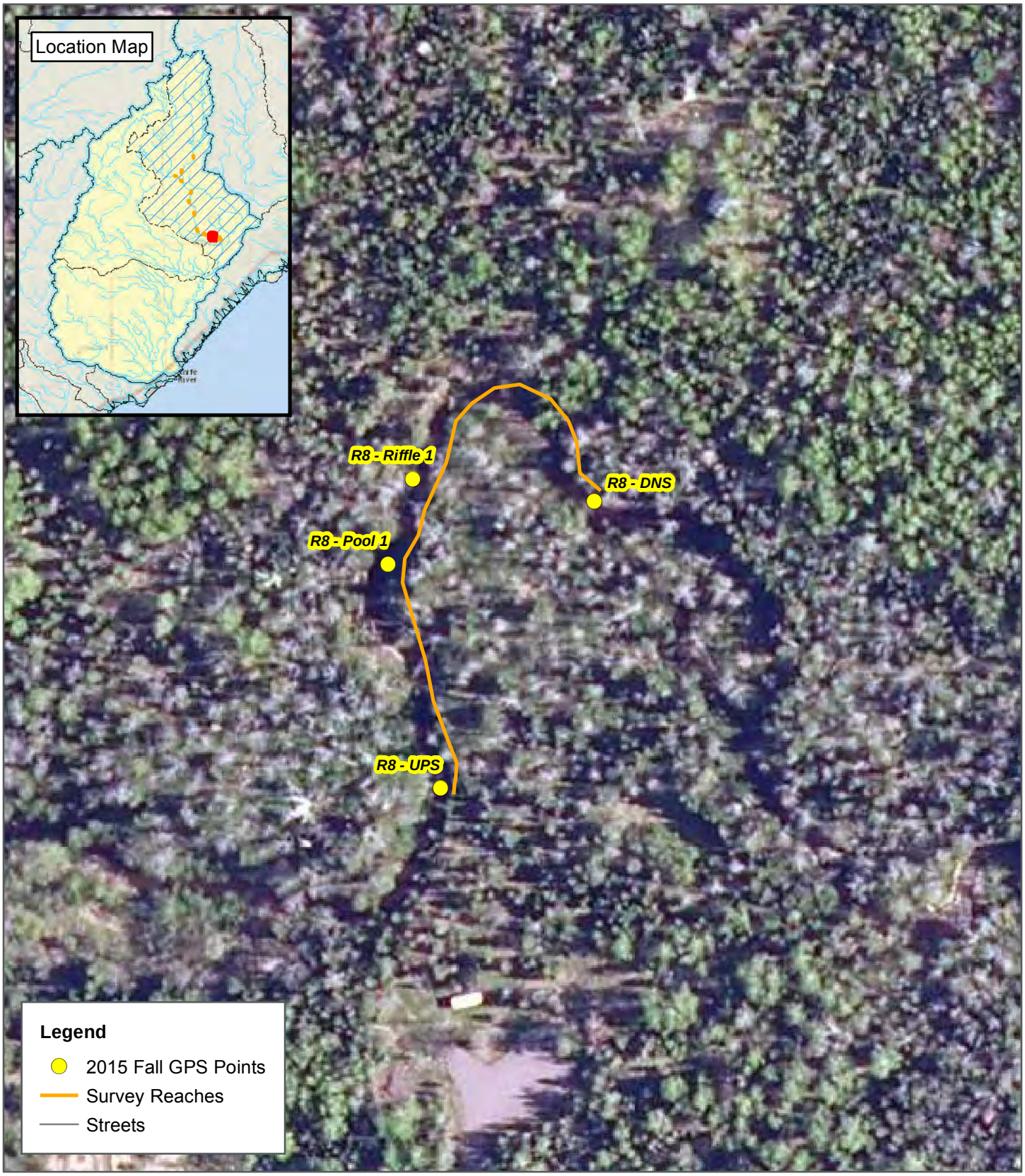
Date Created: 3/28/2016 Date Revised: 3/28/2016 File Path: R:\Projects\15\15Y\15Y133600_ETS_KnifeRiver\GIS\MXD\02_Field_Map_Aerial_with_GPS_20160328.mxd

GIS Analyst: alex.cohen

Data Sources: Aerial Imagery: MnGeo WMS Arrowhead 2009 Color



N
W E
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Project No. J15Y133600

Reach 8

Knife River Stream Surveys
Environmental Troubleshooters
Lake County, Minnesota

0 100 200 Feet

Cardno
6140 Cottonwood Dr., Suite A, Fitchburg, WI 53719 USA
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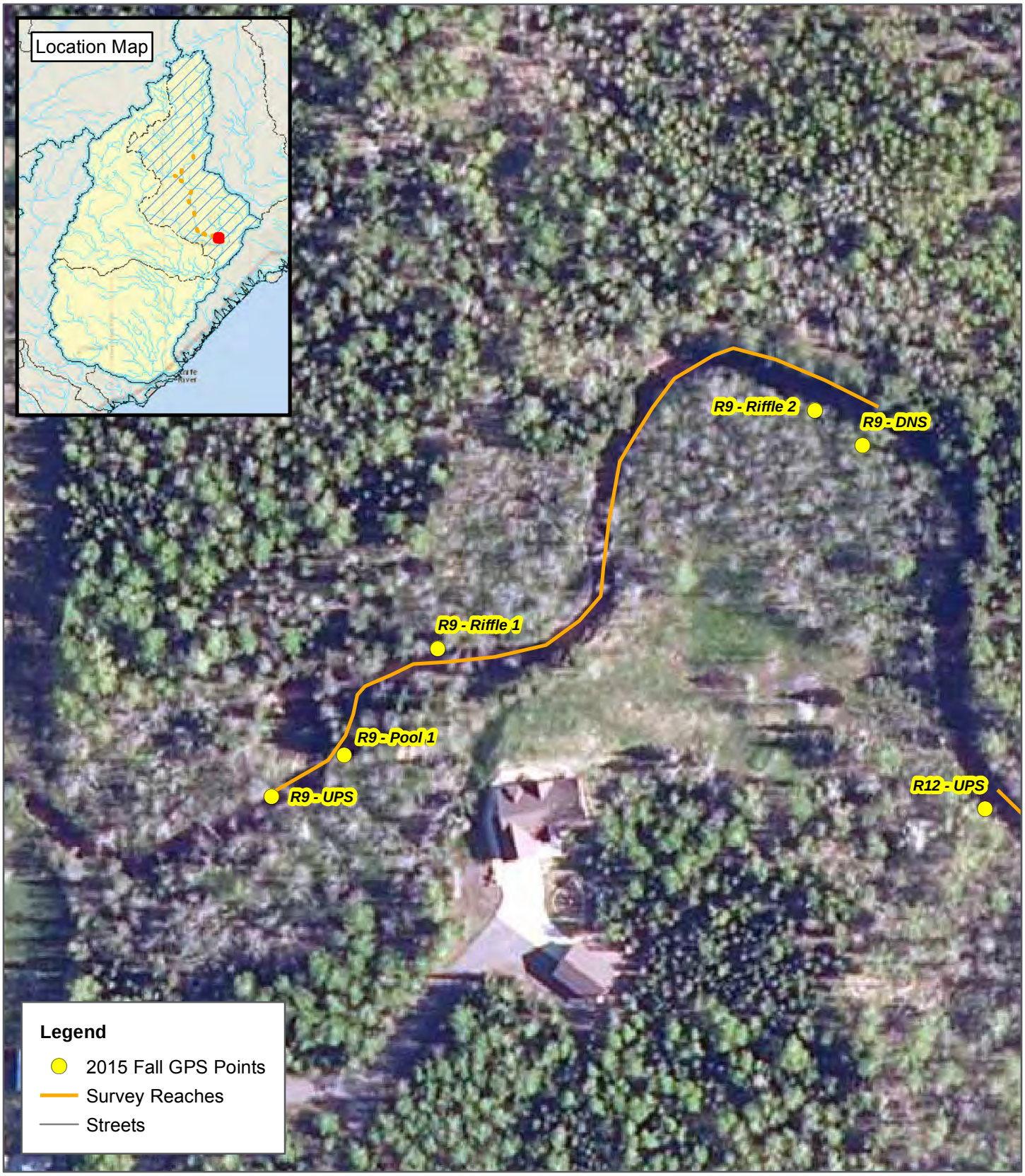
Date Created: 3/28/2016 Date Revised: 3/28/2016 File Path: R:\Projects\15\15Y\15Y133600_ETS_KnifeRiver\GIS\MXD\02_Field_Map_Aerial_with_GPS_20160328.mxd
GIS Analyst: alex.cohen
Data Sources: Aerial Imagery: MnGeo WMS Arrowhead 2009 Color



N
W E
S

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Project No. J15Y133600

Reach 9

Knife River Stream Surveys
Environmental Troubleshooters
Lake County, Minnesota

0 100 200 Feet

Cardno
6140 Cottonwood Dr., Suite A, Fitchburg, WI 53719 USA
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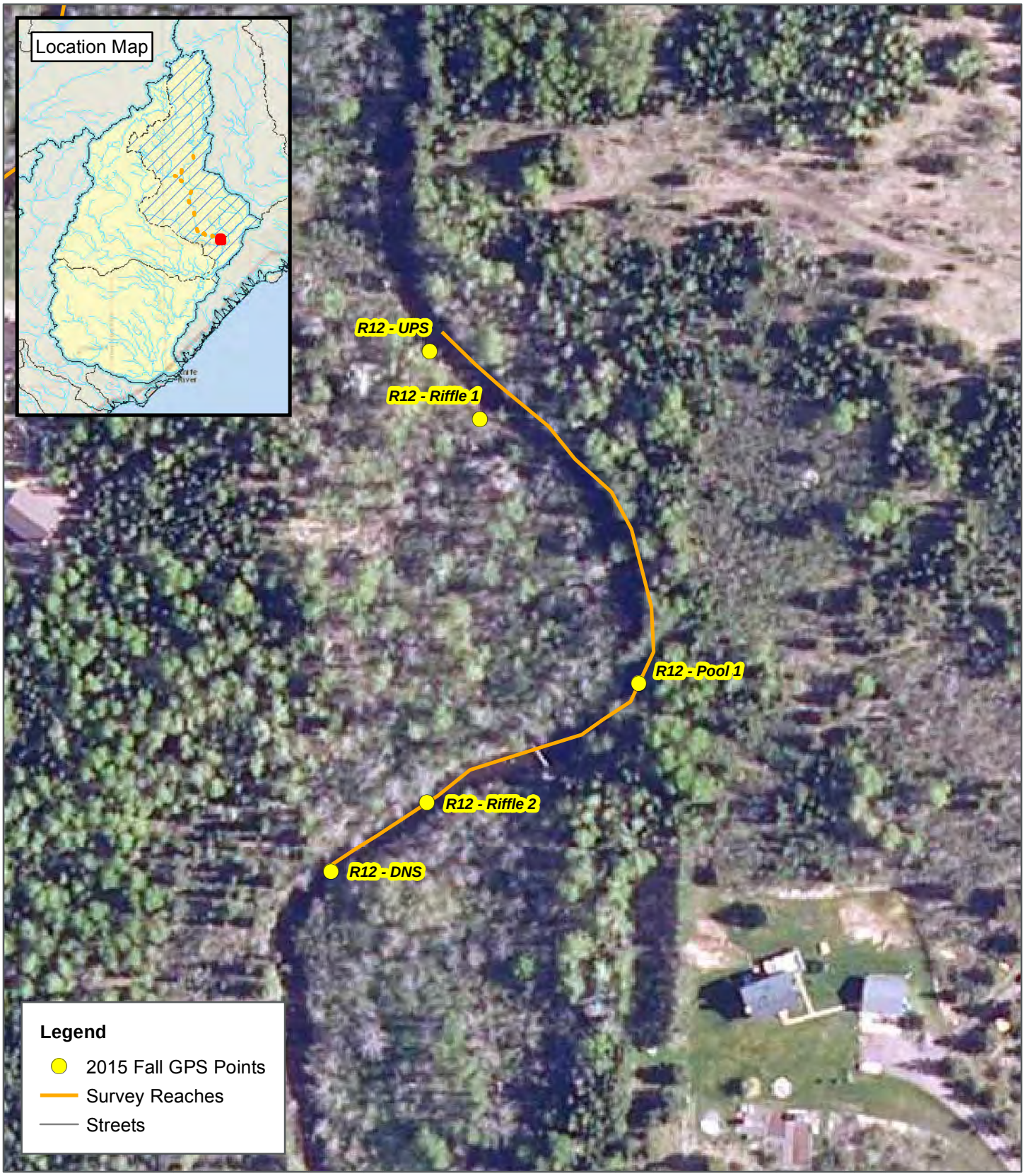
Date Created: 3/28/2016 Date Revised: 3/28/2016 File Path: R:\Projects\15\15Y\15Y133600_ETS_KnifeRiver\GIS\MXD\02_Field_Map_Aerial_with_GPS_20160328.mxd

GIS Analyst: alex.cohen

Data Sources: Aerial Imagery: MnGeo WMS Arrowhead 2009 Color



N
W E
S

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Project No. J15Y133600

Reach 12

Knife River Stream Surveys
Environmental Troubleshooters
Lake County, Minnesota

0 100 200 Feet

Cardno
6140 Cottonwood Dr., Suite A, Fitchburg, WI 53719 USA
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Date Created: 3/28/2016 Date Revised: 3/28/2016 File Path: R:\Projects\15\15Y\15Y133600_ETS_KnifeRiver\GIS\MXD\02_Field_Map_Aerial_with_GPS_20160328.mxd

GIS Analyst: alex.cohen

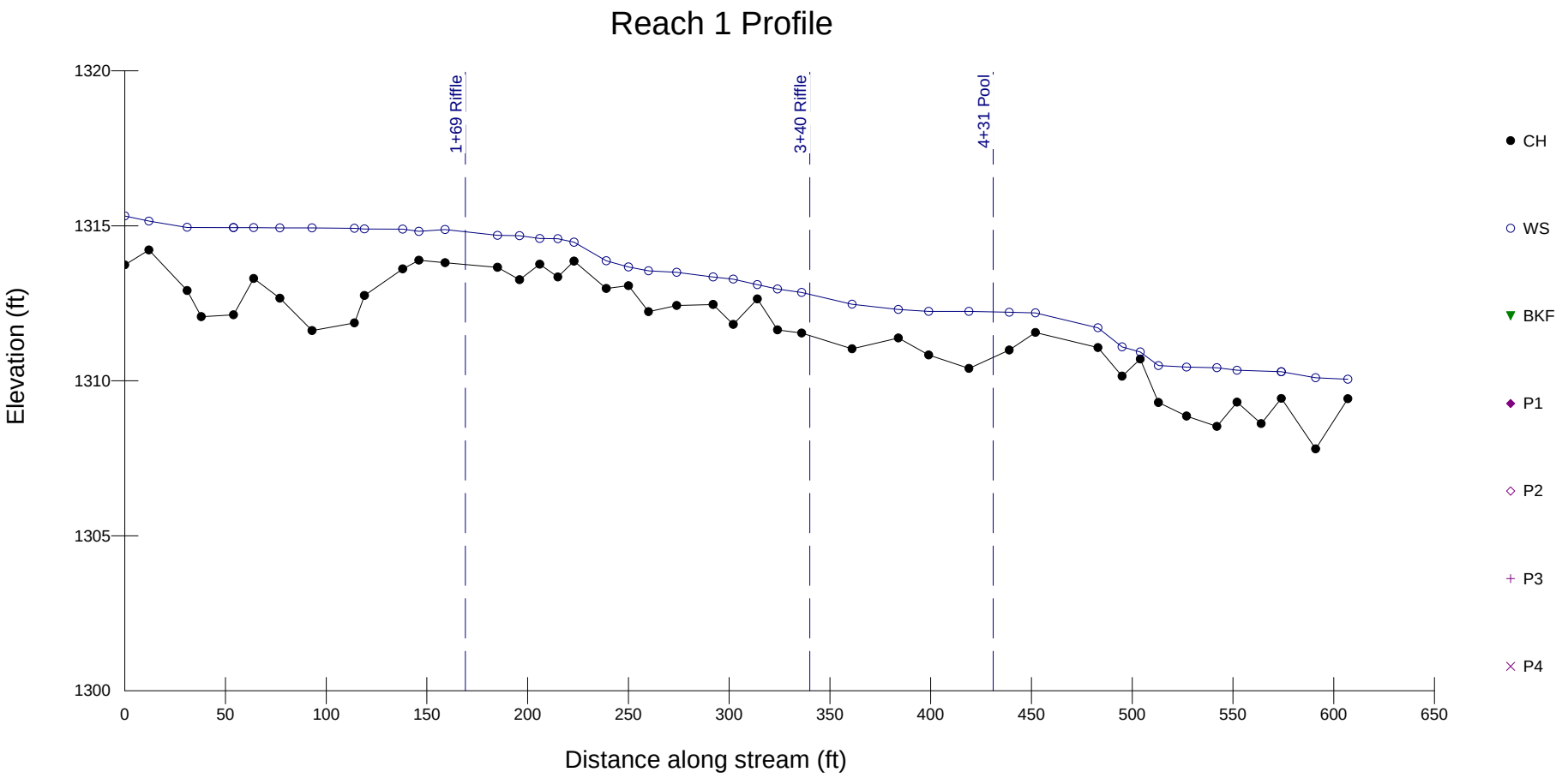
Data Sources: Aerial Imagery: MnGeo WMS Arrowhead 2009 Color

Knife River Assessment Fall 2015

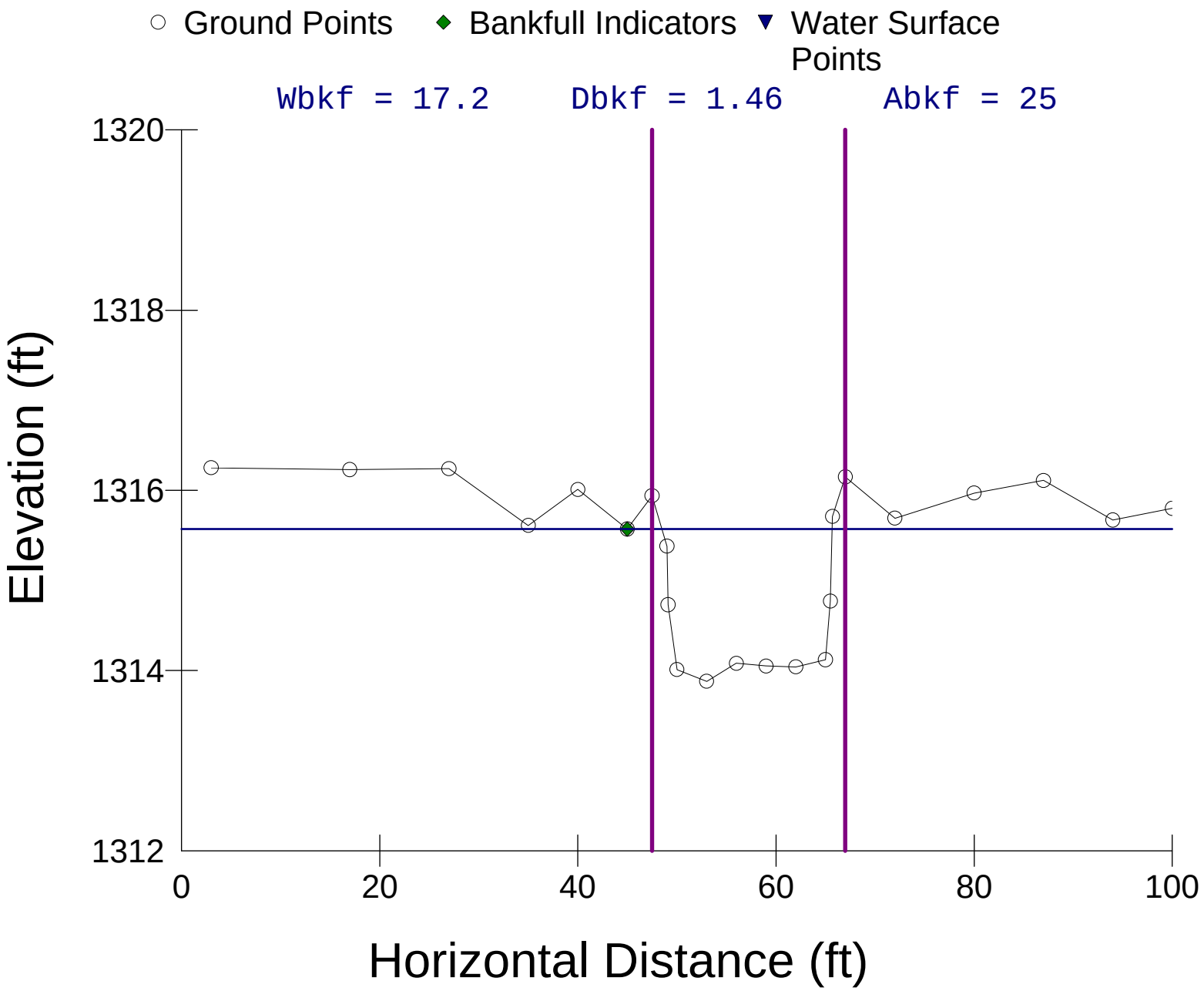
APPENDIX

B

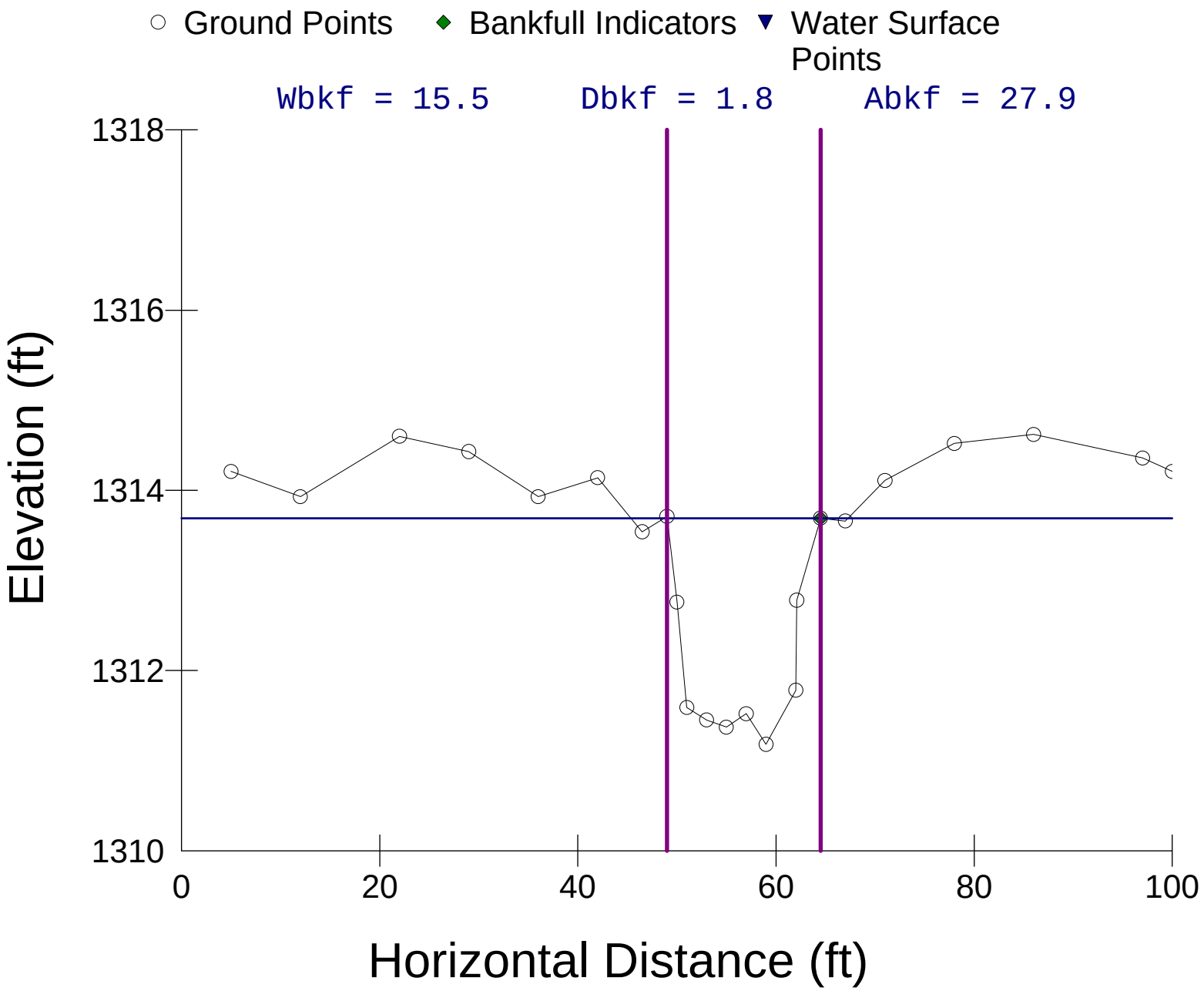
LONG PROFILE, CROSS SECTIONS, AND PEBBLE COUNTS


Reach 1 Profile
1320
1315
1310
1305
1300
Elevation (ft)
1+69 Riffle
3+40 Riffle
4+31 Pool
0
50
100
150
200
250
300
350
400
450
500
550
600
650
Distance along stream (ft)
CH
WS
BKF
P1
P2
P3
P4

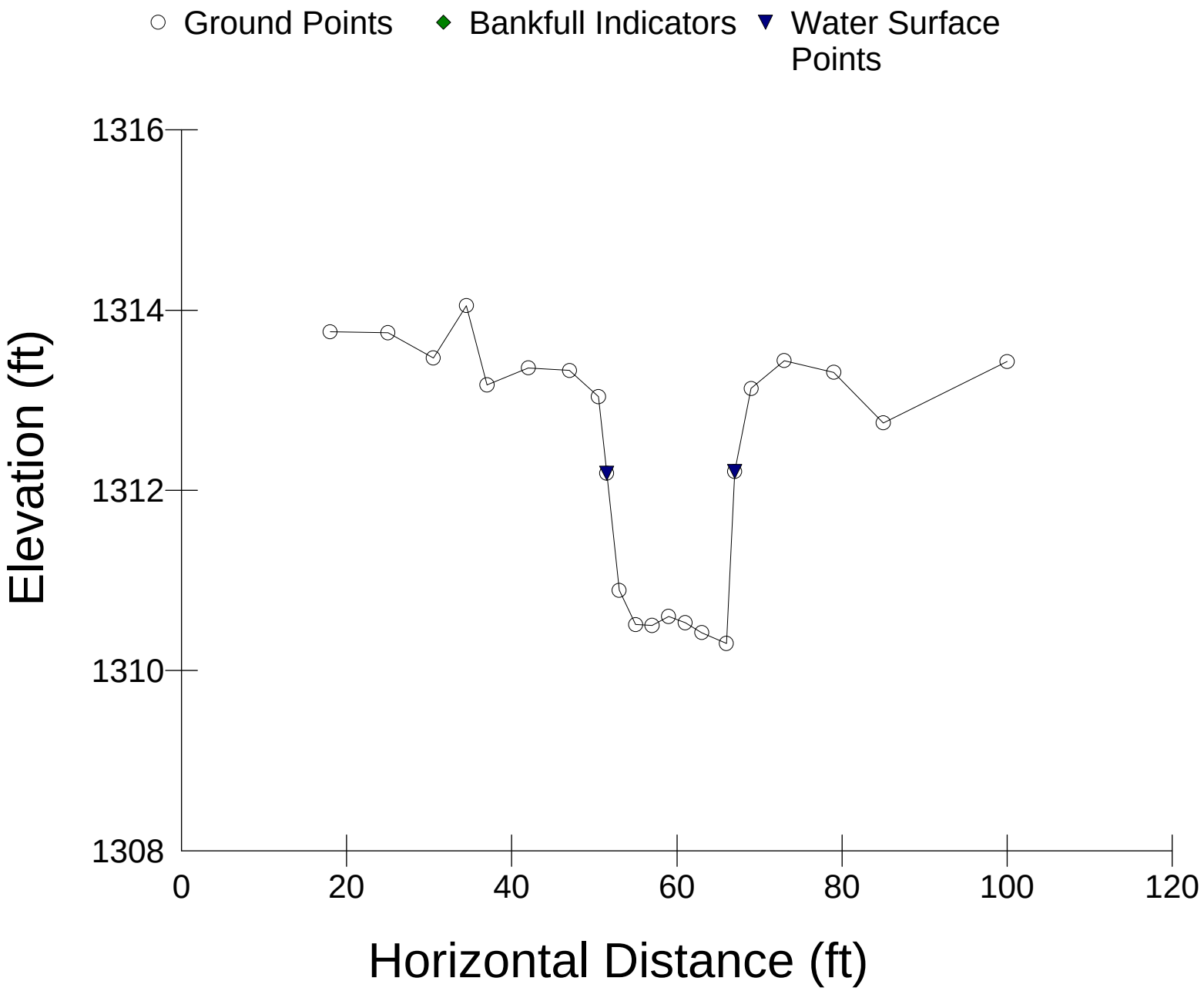
Reach 1 1+69 Riffle



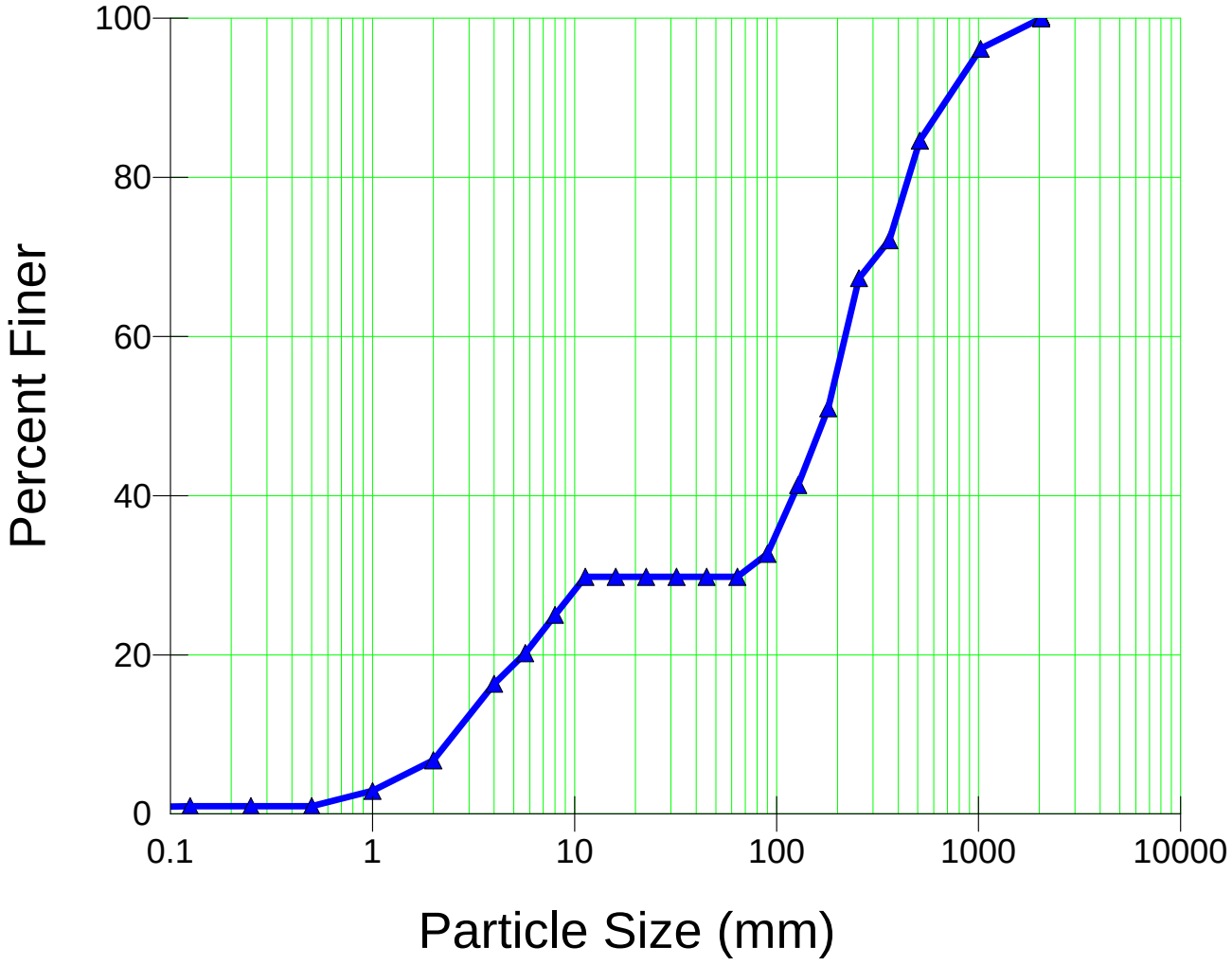
Reach 1 3+40 Riffle

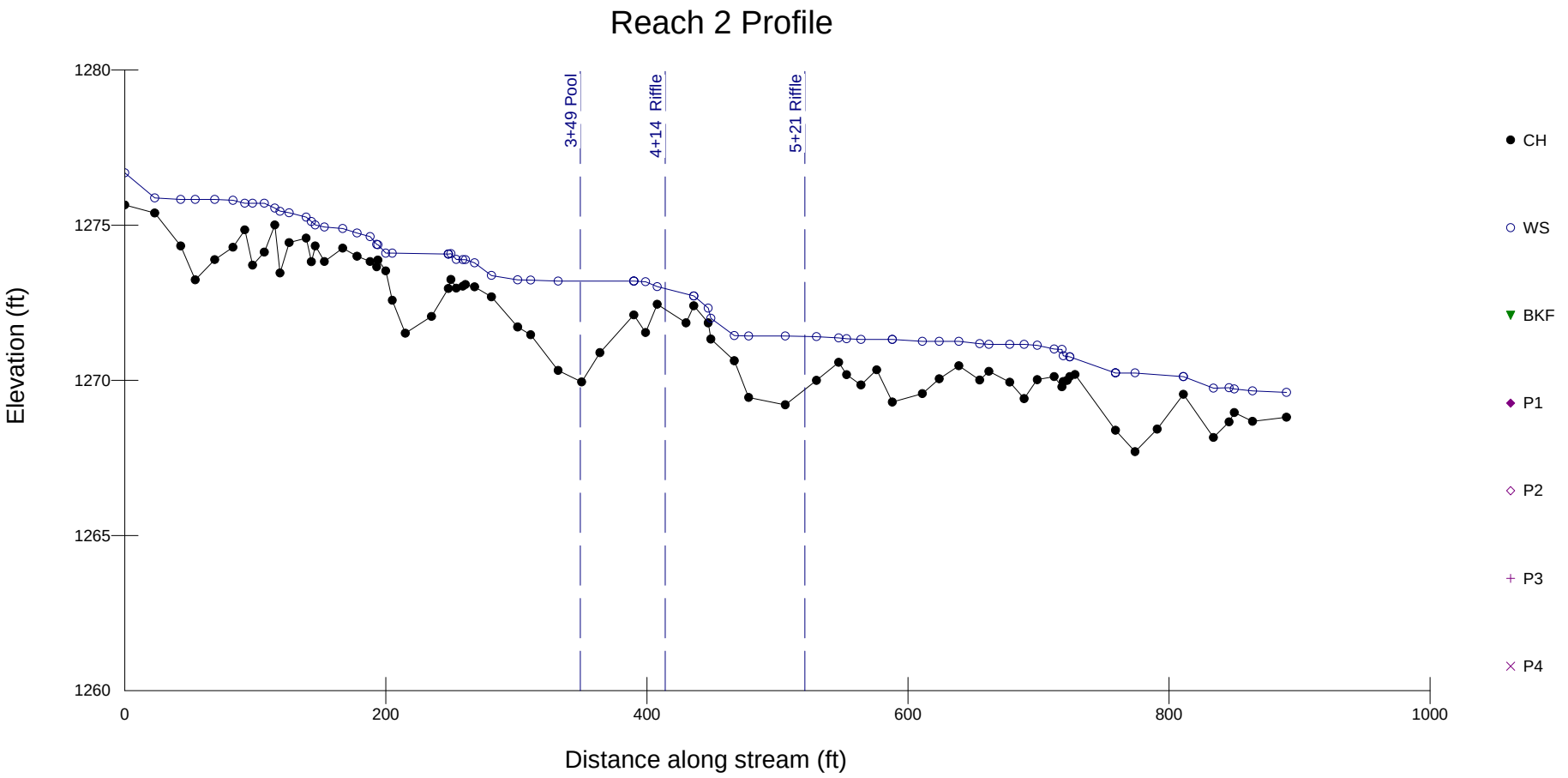


Reach 1 4+31 Pool

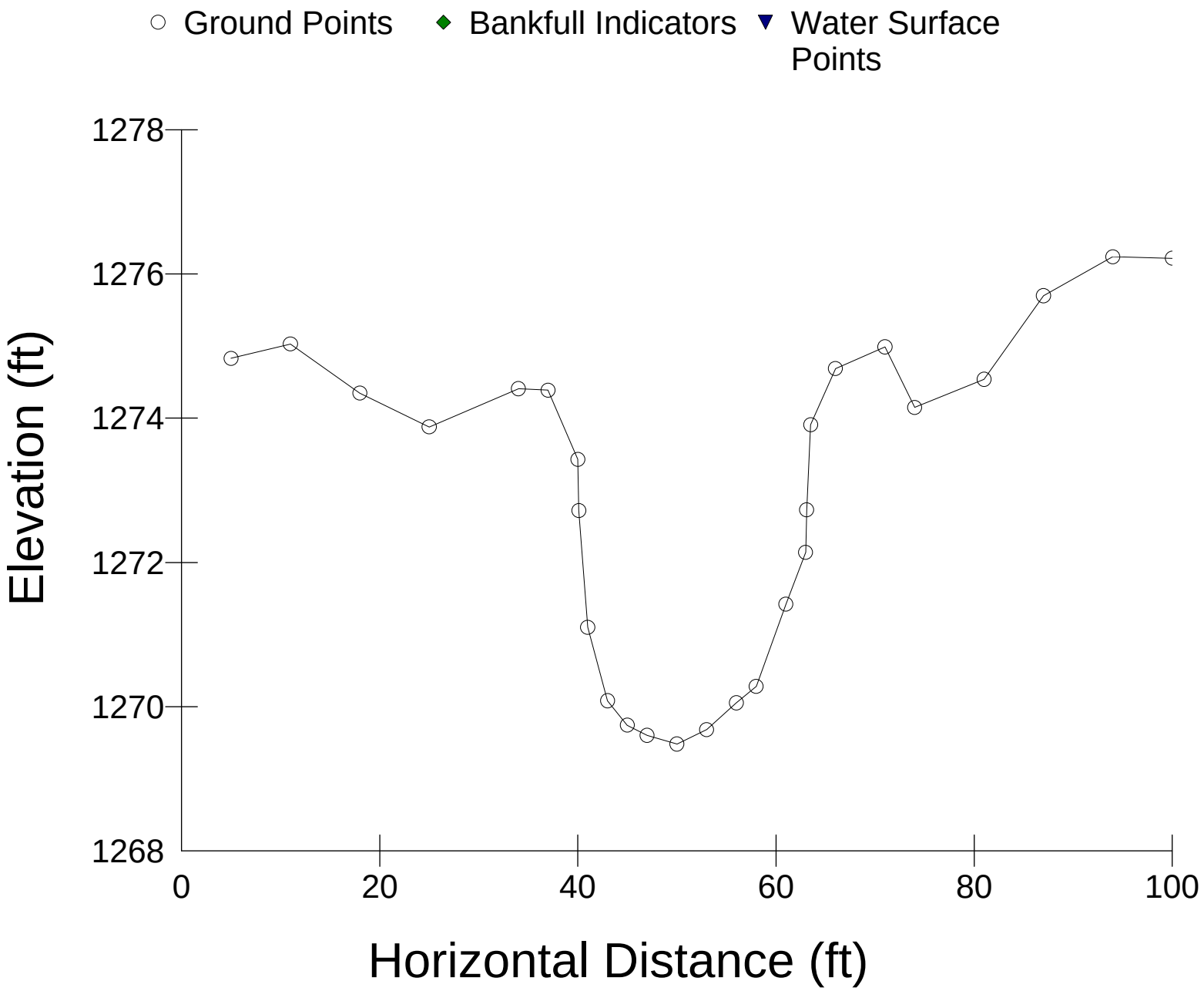


Reach 1

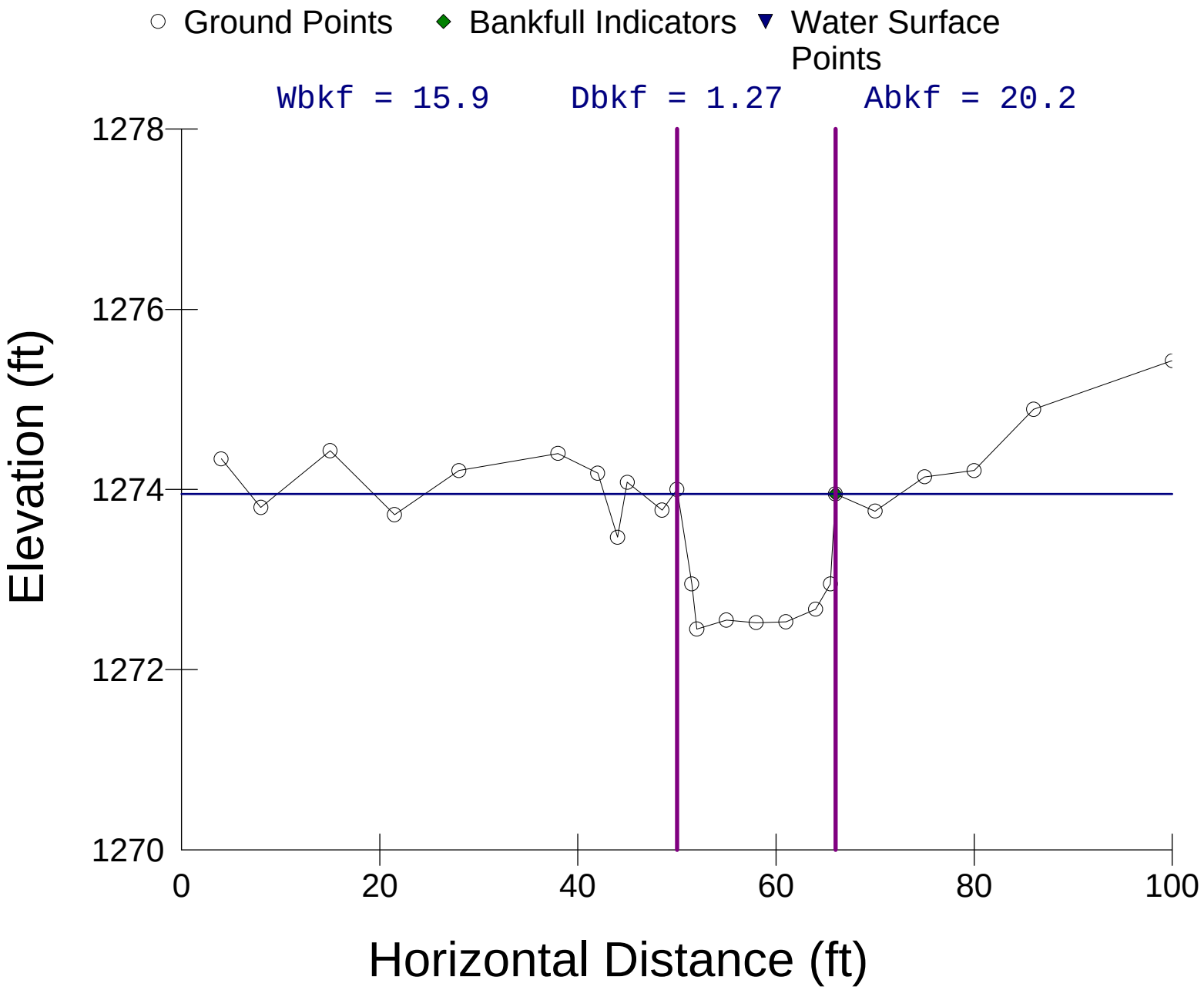

Percent Finer
100
80
60
40
20
0
0.1
1
10
100
1000
10000
Particle Size (mm)


Reach 2 Profile
Elevation (ft)
1280
1275
1270
1265
1260
0
200
400
600
800
1000
Distance along stream (ft)
3+49 Pool
4+14 Riffle
5+21 Riffle
CH
WS
BKF
P1
P2
P3
P4

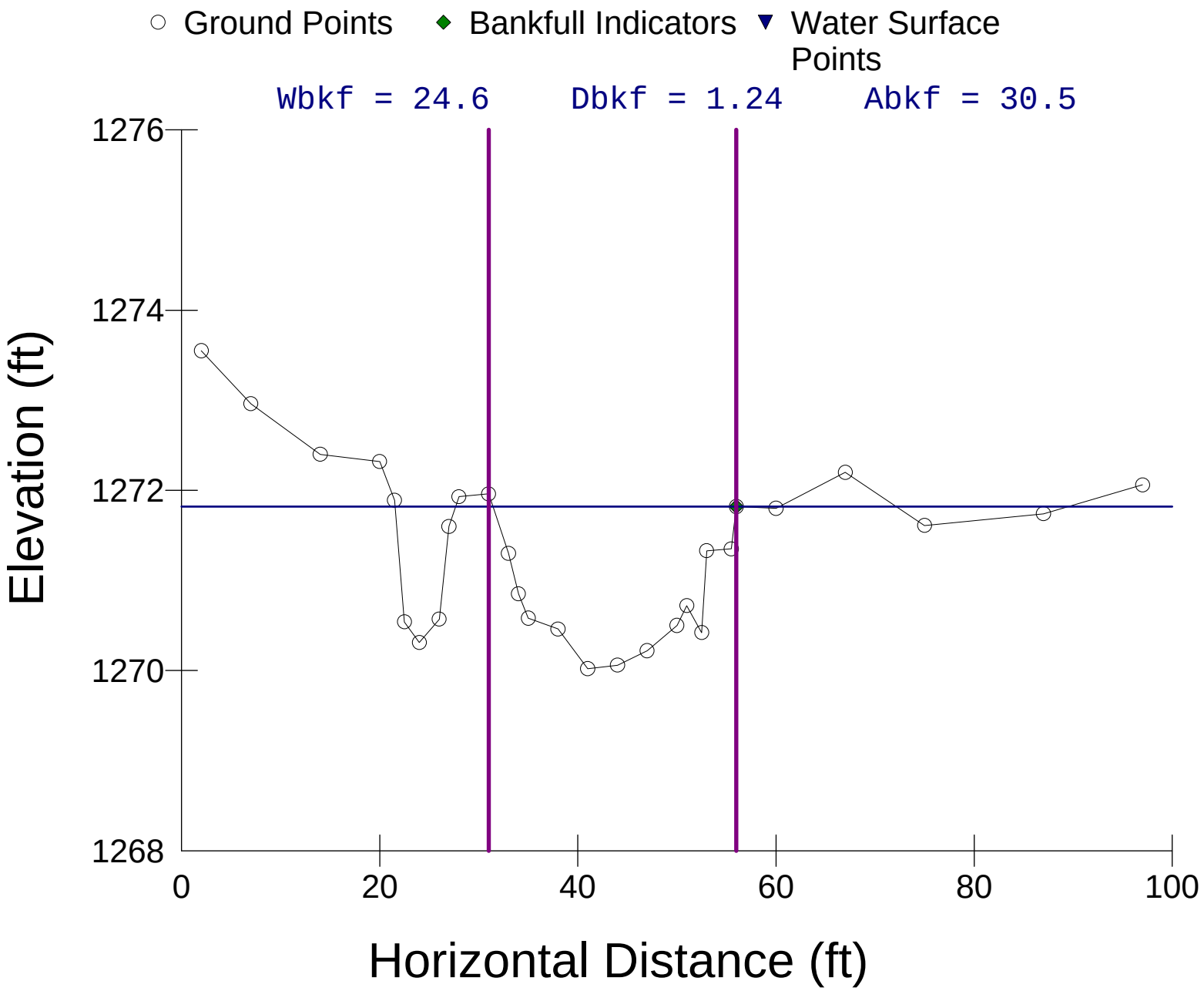
Reach 2 3+49 Pool



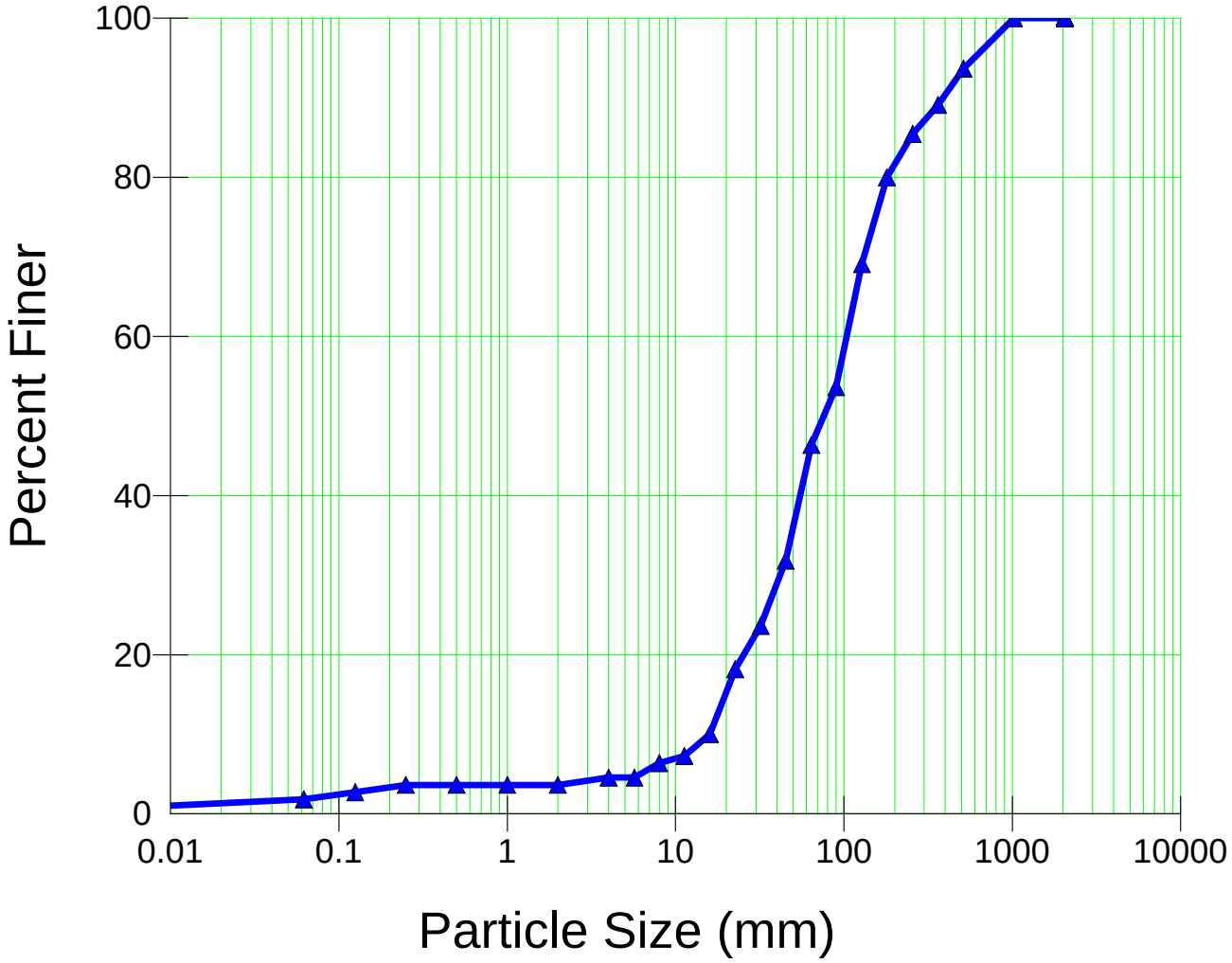
Reach 2 4+14 Riffle

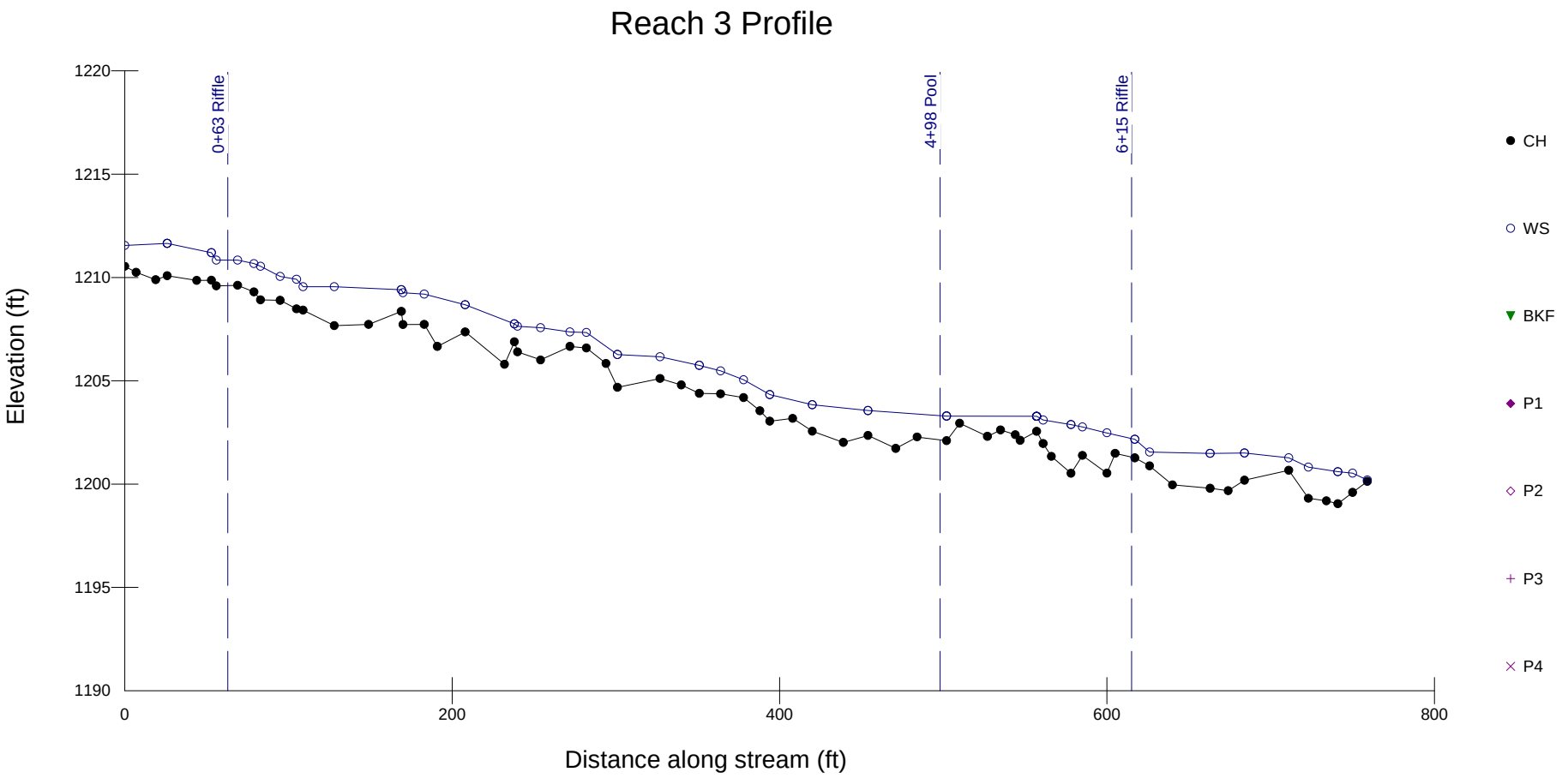


Reach 2 5+21 Riffle

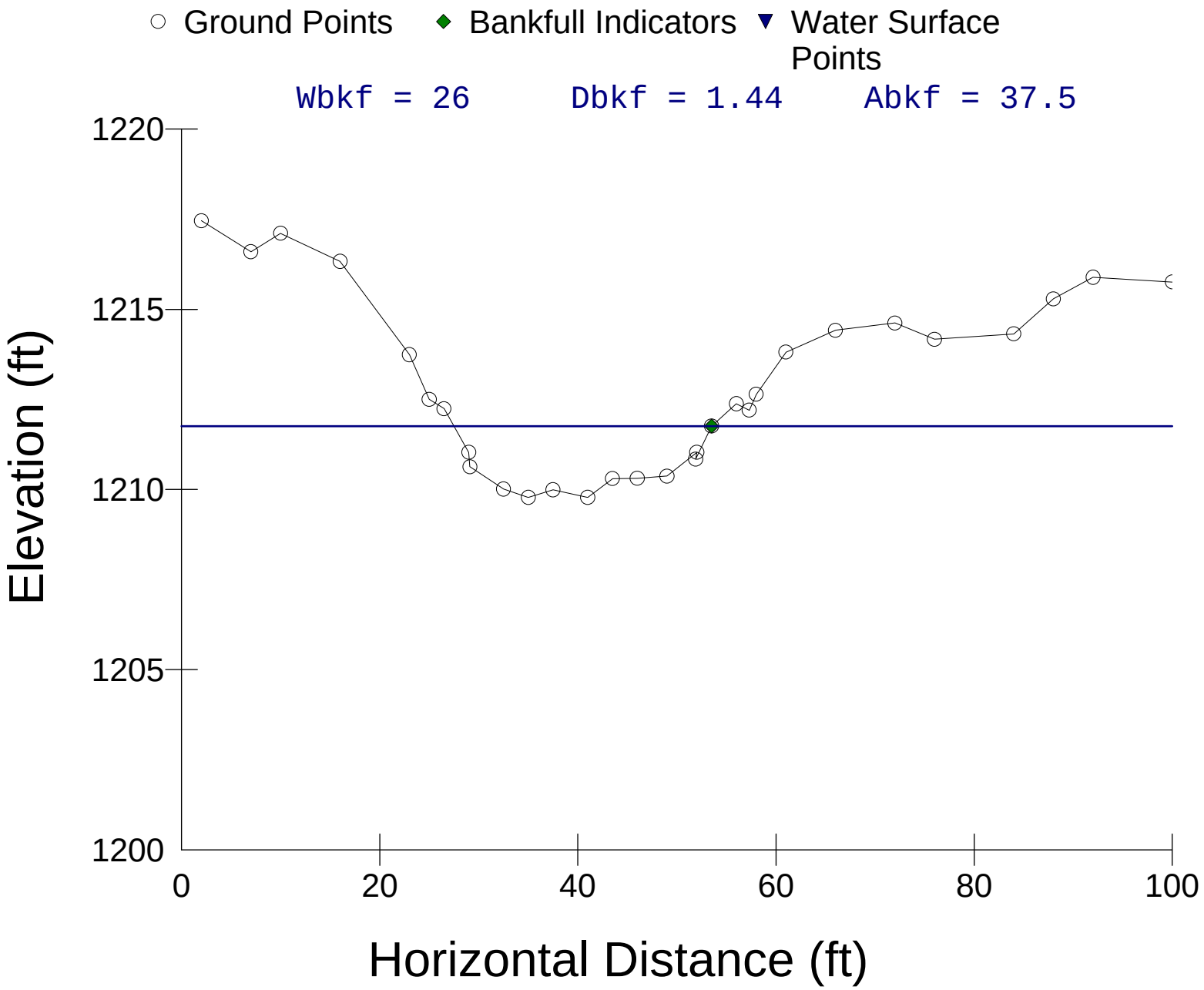


Reach 2

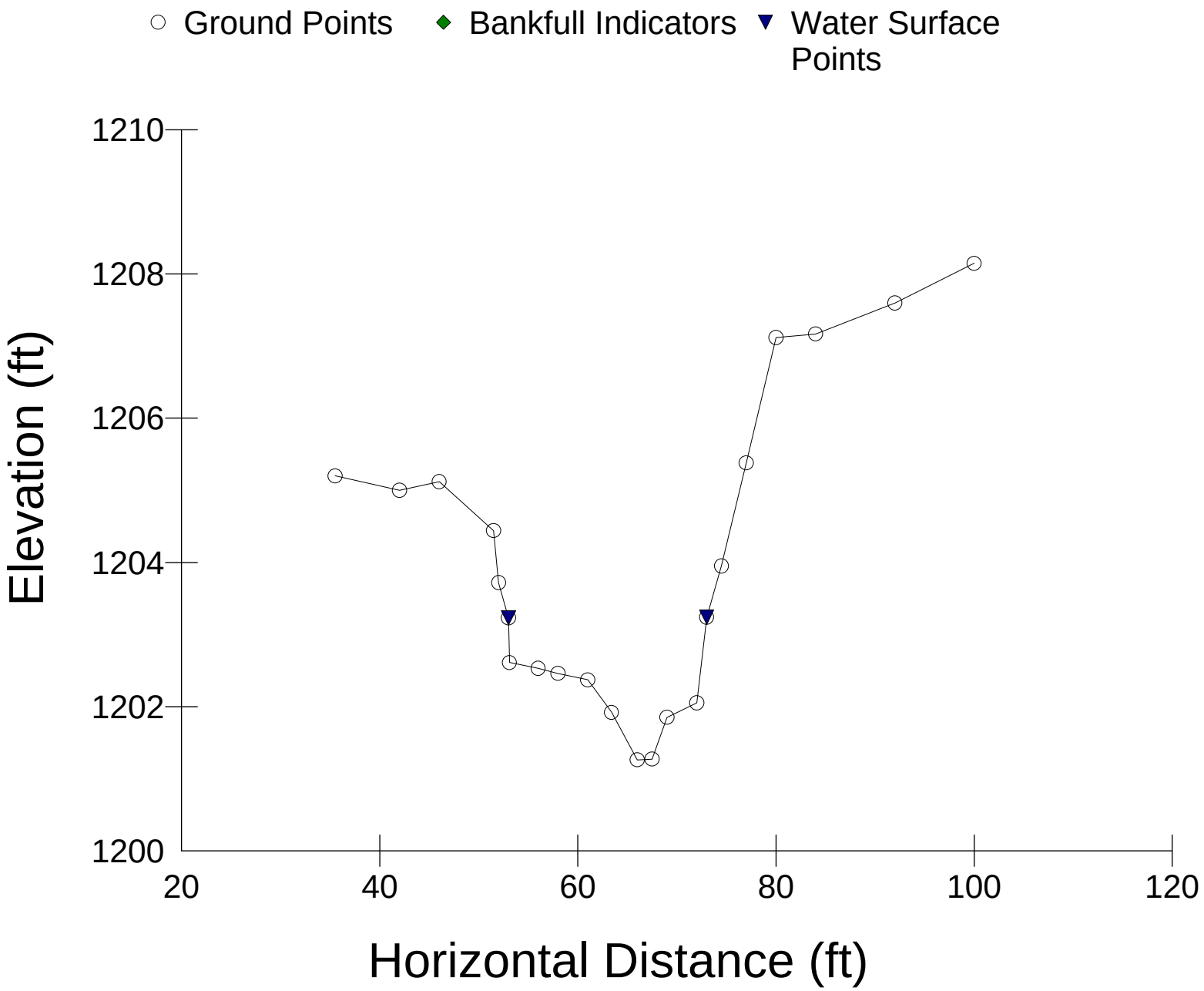

Percent Finer
100
80
60
40
20
0
0.01
0.1
1
10
100
1000
10000
Particle Size (mm)


Reach 3 Profile
Elevation (ft)
1220
1215
1210
1205
1200
1195
1190
0+63 Riffle
4+98 Pool
6+15 Riffle
0
200
400
600
800
Distance along stream (ft)
CH
WS
BKF
P1
P2
P3
P4

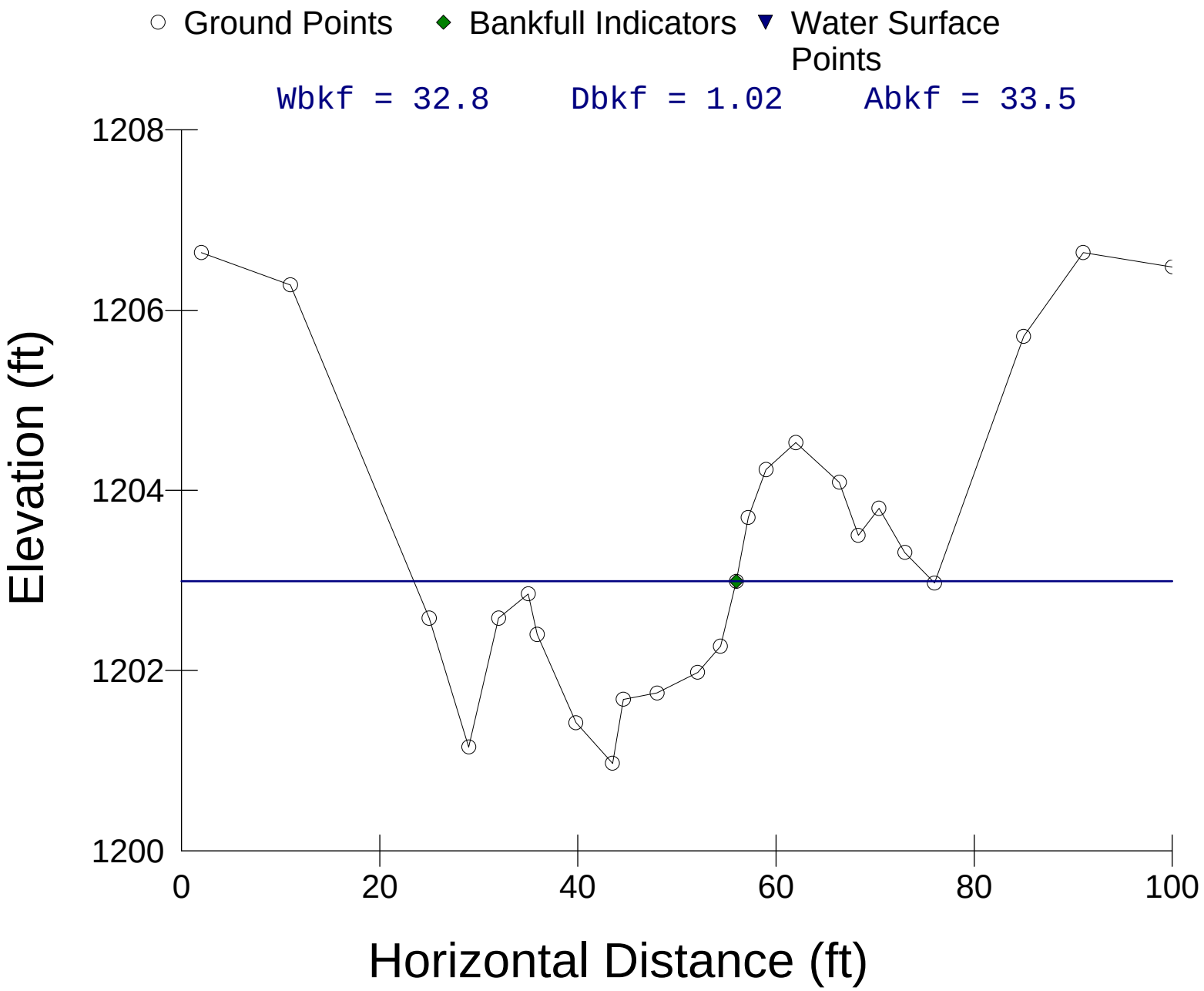
Reach 3 0+63 Riffle

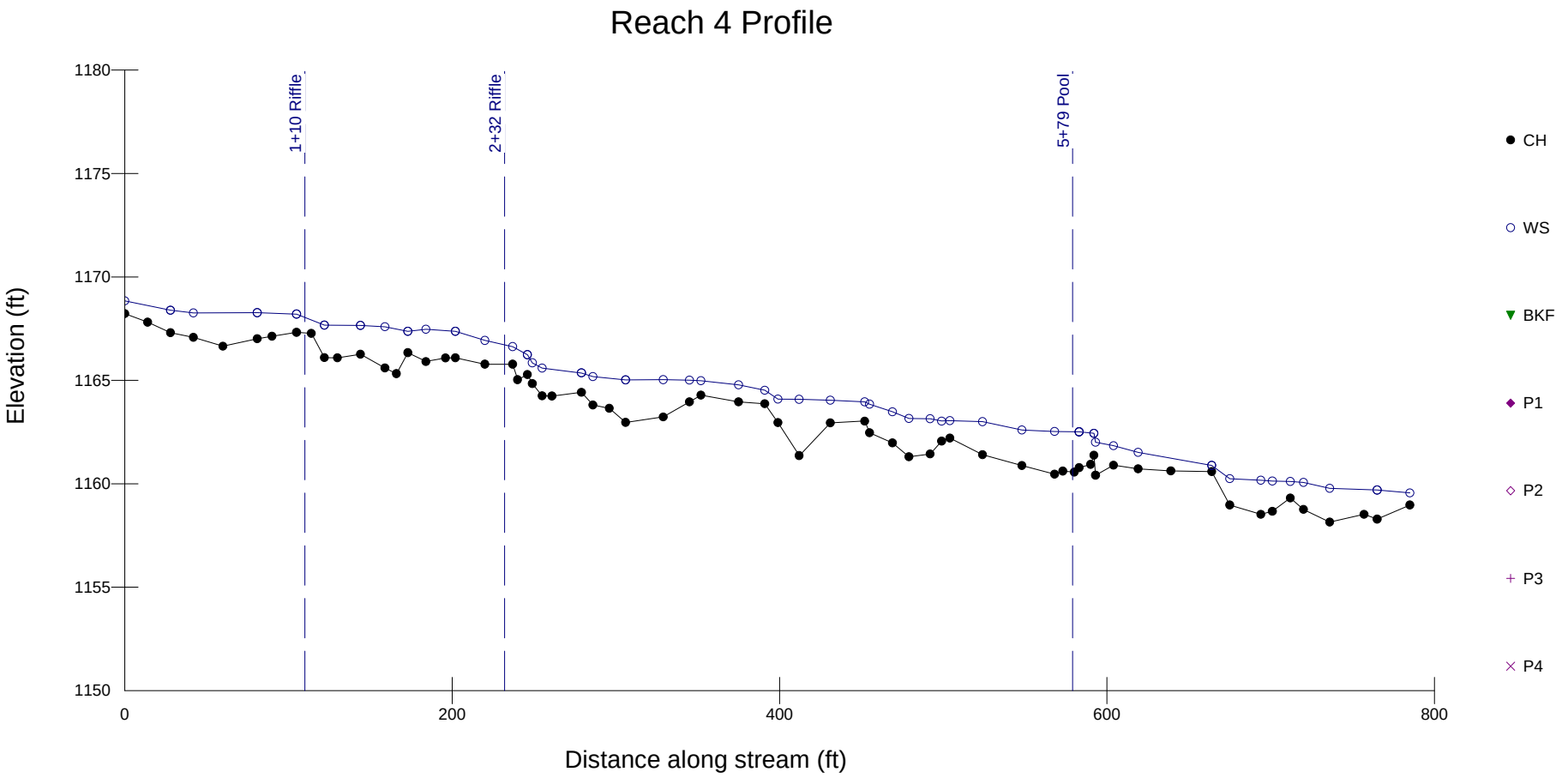


Reach 3 4+98 Pool

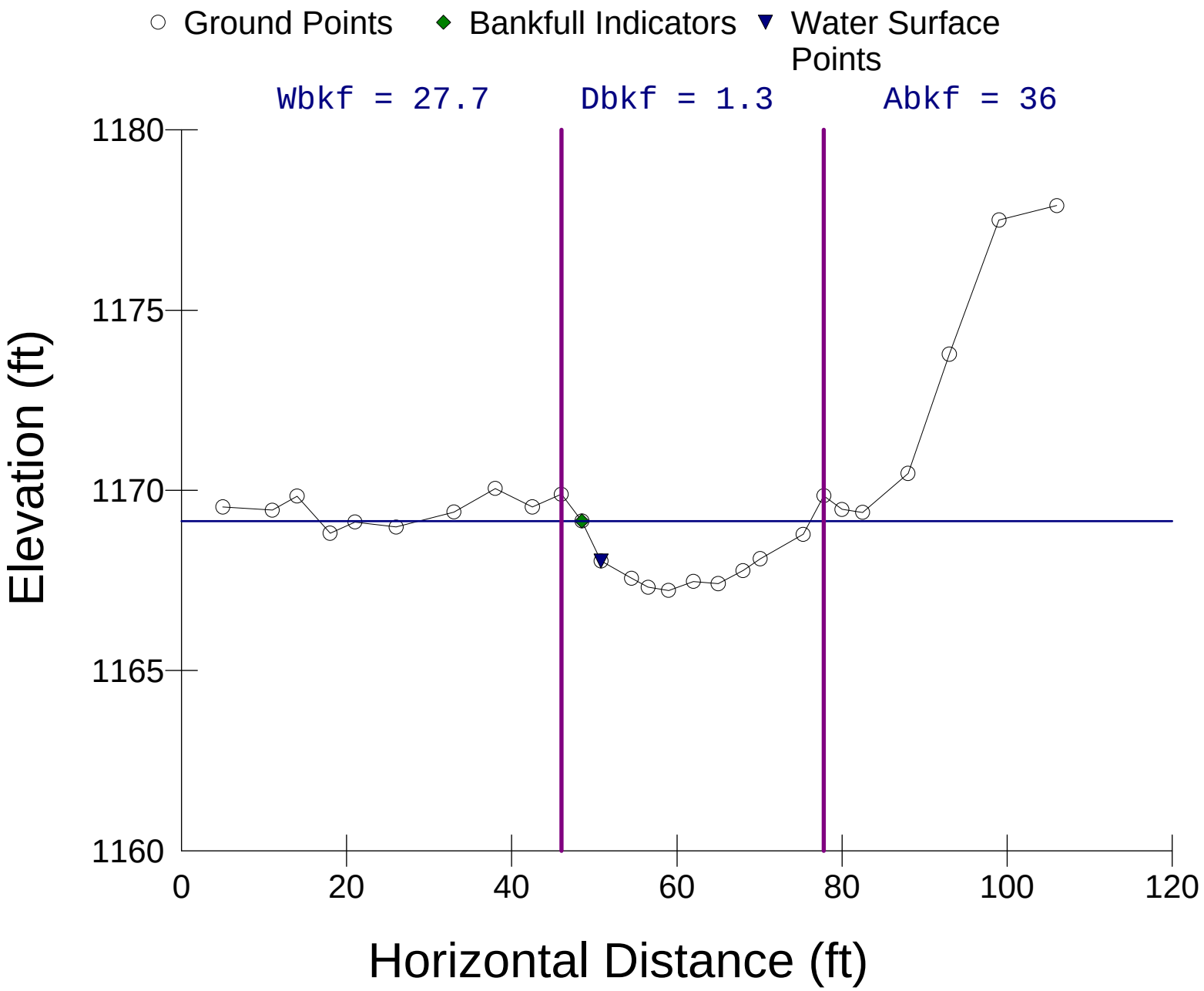


Reach 3 6+15 Riffle

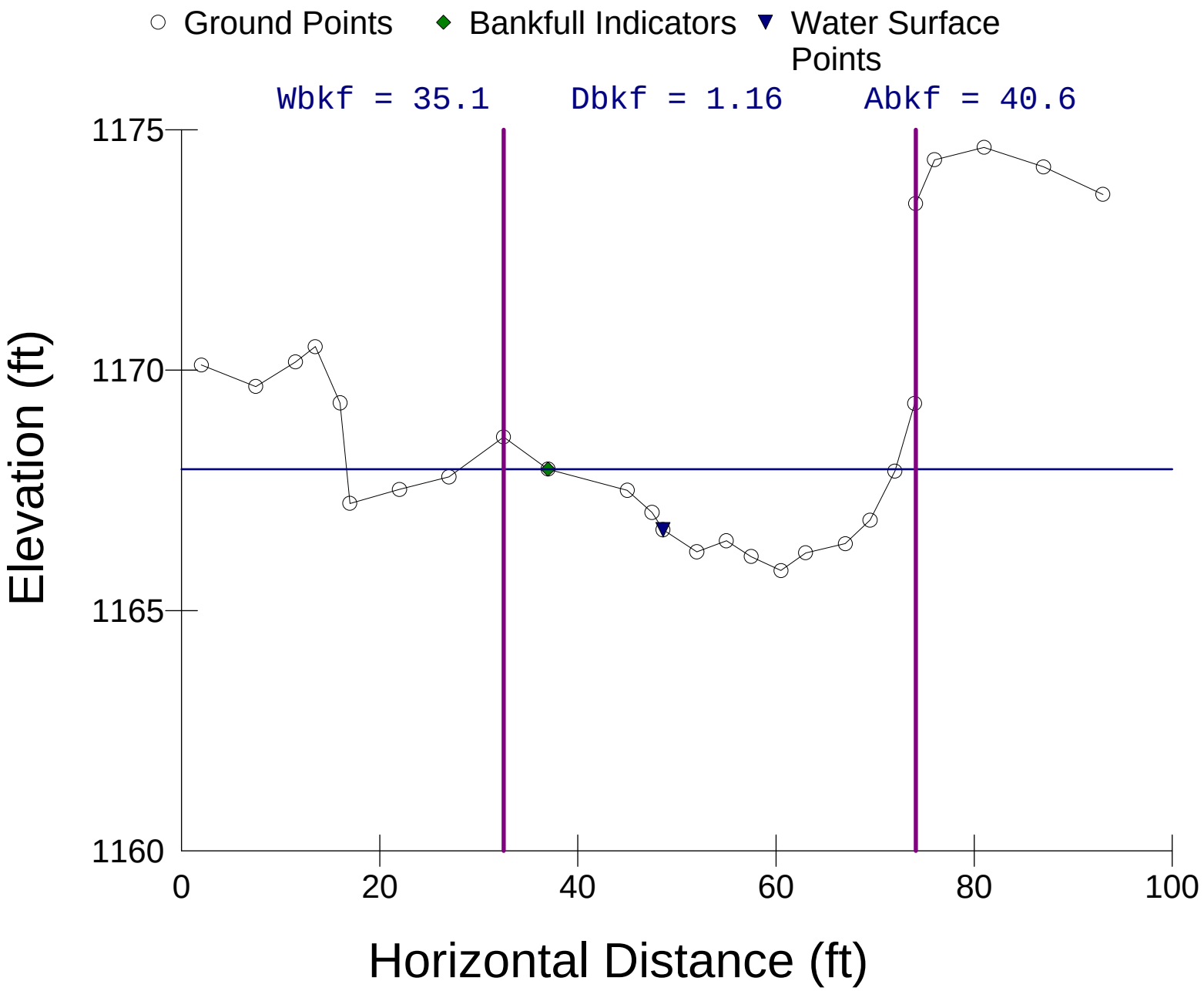



Reach 4 Profile
1180
1175
1170
1165
1160
1155
1150
Elevation (ft)
1+10 Riffle
2+32 Riffle
5+79 Pool
0
200
400
600
800
Distance along stream (ft)
CH
WS
BKF
P1
P2
P3
P4

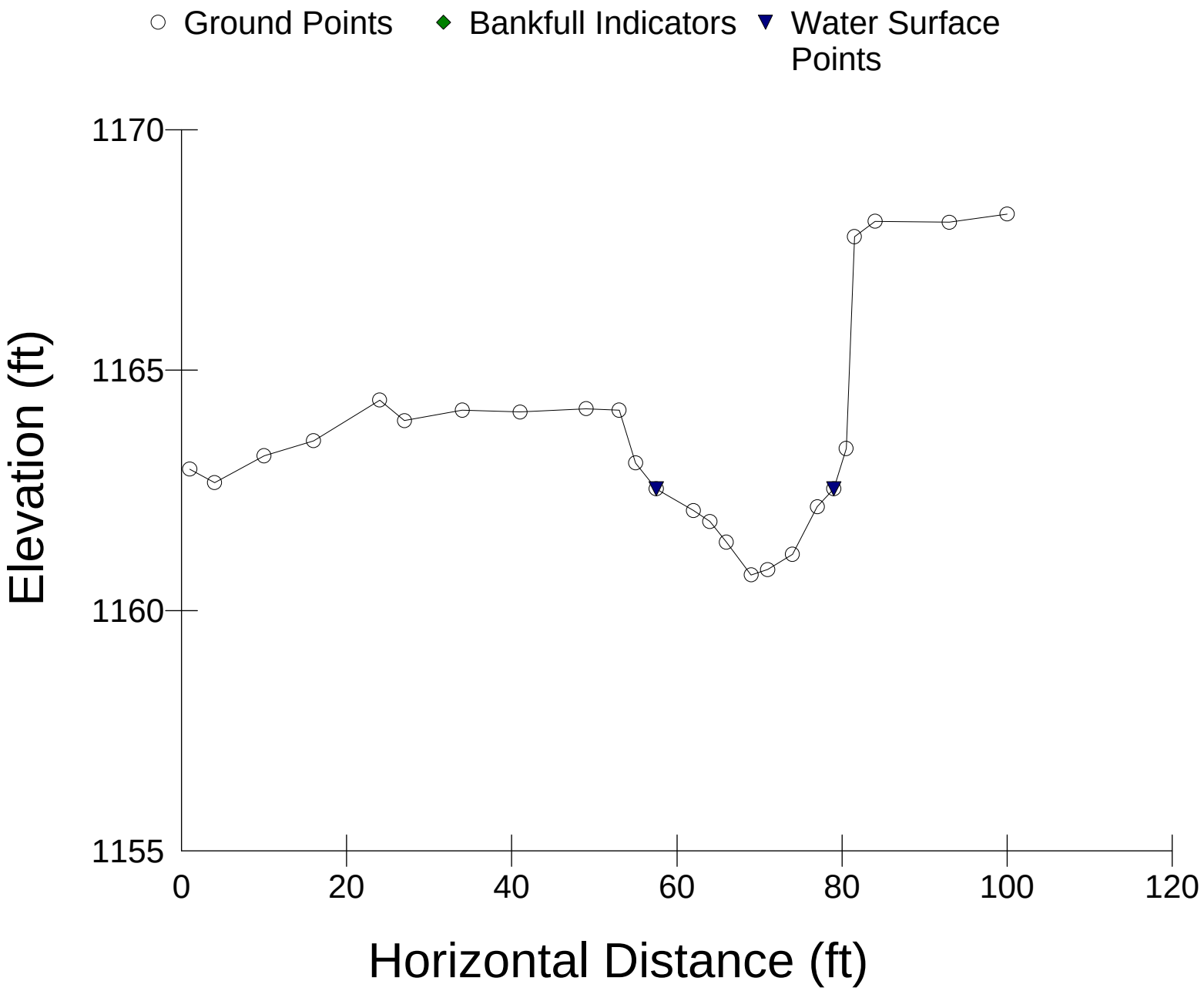
Reach 4 1+10 Riffle



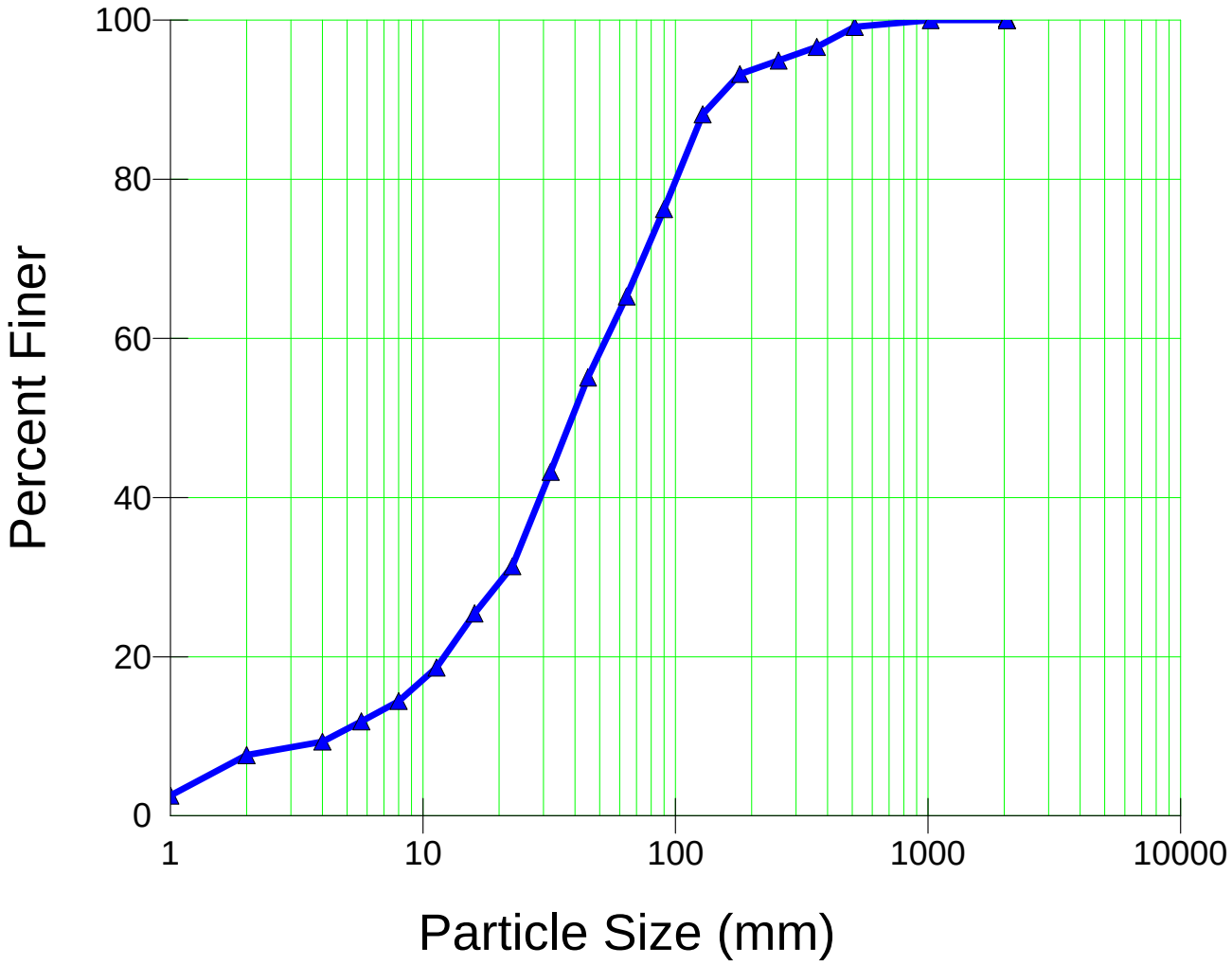
Reach 4 2+32 Riffle

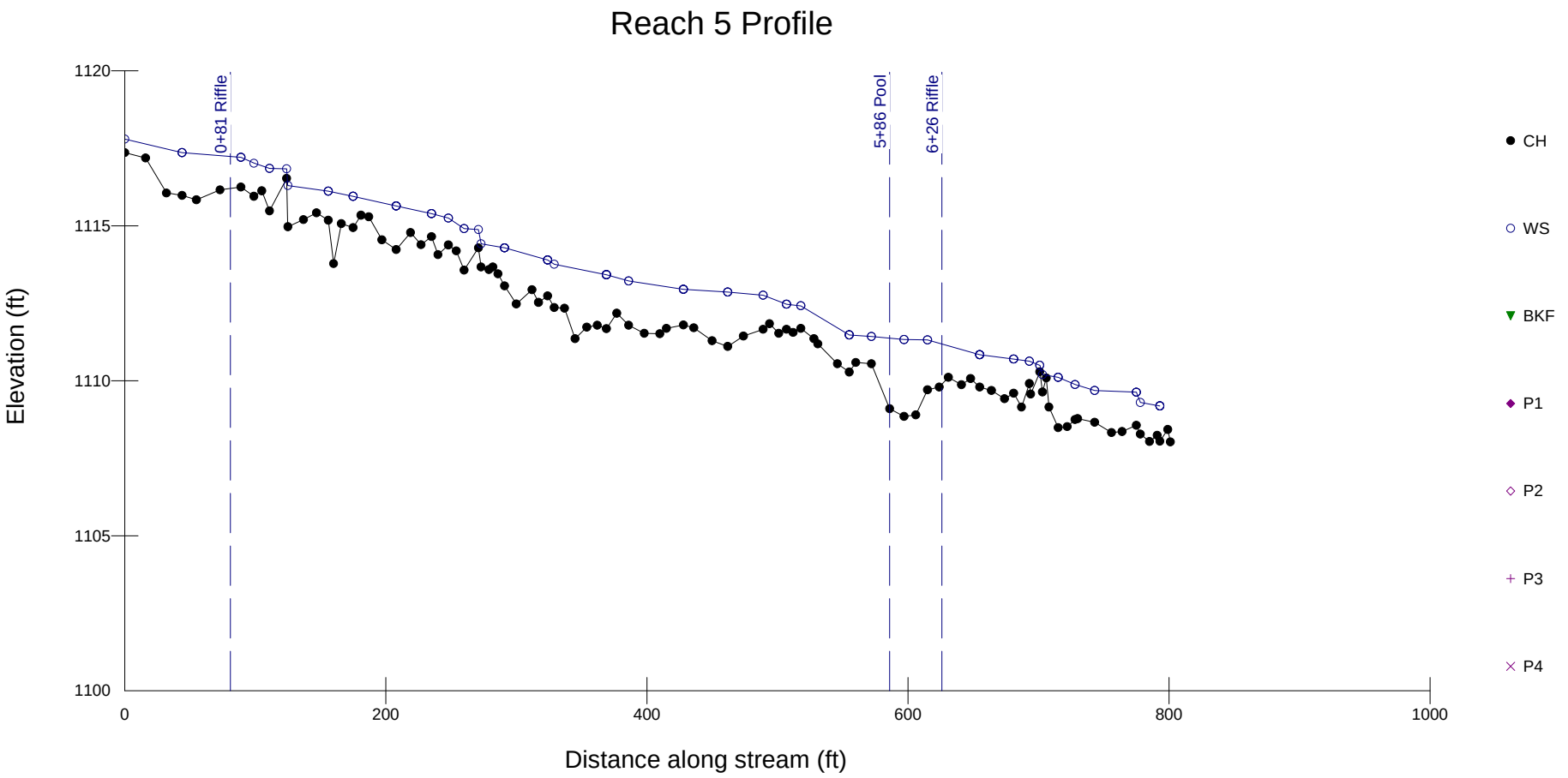


Reach 4 5+79 Pool

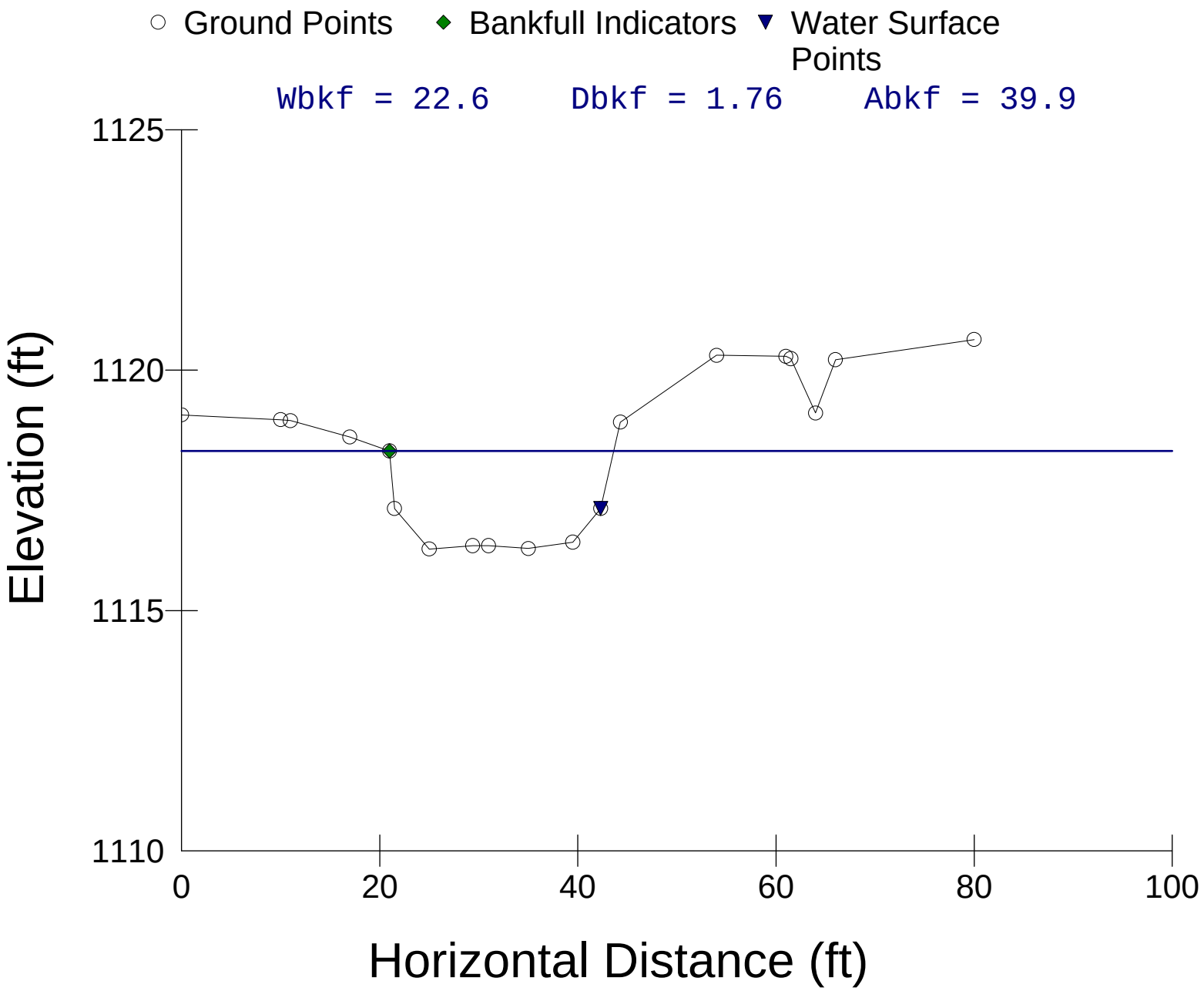


Reach 4

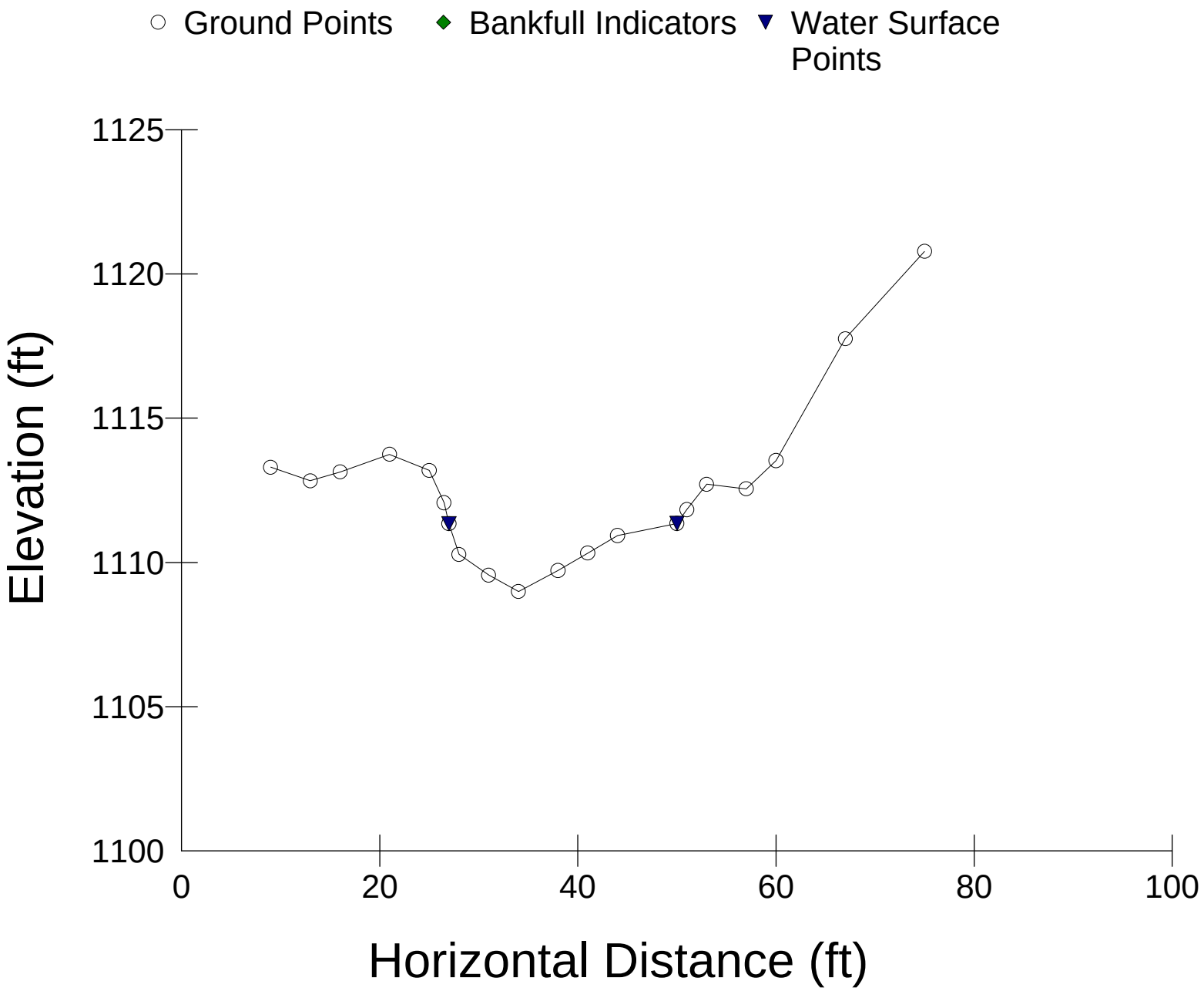

Percent Finer
100
80
60
40
20
0
1
10
100
1000
10000
Particle Size (mm)


Reach 5 Profile
Elevation (ft)
1120
1115
1110
1105
1100
0+81 Riffle
5+86 Pool
6+26 Riffle
0
200
400
600
800
1000
Distance along stream (ft)
CH
WS
BKF
P1
P2
P3
P4

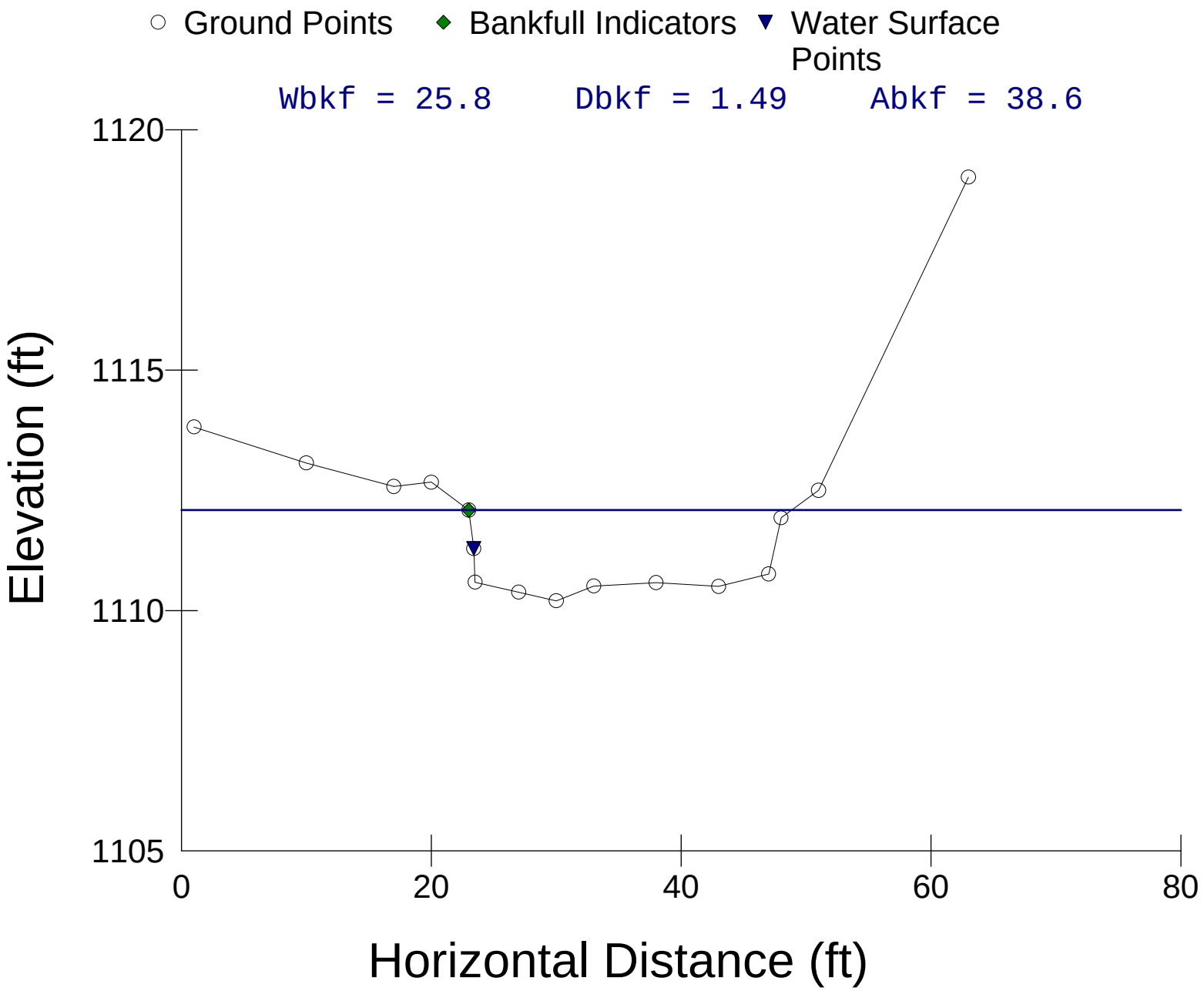
Reach 5 0+81 Riffle



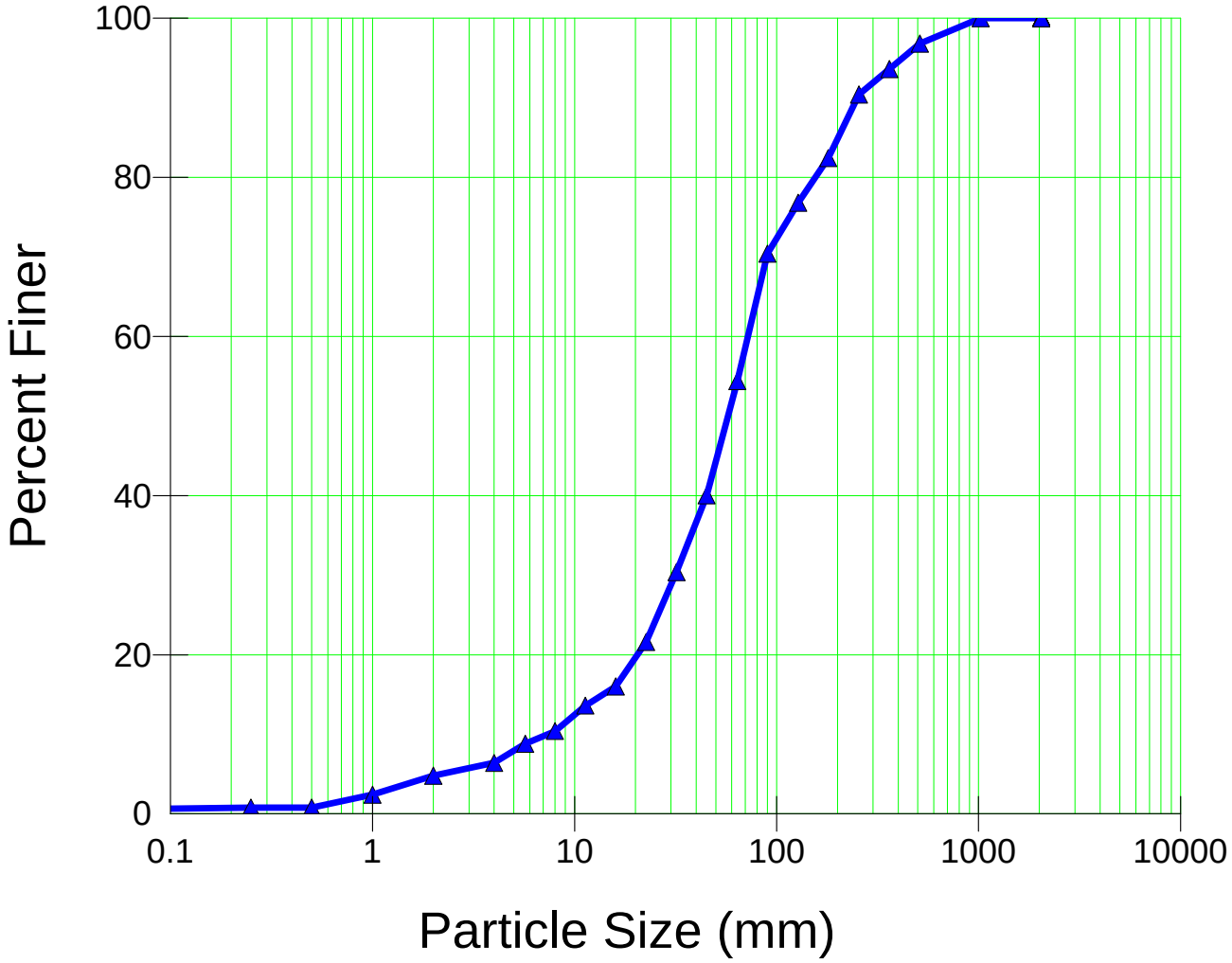
Reach 5 5+86 Pool



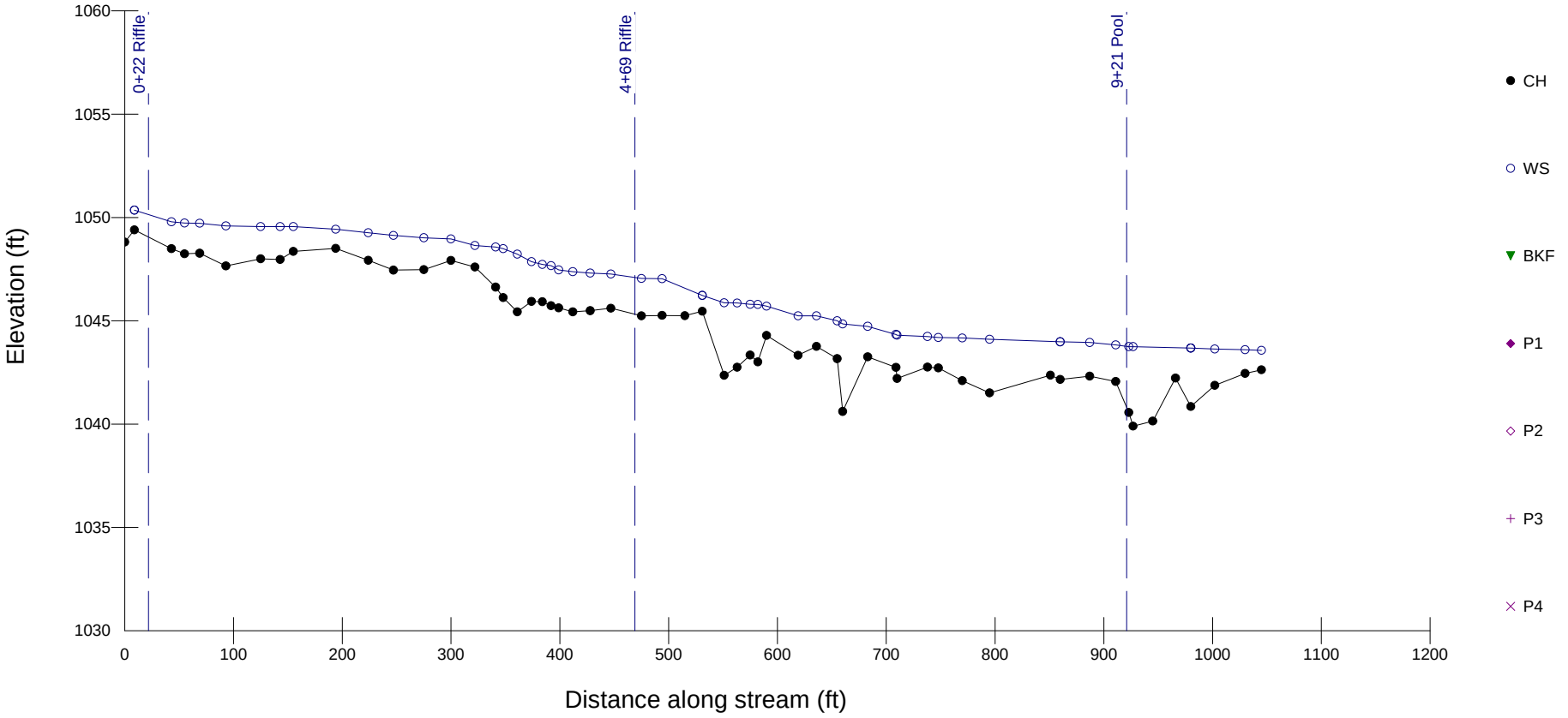
Reach 5 6+26 Riffle



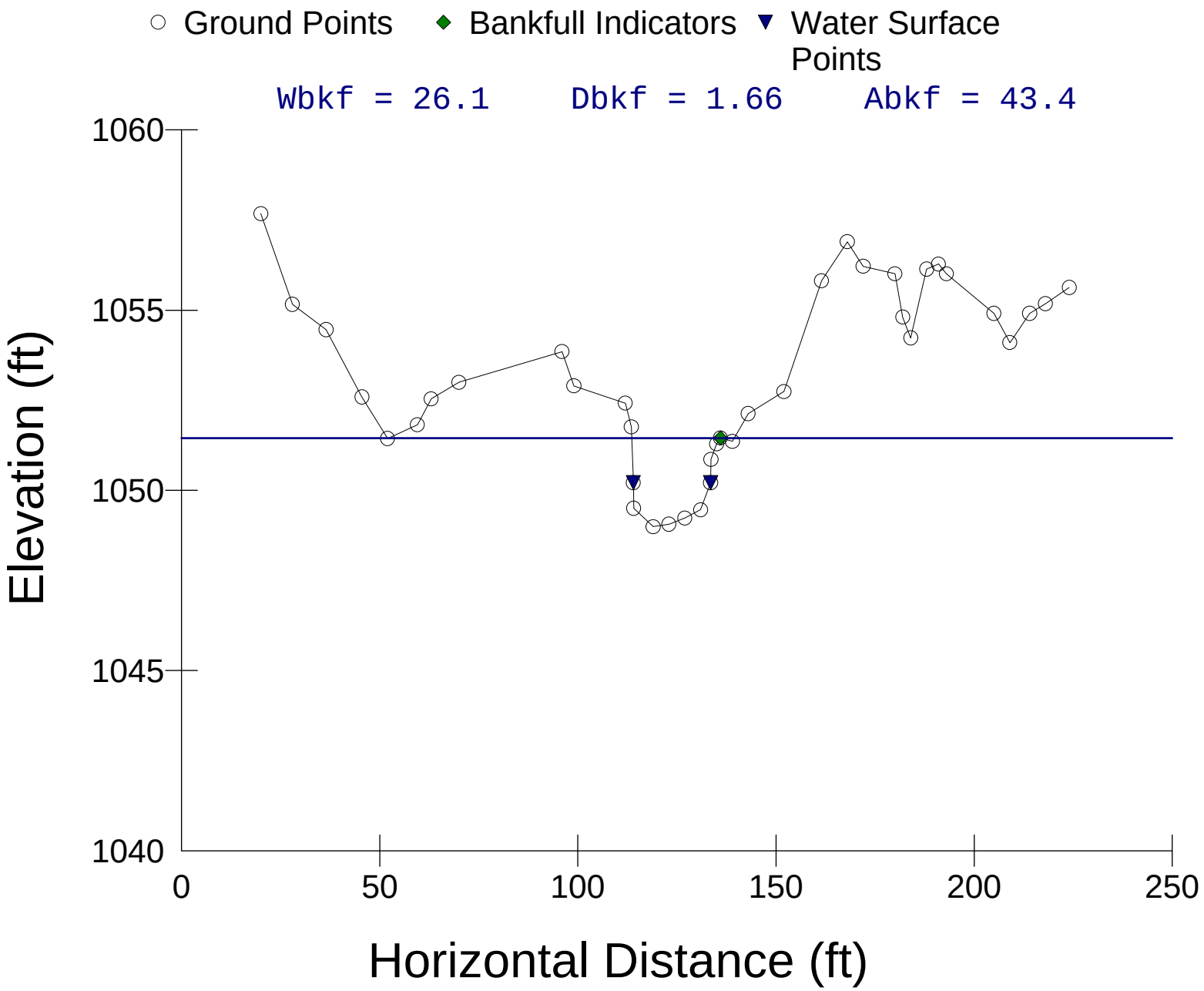
Reach 5


Percent Finer
100
80
60
40
20
0
0.1
1
10
100
1000
10000
Particle Size (mm)

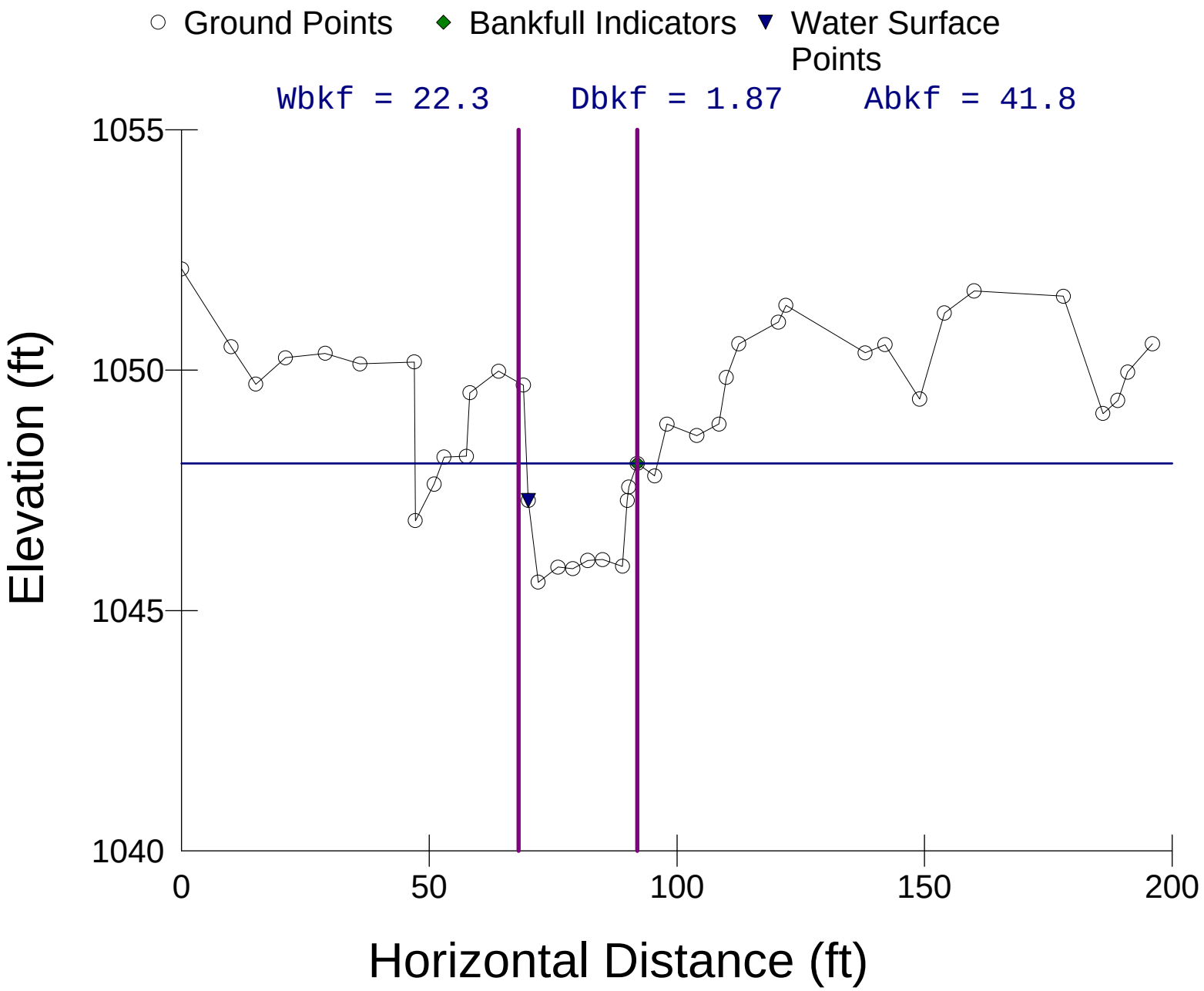
Reach 6 Profile



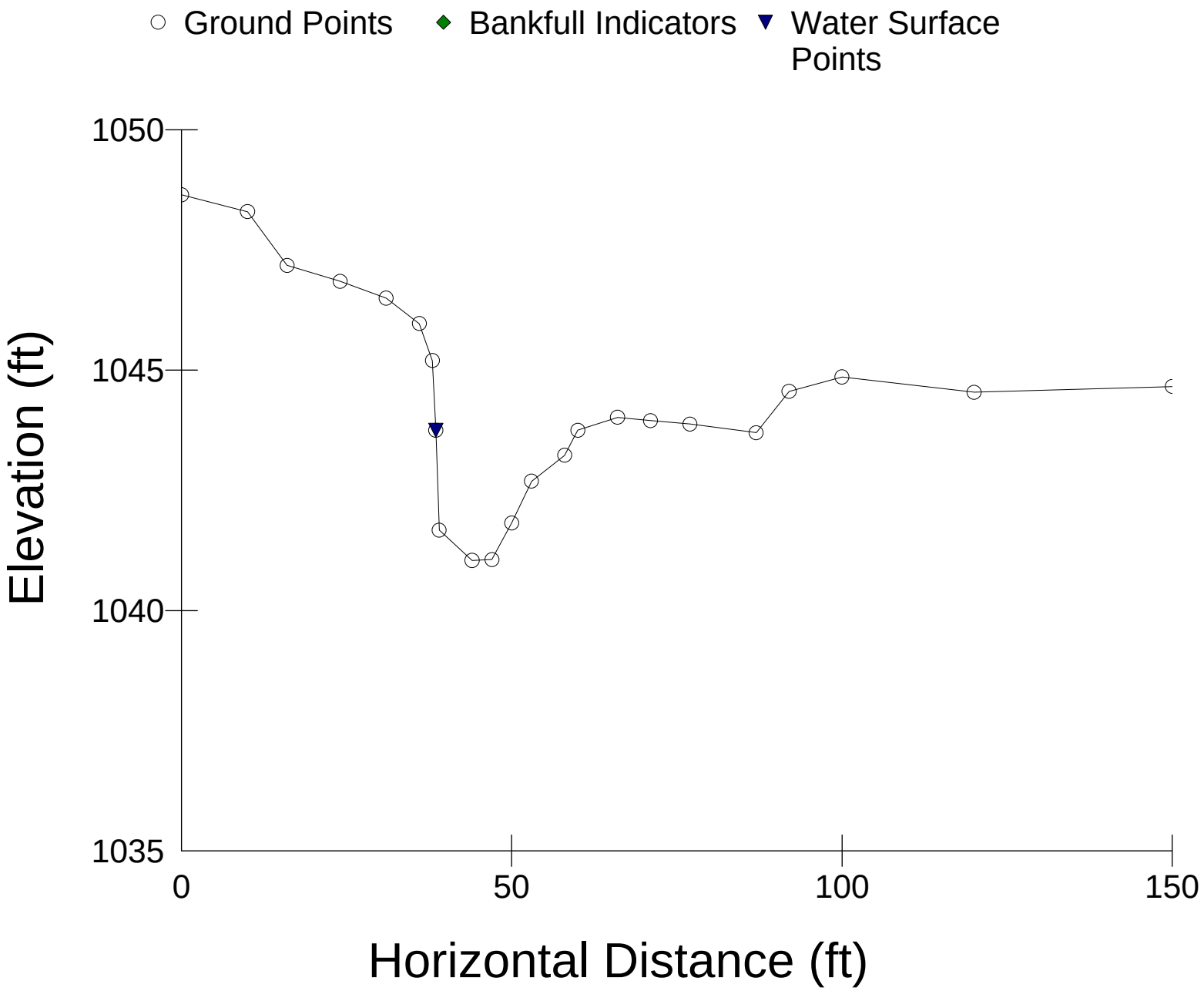
Reach 6 0+22 Riffle

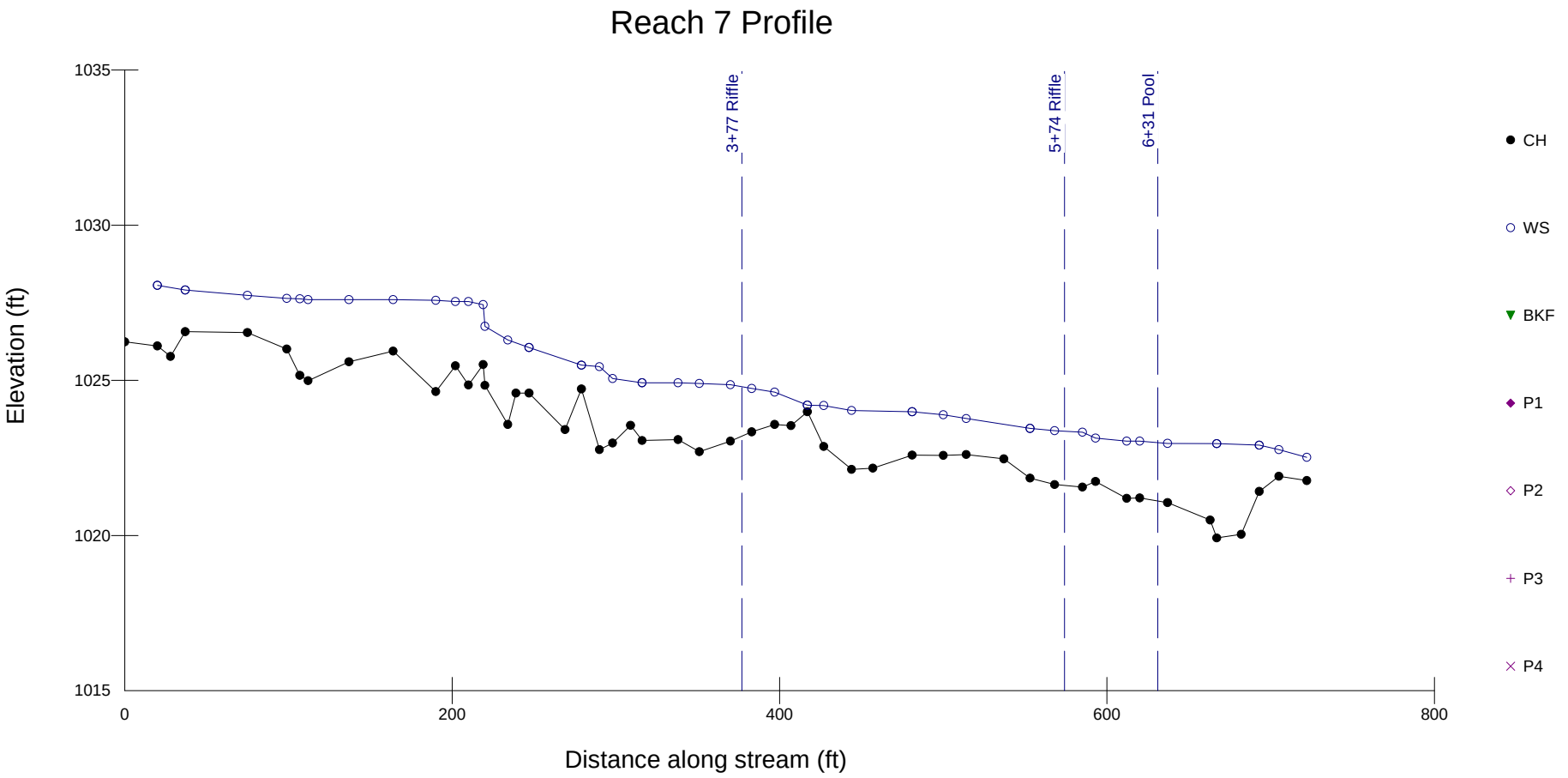


Reach 6 4+69 Riffle

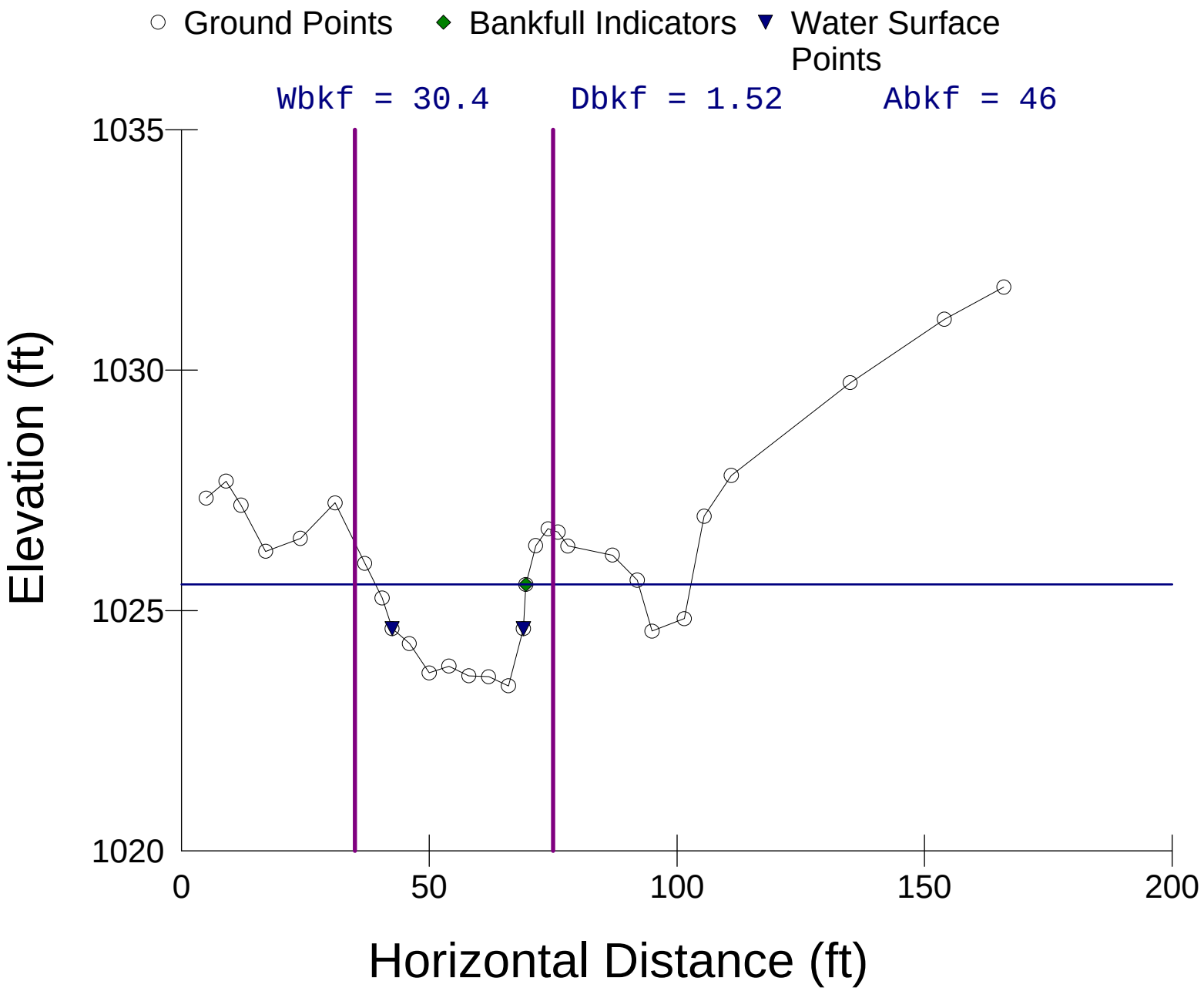


Reach 6 9+21 Pool

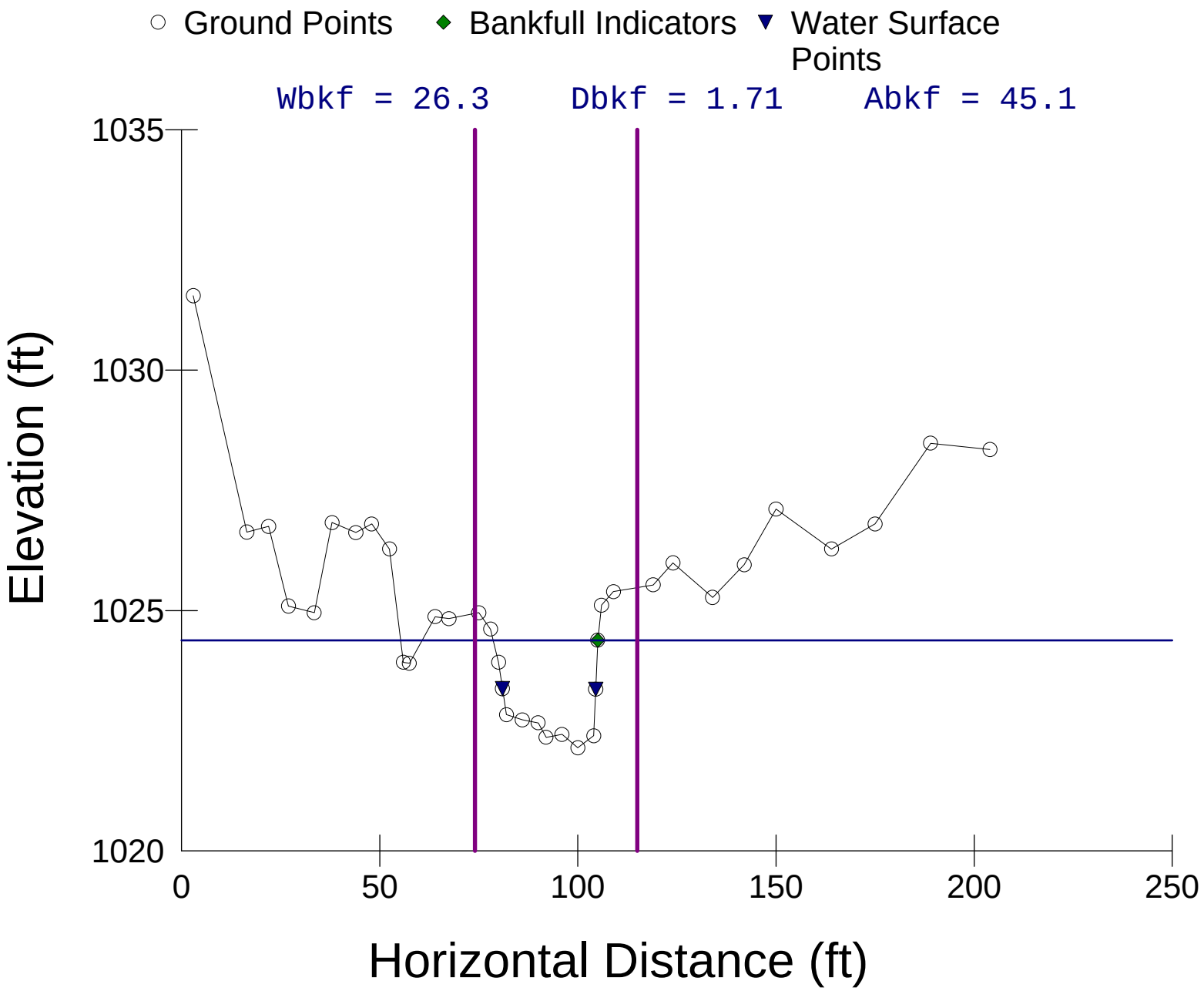



Reach 7 Profile
Elevation (ft)
1035
1030
1025
1020
1015
0
200
400
600
800
Distance along stream (ft)
3+77 Riffle
5+74 Riffle
6+31 Pool
CH
WS
BKF
P1
P2
P3
P4

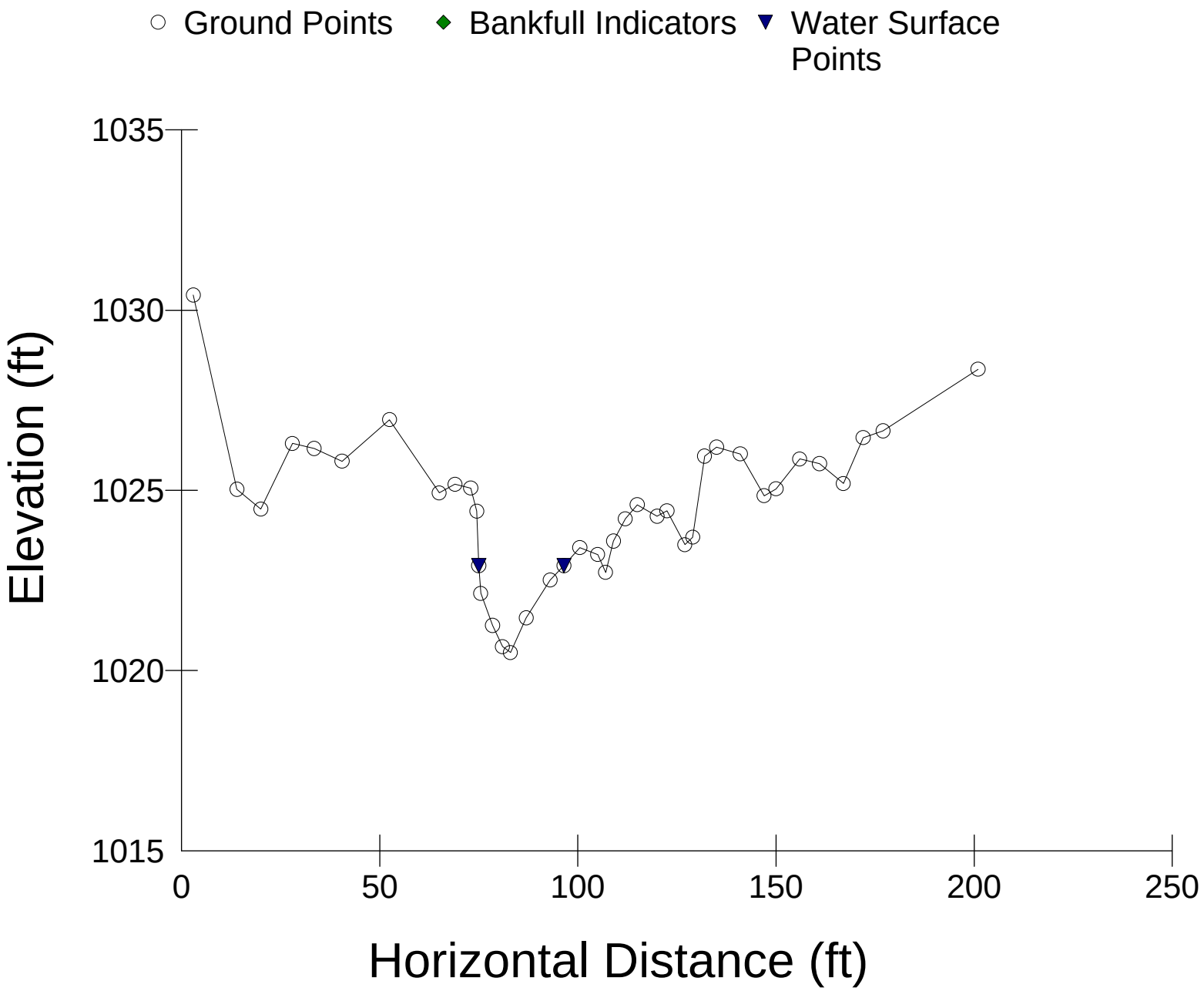
Reach 7 3+77 Riffle



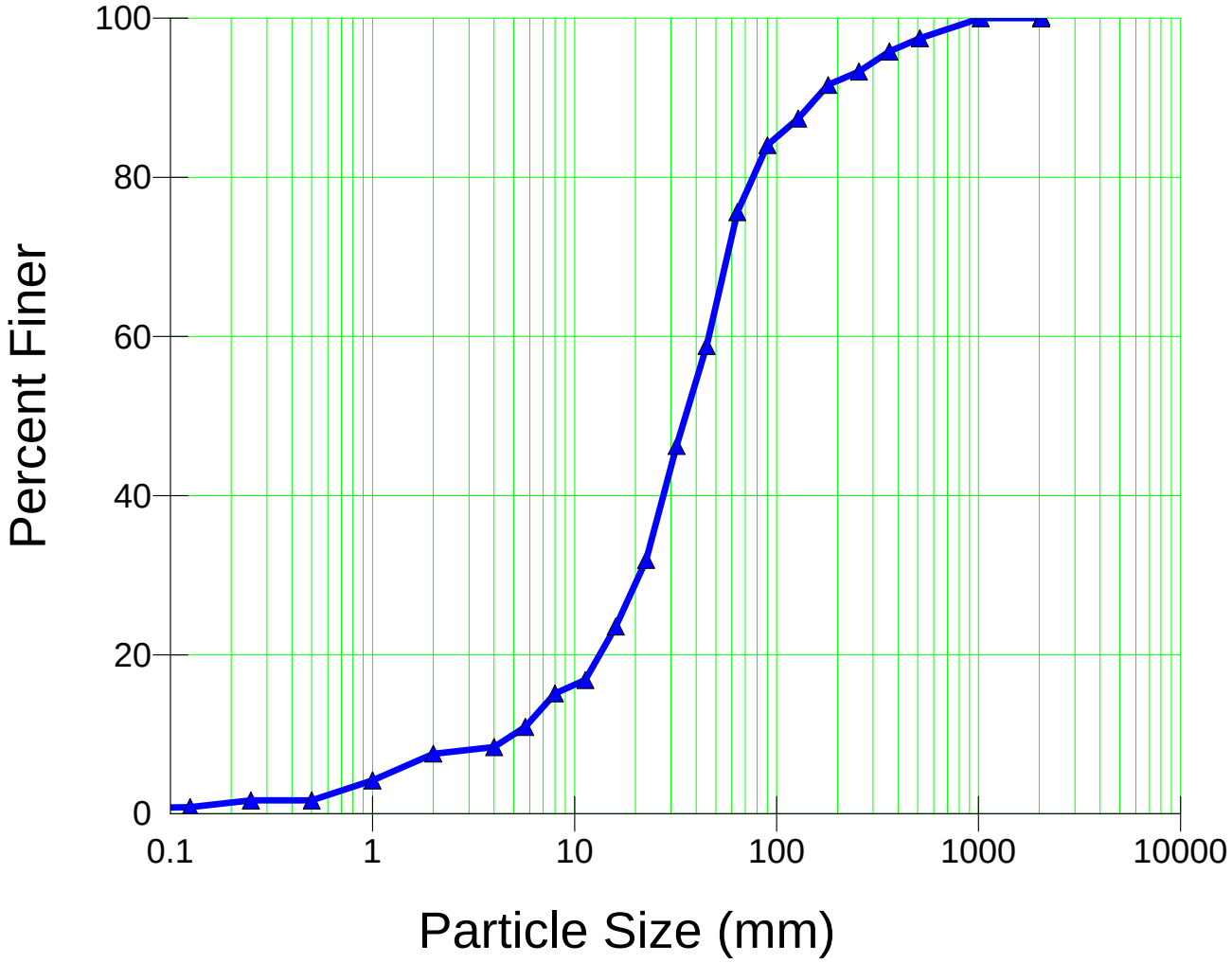
Reach 7 5+74 Riffle



Reach 7 6+31 Pool



Reach 7


Percent Finer
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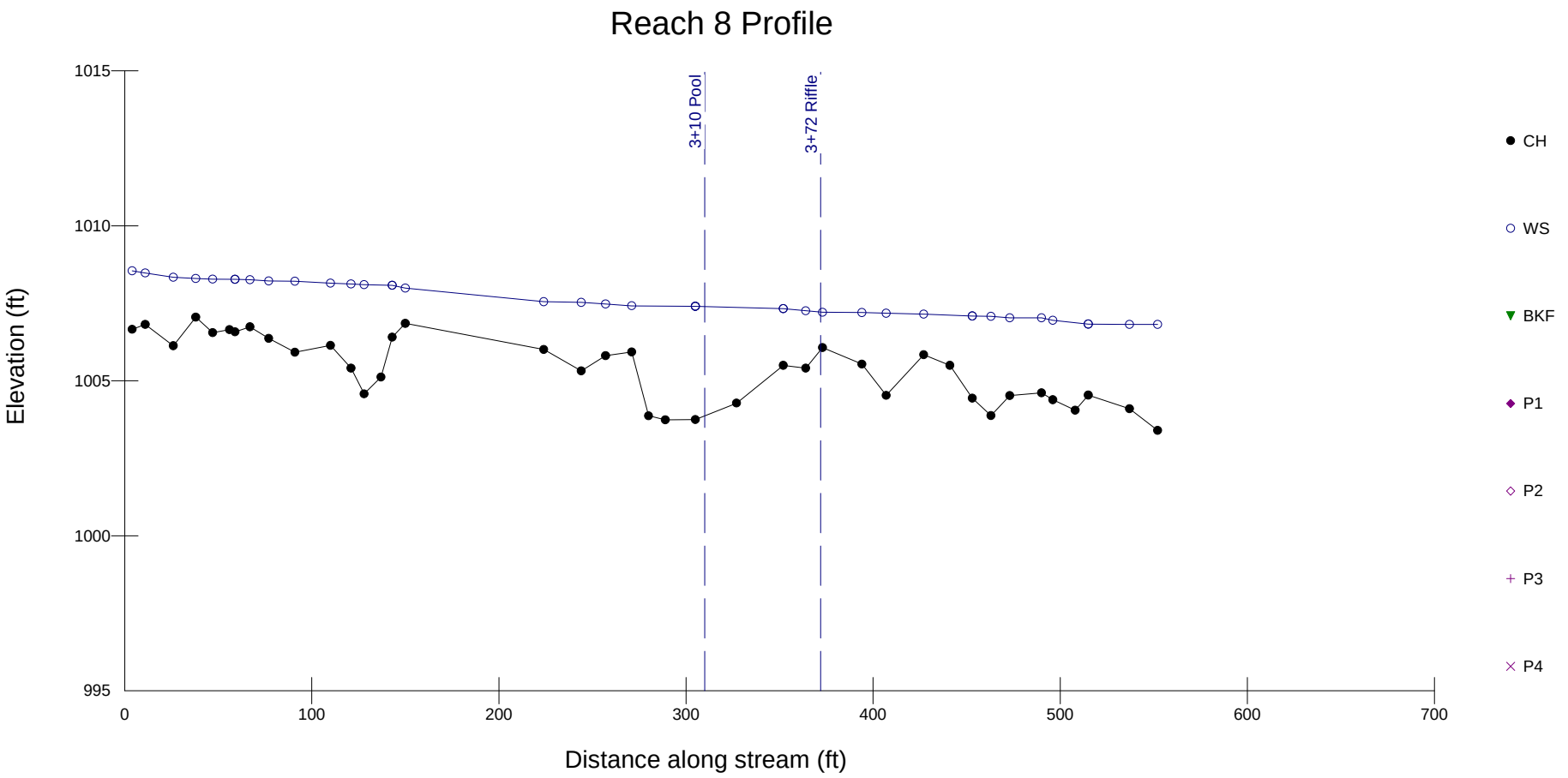
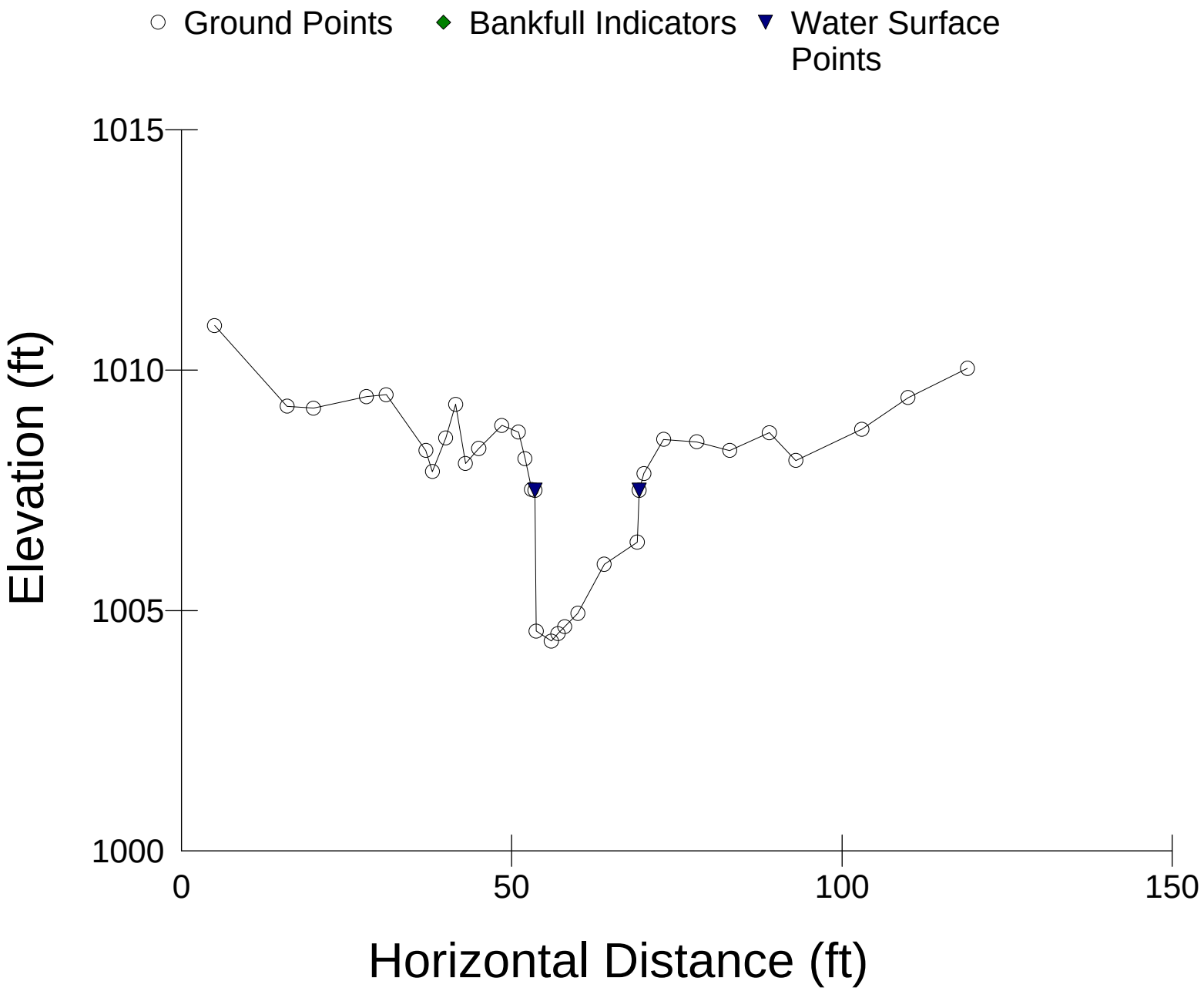
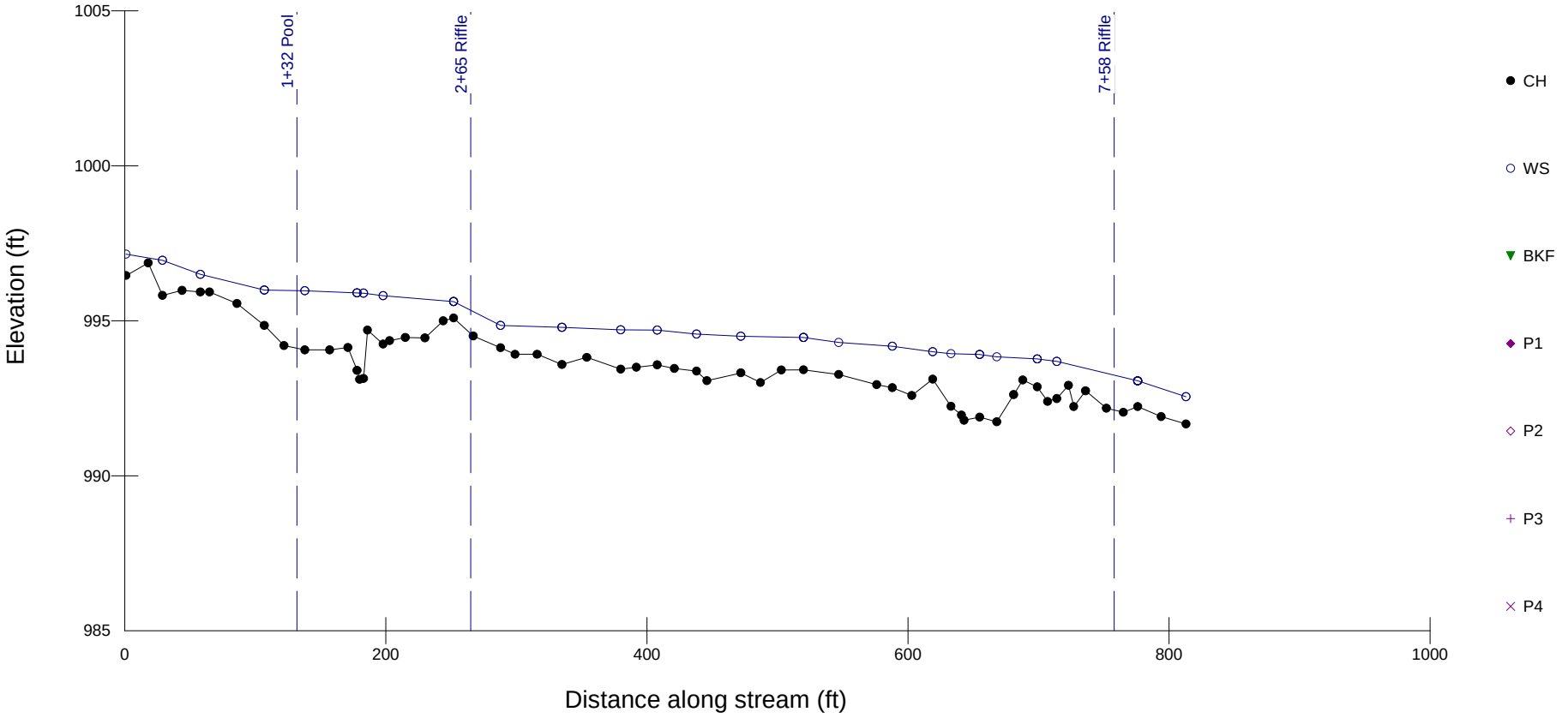
80
60
40
20
0
0.1
1
10
100
1000
10000
Particle Size (mm)


Reach 8 Profile
Elevation (ft)
1015
1010
1005
1000
995
0
100
200
300
400
500
600
700
Distance along stream (ft)
3+10 Pool
3+72 Riffle
CH
WS
BKF
P1
P2
P3
P4

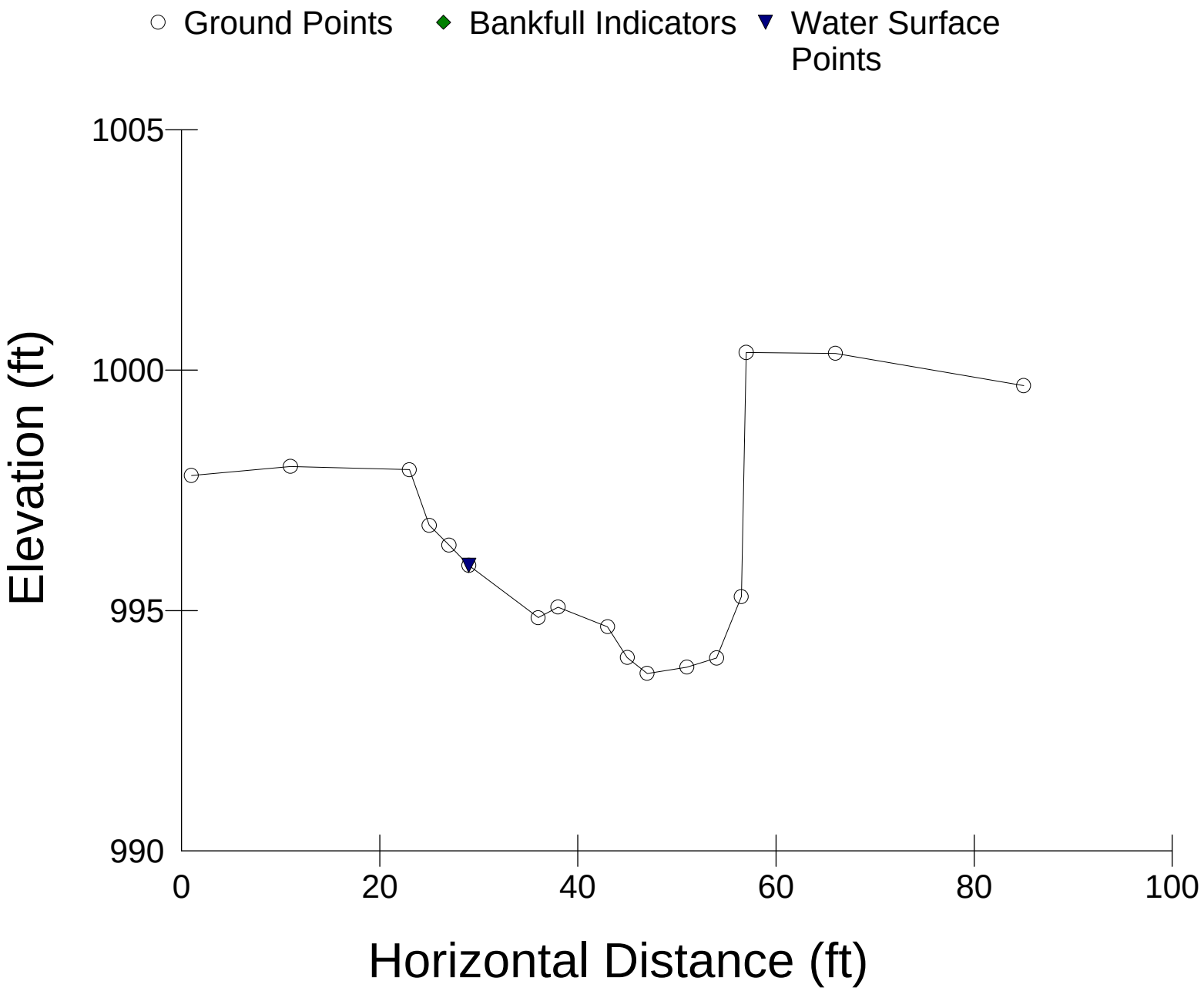
Reach 8 3+10 Pool



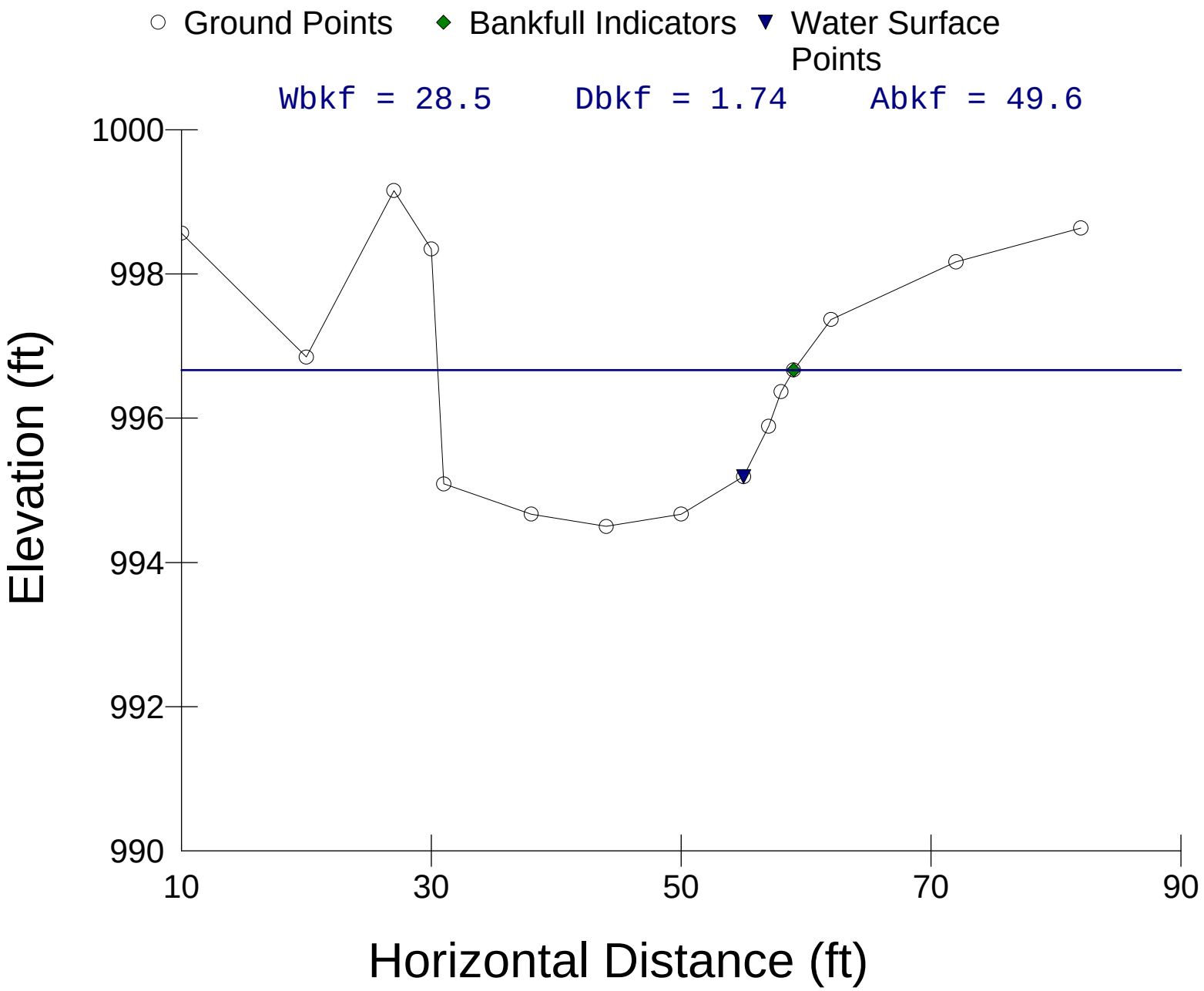
Reach 9 Profile



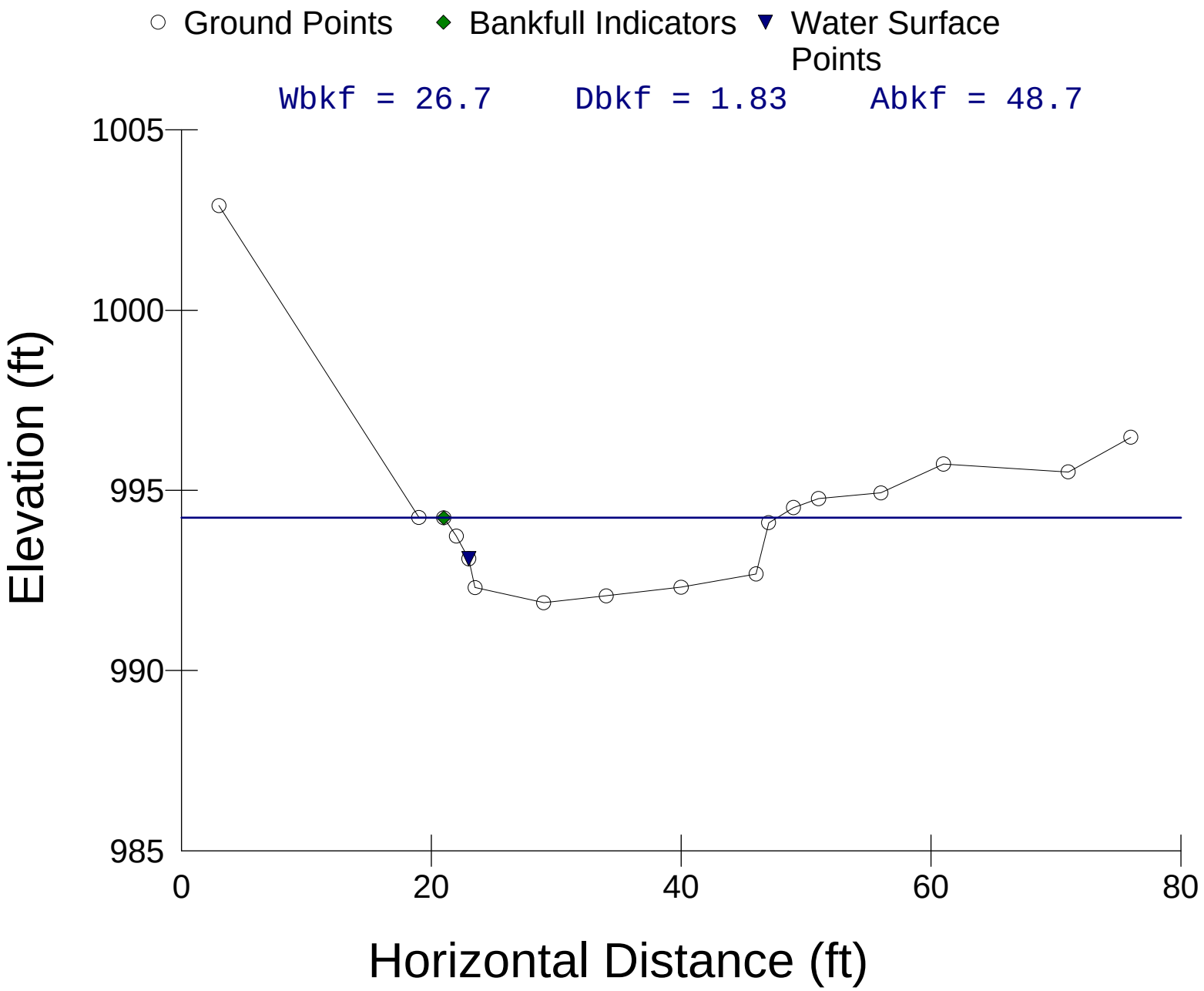
Reach 9 1+32 Pool



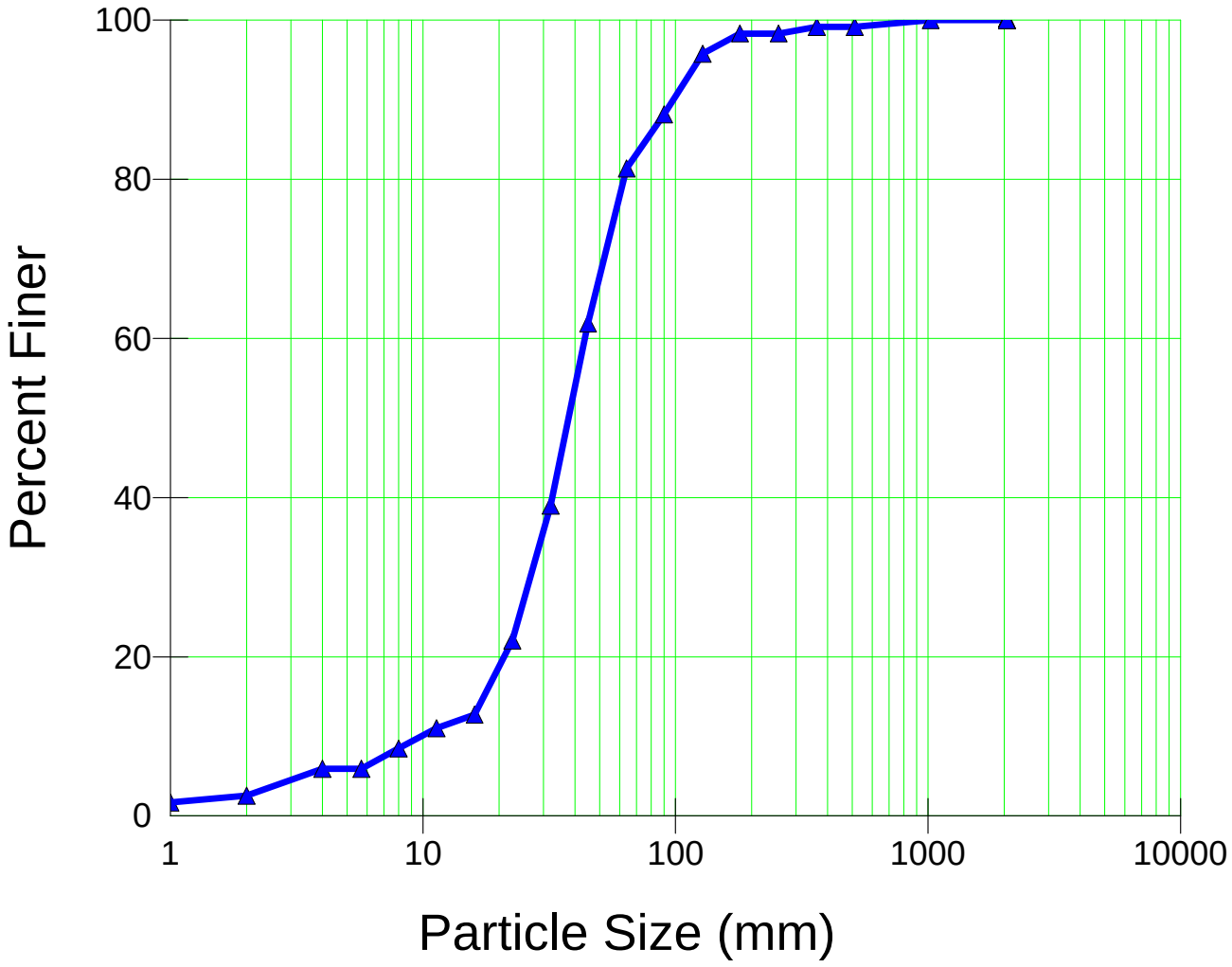
Reach 9 2+65 Riffle

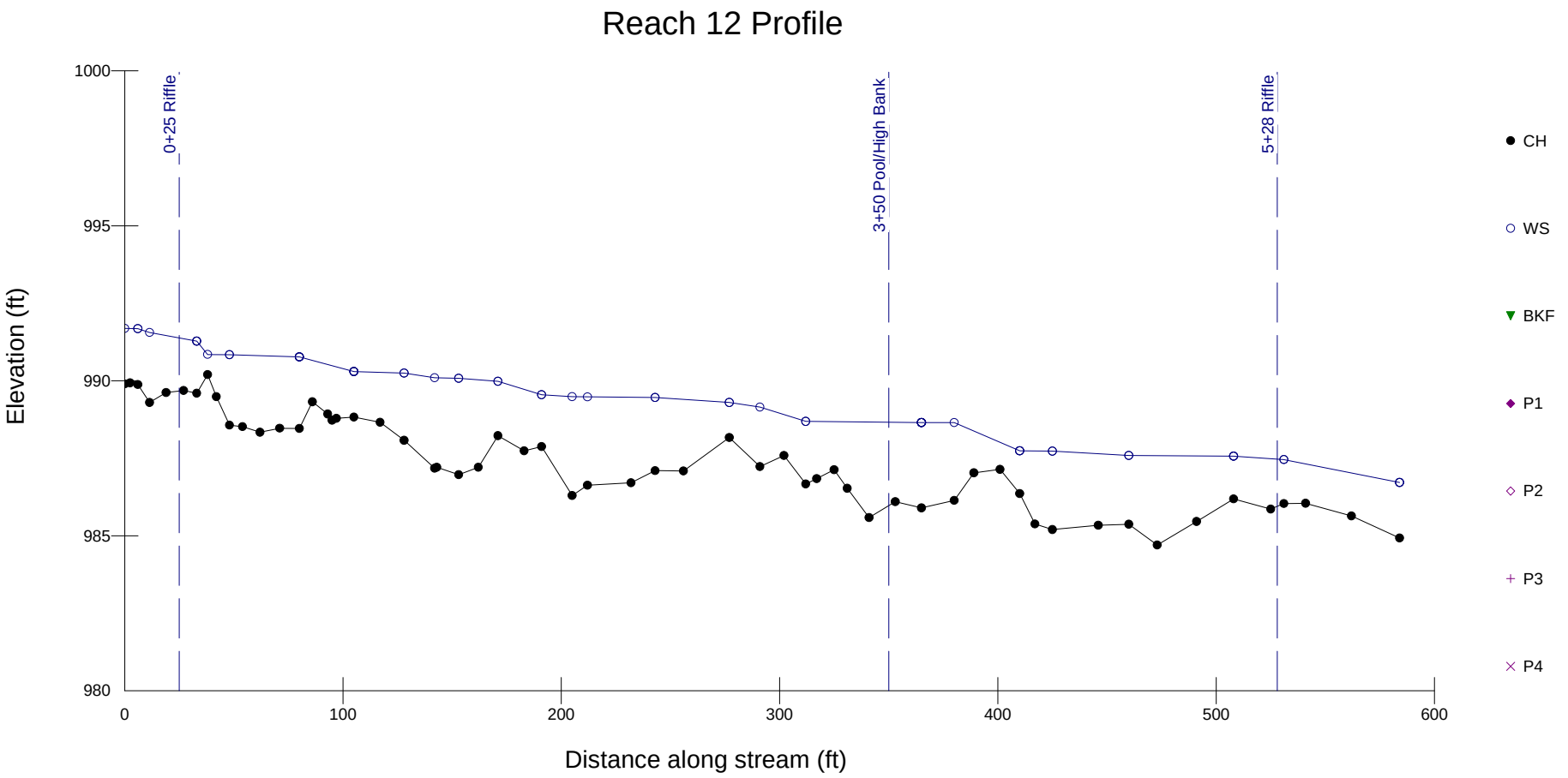


Reach 9 7+58 Riffle

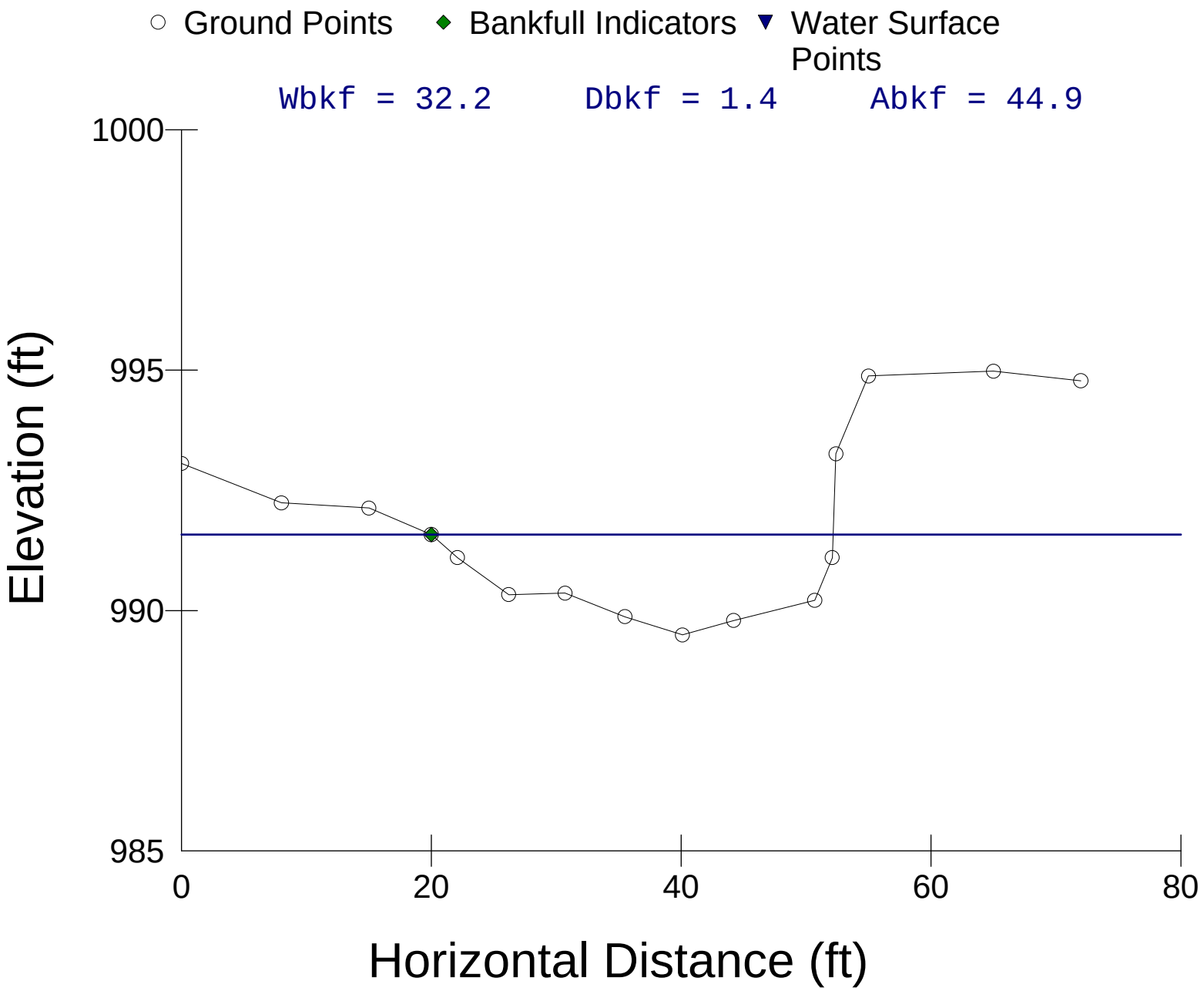


Reach 9

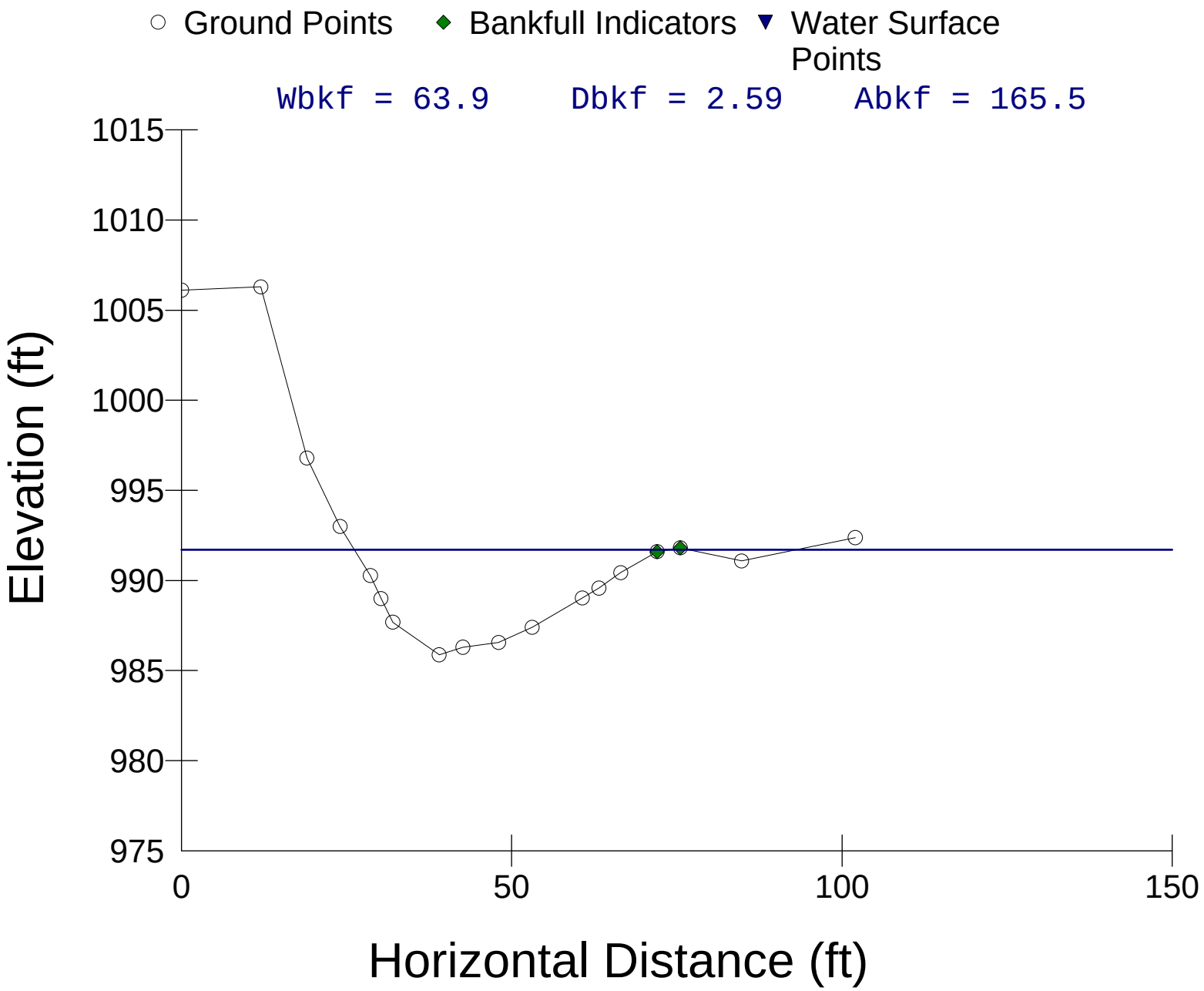

Percent Finer
100
80
60
40
20
0
1
10
100
1000
10000
Particle Size (mm)


Reach 12 Profile
Elevation (ft)
1000
995
990
985
980
0+25 Riffle
3+50 Pool/High Bank
5+28 Riffle
0
100
200
300
400
500
600
Distance along stream (ft)
CH
WS
BKF
P1
P2
P3
P4

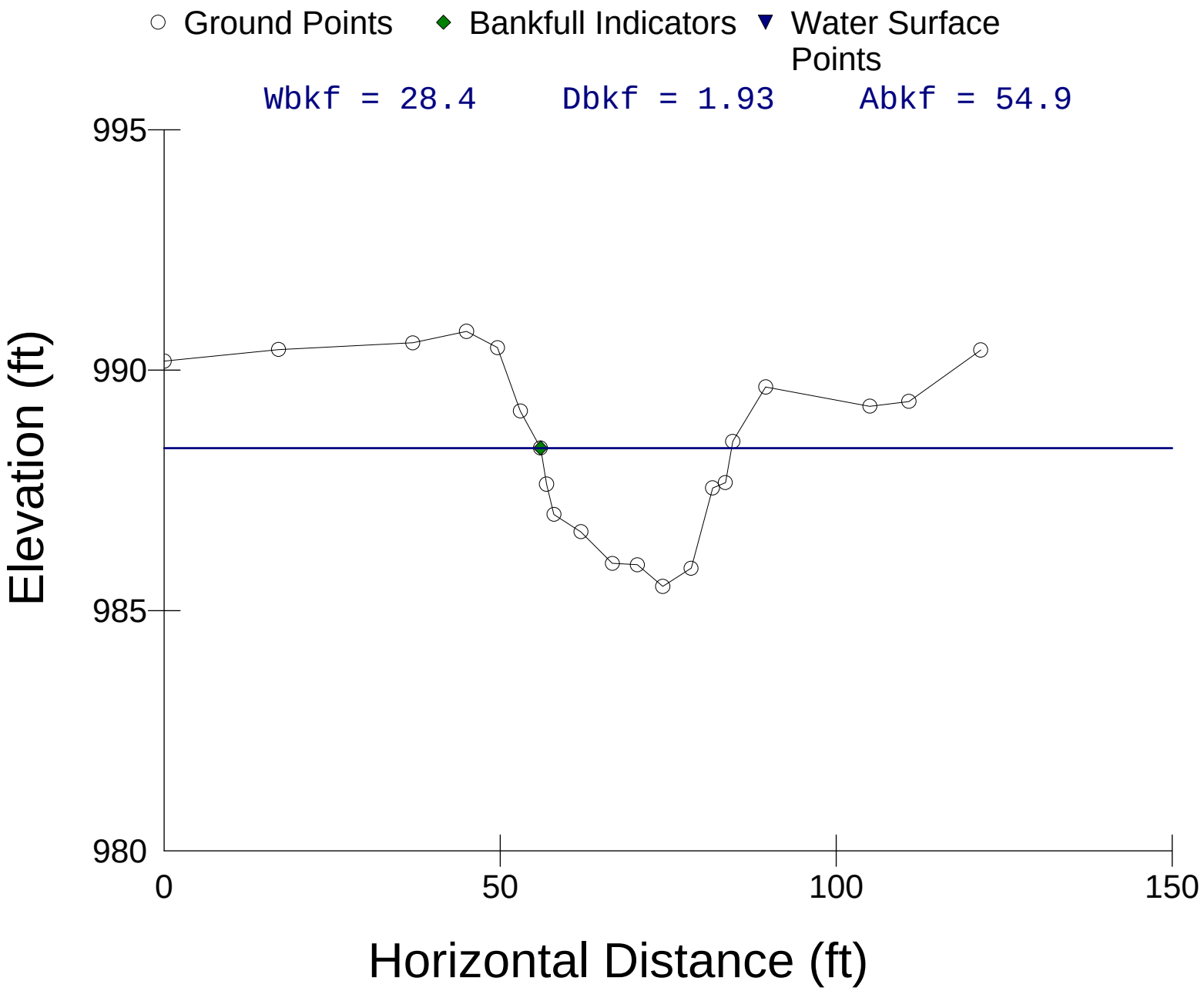
Reach 12 0+25 Riffle



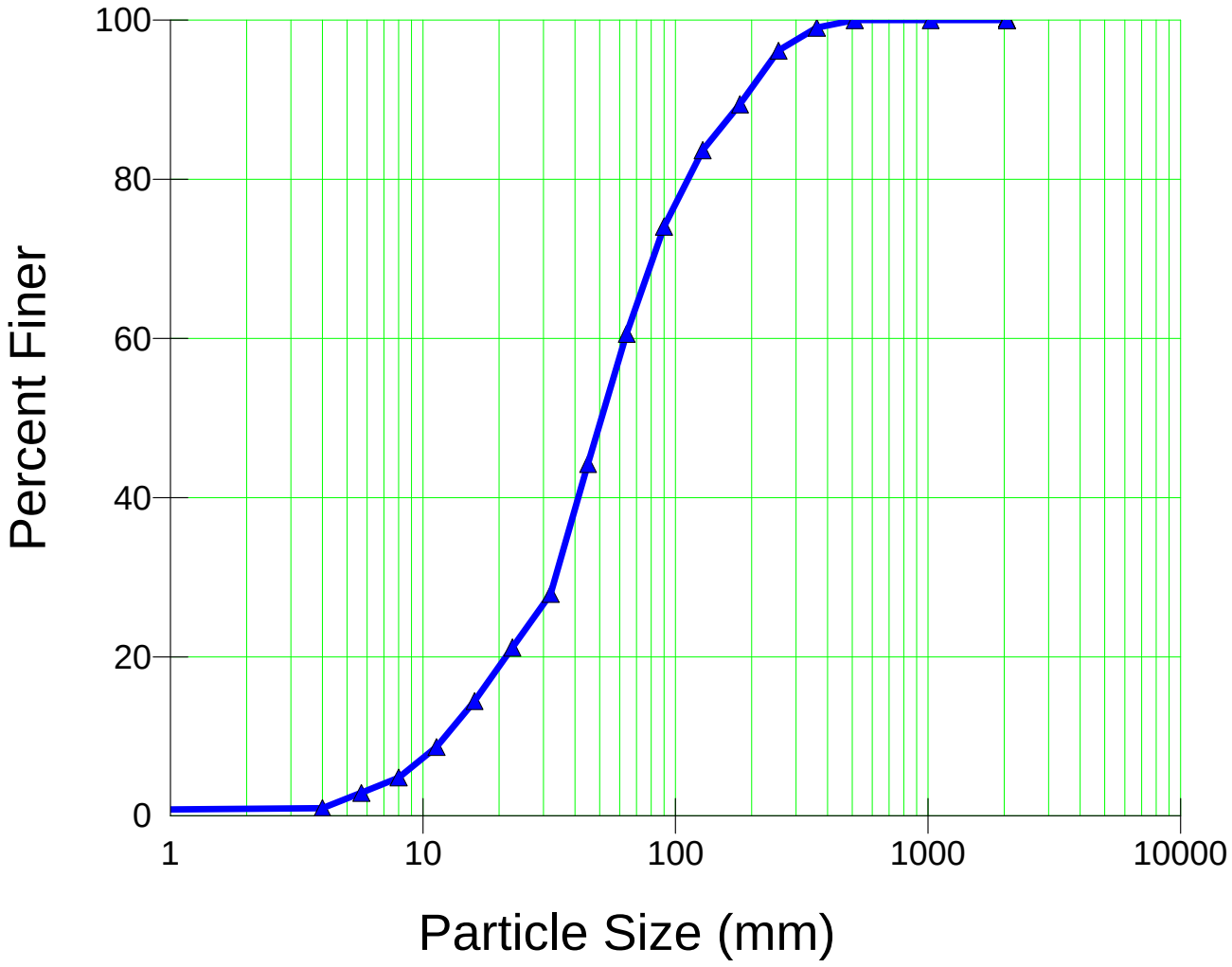
Reach 12 3+50 Pool



Reach 12 5+28 Riffle



Reach 12


Percent Finer
100
80
60
40
20
0
1
10
100
1000
10000
Particle Size (mm)

Knife River Assessment Fall 2015

APPENDIX C

LEVEL III WORKSHEETS

Worksheet 3-4. Meander pattern relations used for interpretations for river stability.

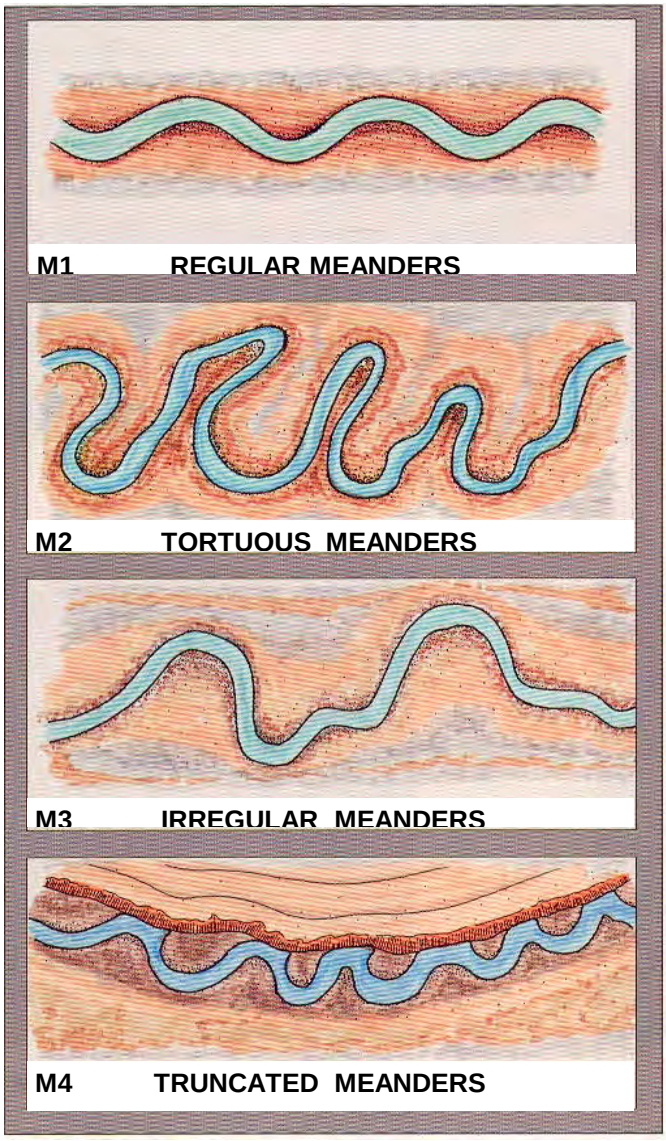
Meander Patterns

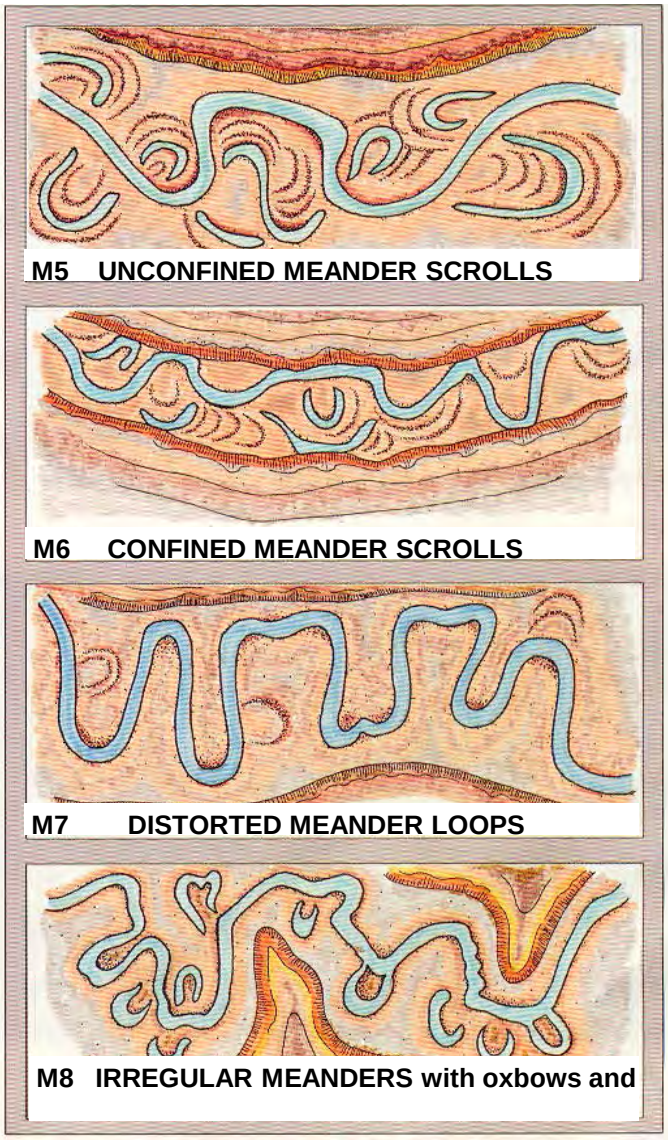
Stream: **Knife River** Reach: **Reach 1**

Observers: **M.Pranckus, B. Wizner, S. Alvar** Date: **12/8/2015**

List ALL CATEGORIES that APPLY ☞	M1	M3			

Various Meander Pattern variables modified from Galay et al. (1973)





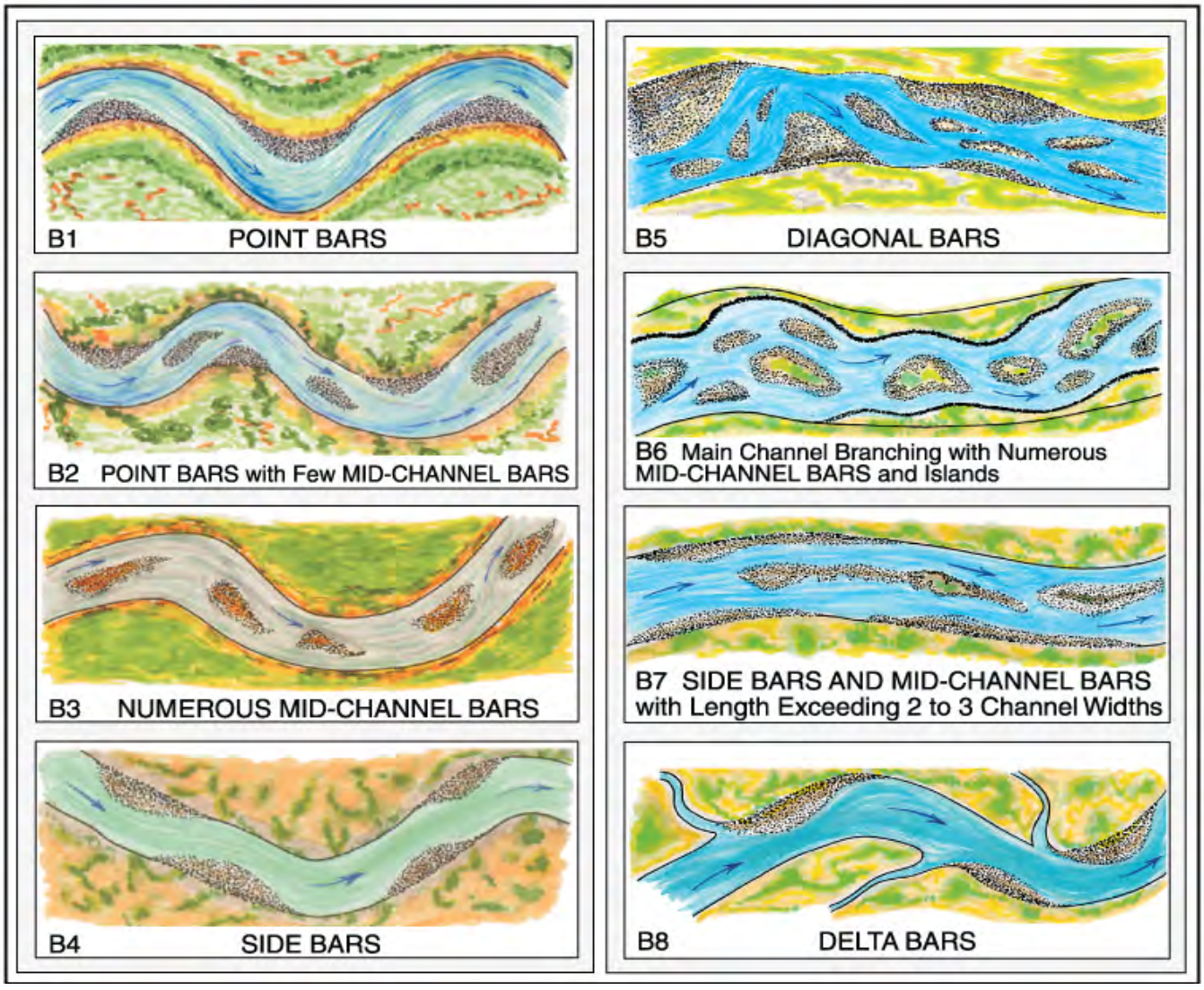
Worksheet 3-5. Depositional patterns used for stabiilty assessment interpretations.

Depositional Patterns

Stream:	**Knife River**	Reach:	**Reach 1**
Observers:	**M.Pranckus, B. Wizner, S. Alvar**	Date:	**12/8/2015**

List ALL CATEGORIES that APPLY ☞	B1	B4			

Various Depositional Features modified from Galay et al. (1973)



Worksheet 3-6. Various categories of in-channel debris, dams and channel blockages used to evaluate channel stability.

Channel Blockages			
Stream: **Knife River**		Location: **Reach 1**	
Observers: **M.Pranckus, B. Wizner, S. Alvar**		Date: **12/8/2015**	
Description/extent		**Materials that upon placement into the active channel or flood-prone area may cause adjustments in channel dimensions or conditions due to influences on the existing flow regime.**	**Check (✓) all that apply**
D1	None	Minor amounts of small, floatable material.	☐
D2	Infrequent	Debris consists of small, easily moved, floatable material, e.g., leaves, needles, small limbs and twigs.	☑
D3	Moderate	Increasing frequency of small- to medium-sized material, such as large limbs, branches and small logs, that when accumulated, affect 10% or less of the active channel cross-section area.	☑
D4	Numerous	Significant build-up of medium- to large-sized materials, e.g., large limbs, branches, small logs or portions of trees that may occupy 10–30% of the active channel cross-section area.	☐
D5	Extensive	Debris "dams" of predominantly larger materials, e.g., branches, logs and trees, occupying 30–50% of the active channel cross-section area, often extending across the width of the active channel.	☐
D6	Dominating	Large, somewhat continuous debris "dams," extensive in nature and occupying over 50% of the active channel cross-section area. Such accumulations may divert water into the flood-prone areas and form fish migration barriers, even when flows are at less than bankfull.	☐
D7	Beaver dams: Few	An infrequent number of dams spaced such that normal streamflow and expected channel conditions exist in the reaches between dams.	☐
D8	Beaver dams: Frequent	Frequency of dams is such that backwater conditions exist for channel reaches between structures where streamflow velocities are reduced and channel dimensions or conditions are influenced.	☐
D9	Beaver dams: Abandoned	Numerous abandoned dams, many of which have filled with sediment and/or breached, initiating a series of channel adjustments, such as bank erosion, lateral migration, avulsion, aggradation and degradation.	☐
D10	Human influences	Structures, facilities or materials related to land uses or development located within the flood-prone area, such as diversions or low-head dams, controlled by-pass channels, velocity control structures and various transportation encroachments that have an influence on the existing flow regime, such that significant channel adjustments occur.	☐

Worksheet 3-10. Pfankuch (1975) channel stability rating procedure, as modified by Rosgen (1996, 2001c, 2006b).

Stream: Knife River **Location:** Reach 1 **Valley Type:** **Observers:** M.Pranckus, B. Wizner **Date:** 12/8/2015

Location	Key	Category	Excellent		Good		Fair		Poor	
			Description	Rating	Description	Rating	Description	Rating	Description	Rating
Upper banks	1	Landform slope	Bank slope gradient <30%.	2	Bank slope gradient 30–40%.	4	Bank slope gradient 40–60%.	6	Bank slope gradient > 60%.	8
	2	Mass erosion	No evidence of past or future mass erosion.	3	Infrequent. Mostly healed over. Low future potential.	6	Frequent or large, causing sediment nearly yearlong.	9	Frequent or large, causing sediment nearly yearlong OR imminent danger of same.	12
	3	Debris jam potential	Essentially absent from immediate channel area.	2	Present, but mostly small twigs and limbs.	4	Moderate to heavy amounts, mostly larger sizes.	6	Moderate to heavy amounts, predominantly larger sizes.	8
	4	Vegetative bank protection	> 90% plant density. Vigor and variety suggest a deep, dense soil-binding root mass.	3	70–90% density. Fewer species or less vigor suggest less dense or deep root mass.	6	50–70% density. Lower vigor and fewer species from a shallow, discontinuous root mass.	9	<50% density plus fewer species and less vigor indicating poor, discontinuous and shallow root mass.	12
Lower banks	5	Channel capacity	Bank heights sufficient to contain the bankfull stage. Width/depth ratio departure from reference width/depth ratio = 1.0. Bank-Height Ratio (BHR) = 1.0.	1	Bankfull stage is contained within banks. Width/depth ratio departure from reference width/depth ratio = 1.0–1.2. Bank-Height Ratio (BHR) = 1.0–1.1.	2	Bankfull stage is not contained. Width/depth ratio departure from reference width/depth ratio = 1.2–1.4. Bank-Height Ratio (BHR) = 1.1–1.3.	3	Bankfull stage is not contained; over-bank flows are common with flows less than bankfull. Width/depth ratio departure from reference width/depth ratio > 1.4. Bank-Height Ratio (BHR) > 1.3.	4
	6	Bank rock content	> 65% with large angular boulders. 12"+ common.	2	40–65%. Mostly boulders and small cobbles 6–12".	4	20–40%. Most in the 3–6" diameter class.	6	<20% rock fragments of gravel sizes, 1–3" or less.	8
	7	Obstructions to flow	Rocks and logs firmly imbedded. Flow pattern w/o cutting or deposition. Stable bed.	2	Some present causing erosive cross currents and minor pool filling. Obstructions fewer and less firm.	4	Moderately frequent, unstable obstructions move with high flows causing bank cutting and pool filling.	6	Frequent obstructions and deflectors cause bank erosion yearlong. Sediment traps full, channel migration occurring.	8
	8	Cutting	Little or none. Infrequent raw banks <6".	4	Some, intermittently at outcurves and constrictions. Raw banks may be up to 12".	6	Significant. Cuts 12–24" high. Root mat overhangs and sloughing evident.	12	Almost continuous cuts, some over 24" high. Failure of overhangs frequent.	16
	9	Deposition	Little or no enlargement of channel or point bars.	4	Some new bar increase, mostly from coarse gravel.	8	Moderate depostion of new gravel and coarse sand on old and some new bars.	12	Extensive deposit of predominantly fine particles. Accelerated bar development.	16
Bottom	10	Rock angularity	Sharp edges and corners. Plane surfaces rough.	1	Rounded corners and edges. Surfaces smooth and flat.	2	Corners and edges well rounded in 2 dimensions.	3	Well rounded in all dimensions, surfaces smooth.	4
	11	Brightness	Surfaces dull, dark or stained. Generally not bright.	1	Mostly dull, but may have <35% bright surfaces.	2	Mixture dull and bright, i.e., 35–65% mixture range.	3	Predominantly bright, > 65%, exposed or scoured surfaces.	4
	12	Consolidation of particles	Assorted sizes tightly packed or overlapping.	2	Moderately packed with some overlapping.	4	Mostly loose assortment with no apparent overlap.	6	No packing evident. Loose assortment, easily moved.	8
	13	Bottom size distribution	No size change evident. Stable material 80–100%.	4	Distribution shift light. Stable material 50–80%.	8	Moderate change in sizes. Stable materials 20–50%.	12	Marked distribution change. Stable materials 0–20%.	16
	14	Scouring and deposition	<5% of bottom affected by scour or deposition.	6	5–30% affected. Scour at constrictions and where grades steepen. Some deposition in pools.	12	30–50% affected. Deposits and scour at obstructions, constrictions and bends. Some filling of pools.	18	More than 50% of the bottom in a state of flux or change nearly yearlong.	24
	15	Aquatic vegetation	Abundant growth moss-like, dark green perennial. In swift water too.	1	Common. Algae forms in low velocity and pool areas. Moss here too.	2	Present but spotty, mostly in backwater. Seasonal algae growth makes rocks slick.	3	Perennial types scarce or absent. Yellow-green, short-term bloom may be present.	4
			Excellent total =	**24**	**Good total =**	**25.5**	**Fair total =**	**0**	**Poor total =**	**0**

Stream type	A1	A2	A3	A4	A5	A6	B1	B2	B3	B4	B5	B6	C1	C2	C3	C4	C5	C6	D3	D4	D5	D6
Good (Stable)	38-43	38-43	54-90	60-95	60-95	50-80	38-45	38-45	40-60	40-64	48-68	40-60	38-50	38-50	60-85	70-90	70-90	60-85	85-107	85-107	85-107	67-98
Fair (Mod. unstable	44-47	44-47	91-129	96-132	96-142	81-110	46-58	46-58	61-78	65-84	69-88	61-78	51-61	51-61	86-105	91-110	91-110	86-105	108-132	108-132	108-132	99-125
Poor (Unstable)	48+	48+	130+	133+	143+	111+	59+	59+	79+	85+	89+	79+	62+	62+	106+	111+	111+	106+	133+	133+	133+	126+

Stream type	DA3	DA4	DA5	DA6	E3	E4	E5	E6	F1	F2	F3	F4	F5	F6	G1	G2	G3	G4	G5	G6
Good (Stable)	40-63	40-63	40-63	40-63	40-63	50-75	50-75	40-63	60-85	60-85	85-110	85-110	90-115	80-95	40-60	40-60	85-107	85-107	90-112	85-107
Fair (Mod. unstable	64-86	64-86	64-86	64-86	64-86	76-96	76-96	64-86	86-105	86-105	111-125	111-125	116-130	96-110	61-78	61-78	108-120	108-120	113-125	108-120
Poor (Unstable)	87+	87+	87+	87+	87+	97+	97+	87+	106+	106+	126+	126+	131+	111+	79+	79+	121+	121+	126+	121+

*Rating is adjusted to potential stream type, not existing.

Grand total =	**49.5**
Existing stream type =	**E**
***Potential stream type =**	
Modified channel stability rating =	**Good**

Worksheet 3-4. Meander pattern relations used for interpretations for river stability.

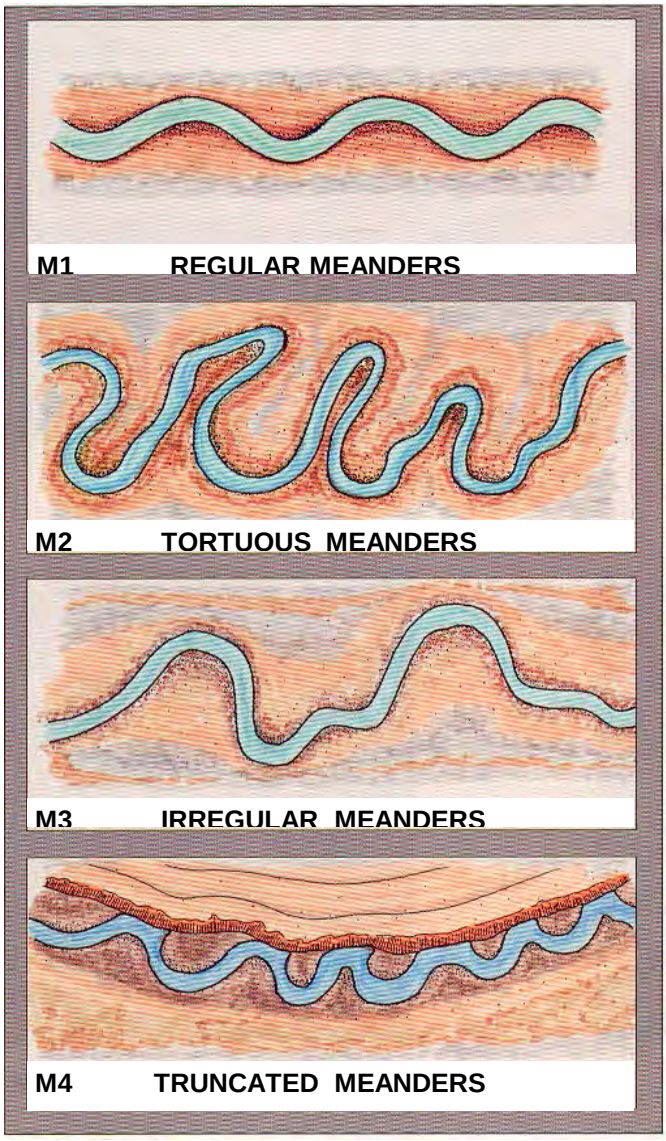
Meander Patterns

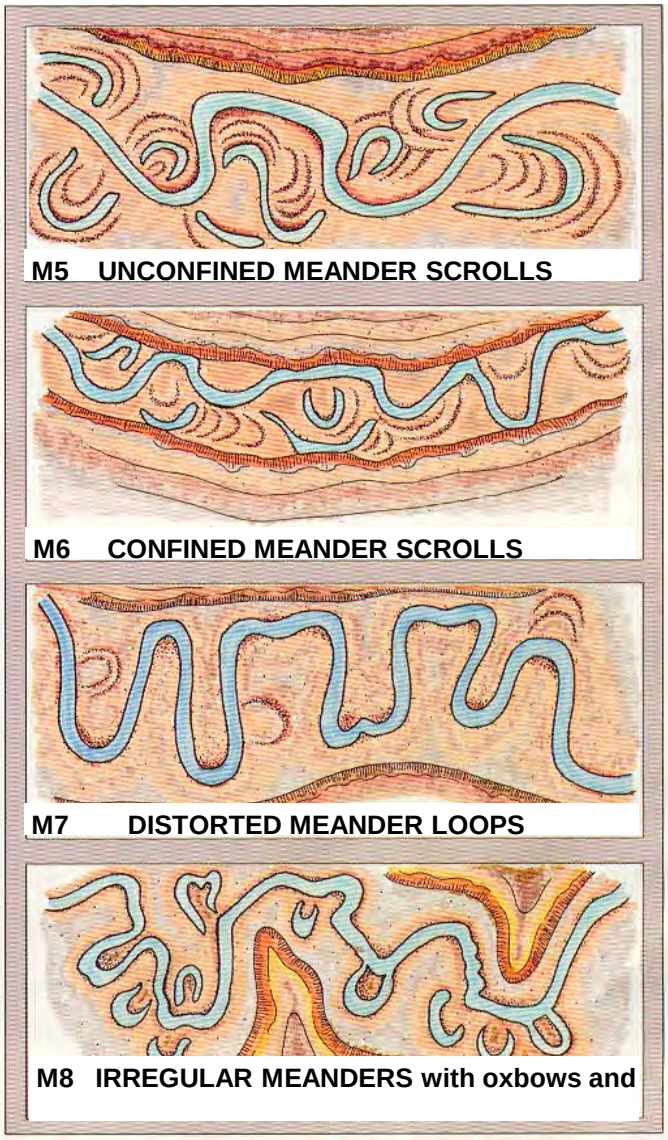
Stream: **Knife River** Reach: **Reach 2**

Observers: **M.Pranckus, B. Wizner, S. Alvar** Date: **12/10/2015**

List ALL CATEGORIES that APPLY ☞	M3	M1			

Various Meander Pattern variables modified from Galay et al. (1973)





Worksheet 3-5. Depositional patterns used for stabiilty assessment interpretations.

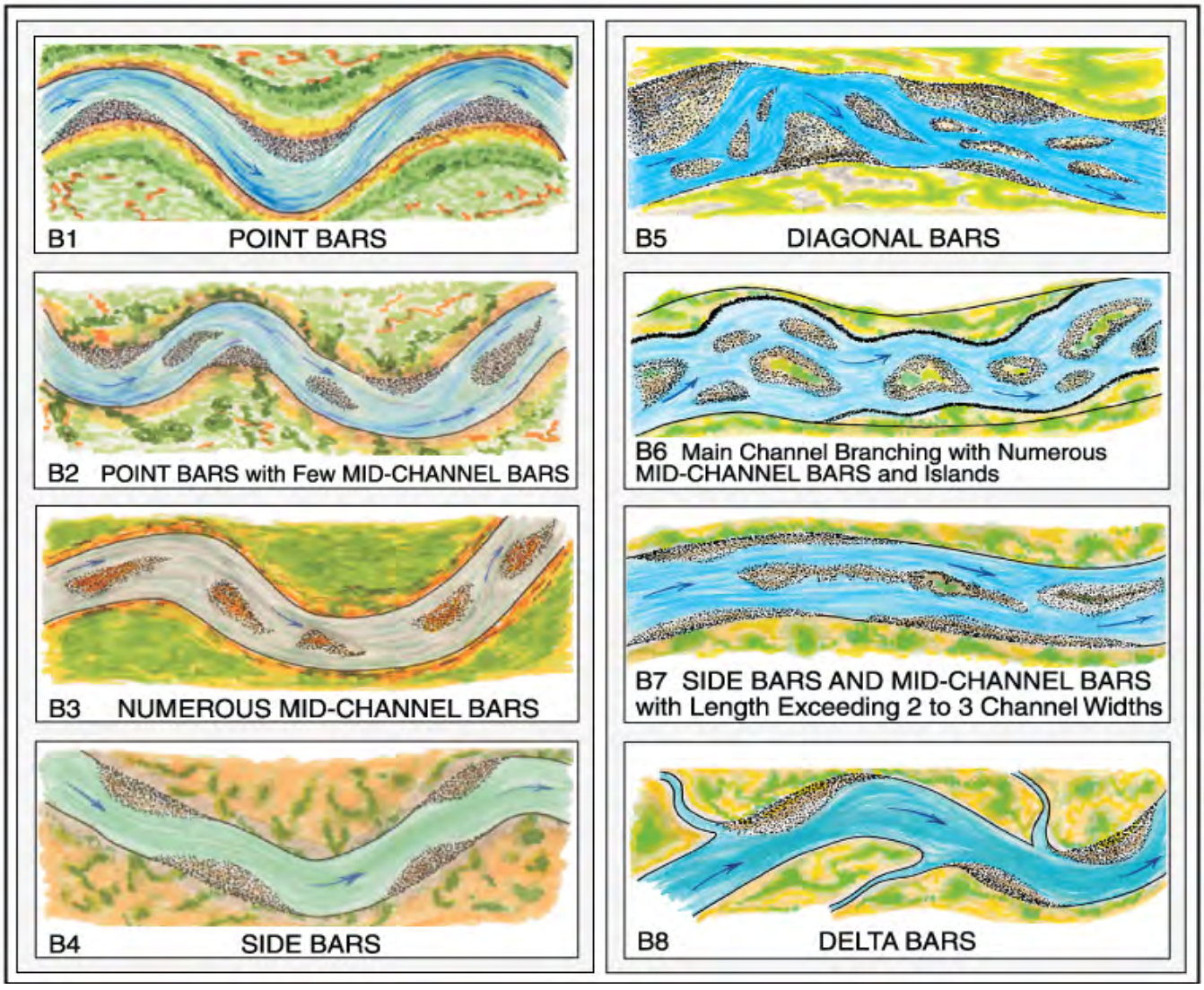
Depositional Patterns

Stream: **Knife River** Reach: **Reach 2**

Observers: **M.Pranckus, B.Wizner, S. Alver** Date: **12/10/2015**

List ALL CATEGORIES that APPLY ☞	B1	B8			

Various Depositional Features modified from Galay et al. (1973)



Worksheet 3-6. Various categories of in-channel debris, dams and channel blockages used to evaluate channel stability.

Channel Blockages			
Stream: **Knife River**		Location: **Reach 2**	
Observers: **M.Pranckus, B.Wizner, S.Alvar**		Date: **12/10/2015**	
Description/extent		**Materials that upon placement into the active channel or flood-prone area may cause adjustments in channel dimensions or conditions due to influences on the existing flow regime.**	**Check (✓) all that apply**
D1	None	Minor amounts of small, floatable material.	☐
D2	Infrequent	Debris consists of small, easily moved, floatable material, e.g., leaves, needles, small limbs and twigs.	☑
D3	Moderate	Increasing frequency of small- to medium-sized material, such as large limbs, branches and small logs, that when accumulated, affect 10% or less of the active channel cross-section area.	☑
D4	Numerous	Significant build-up of medium- to large-sized materials, e.g., large limbs, branches, small logs or portions of trees that may occupy 10–30% of the active channel cross-section area.	☑
D5	Extensive	Debris "dams" of predominantly larger materials, e.g., branches, logs and trees, occupying 30–50% of the active channel cross-section area, often extending across the width of the active channel.	☐
D6	Dominating	Large, somewhat continuous debris "dams," extensive in nature and occupying over 50% of the active channel cross-section area. Such accumulations may divert water into the flood-prone areas and form fish migration barriers, even when flows are at less than bankfull.	☐
D7	Beaver dams: Few	An infrequent number of dams spaced such that normal streamflow and expected channel conditions exist in the reaches between dams.	☐
D8	Beaver dams: Frequent	Frequency of dams is such that backwater conditions exist for channel reaches between structures where streamflow velocities are reduced and channel dimensions or conditions are influenced.	☐
D9	Beaver dams: Abandoned	Numerous abandoned dams, many of which have filled with sediment and/or breached, initiating a series of channel adjustments, such as bank erosion, lateral migration, avulsion, aggradation and degradation.	☐
D10	Human influences	Structures, facilities or materials related to land uses or development located within the flood-prone area, such as diversions or low-head dams, controlled by-pass channels, velocity control structures and various transportation encroachments that have an influence on the existing flow regime, such that significant channel adjustments occur.	☐

Worksheet 3-10. Pfankuch (1975) channel stability rating procedure, as modified by Rosgen (1996, 2001c, 2006b).

Stream: Knife River **Location:** Reach 2 **Valley Type:** **Observers:** M.Pranckus, B.Wizner **Date:** 12/10/2015

Location	Key	Category	Excellent		Good		Fair		Poor	
			Description	Rating	Description	Rating	Description	Rating	Description	Rating
Upper banks	1	Landform slope	Bank slope gradient <30%.	2	Bank slope gradient 30–40%.	4	Bank slope gradient 40–60%.	6	Bank slope gradient > 60%.	8
	2	Mass erosion	No evidence of past or future mass erosion.	3	Infrequent. Mostly healed over. Low future potential.	6	Frequent or large, causing sediment nearly yearlong.	9	Frequent or large, causing sediment nearly yearlong OR imminent danger of same.	12
	3	Debris jam potential	Essentially absent from immediate channel area.	2	Present, but mostly small twigs and limbs.	4	Moderate to heavy amounts, mostly larger sizes.	6	Moderate to heavy amounts, predominantly larger sizes.	8
	4	Vegetative bank protection	> 90% plant density. Vigor and variety suggest a deep, dense soil-binding root mass.	3	70–90% density. Fewer species or less vigor suggest less dense or deep root mass.	6	50–70% density. Lower vigor and fewer species from a shallow, discontinuous root mass.	9	<50% density plus fewer species and less vigor indicating poor, discontinuous and shallow root mass.	12
Lower banks	5	Channel capacity	Bank heights sufficient to contain the bankfull stage. Width/depth ratio departure from reference width/depth ratio = 1.0. Bank-Height Ratio (BHR) = 1.0.	1	Bankfull stage is contained within banks. Width/depth ratio departure from reference width/depth ratio = 1.0–1.2. Bank-Height Ratio (BHR) = 1.0–1.1.	2	Bankfull stage is not contained. Width/depth ratio departure from reference width/depth ratio = 1.2–1.4. Bank-Height Ratio (BHR) = 1.1–1.3.	3	Bankfull stage is not contained; over-bank flows are common with flows less than bankfull. Width/depth ratio departure from reference width/depth ratio > 1.4. Bank-Height Ratio (BHR) > 1.3.	4
	6	Bank rock content	> 65% with large angular boulders. 12"+ common.	2	40–65%. Mostly boulders and small cobbles 6–12".	4	20–40%. Most in the 3–6" diameter class.	6	<20% rock fragments of gravel sizes, 1–3" or less.	8
	7	Obstructions to flow	Rocks and logs firmly imbedded. Flow pattern w/o cutting or deposition. Stable bed.	2	Some present causing erosive cross currents and minor pool filling. Obstructions fewer and less firm.	4	Moderately frequent, unstable obstructions move with high flows causing bank cutting and pool filling.	6	Frequent obstructions and deflectors cause bank erosion yearlong. Sediment traps full, channel migration occurring.	8
	8	Cutting	Little or none. Infrequent raw banks <6".	4	Some, intermittently at outcurves and constrictions. Raw banks may be up to 12".	6	Significant. Cuts 12–24" high. Root mat overhangs and sloughing evident.	12	Almost continuous cuts, some over 24" high. Failure of overhangs frequent.	16
	9	Deposition	Little or no enlargement of channel or point bars.	4	Some new bar increase, mostly from coarse gravel.	8	Moderate depostion of new gravel and coarse sand on old and some new bars.	12	Extensive deposit of predominantly fine particles. Accelerated bar development.	16
Bottom	10	Rock angularity	Sharp edges and corners. Plane surfaces rough.	1	Rounded corners and edges. Surfaces smooth and flat.	2	Corners and edges well rounded in 2 dimensions.	3	Well rounded in all dimensions, surfaces smooth.	4
	11	Brightness	Surfaces dull, dark or stained. Generally not bright.	1	Mostly dull, but may have <35% bright surfaces.	2	Mixture dull and bright, i.e., 35–65% mixture range.	3	Predominantly bright, > 65%, exposed or scoured surfaces.	4
	12	Consolidation of particles	Assorted sizes tightly packed or overlapping.	2	Moderately packed with some overlapping.	4	Mostly loose assortment with no apparent overlap.	6	No packing evident. Loose assortment, easily moved.	8
	13	Bottom size distribution	No size change evident. Stable material 80–100%.	4	Distribution shift light. Stable material 50–80%.	8	Moderate change in sizes. Stable materials 20–50%.	12	Marked distribution change. Stable materials 0–20%.	16
	14	Scouring and deposition	<5% of bottom affected by scour or deposition.	6	5–30% affected. Scour at constrictions and where grades steepen. Some deposition in pools.	12	30–50% affected. Deposits and scour at obstructions, constrictions and bends. Some filling of pools.	18	More than 50% of the bottom in a state of flux or change nearly yearlong.	24
	15	Aquatic vegetation	Abundant growth moss-like, dark green perennial. In swift water too.	1	Common. Algae forms in low velocity and pool areas. Moss here too.	2	Present but spotty, mostly in backwater. Seasonal algae growth makes rocks slick.	3	Perennial types scarce or absent. Yellow-green, short-term bloom may be present.	4
			Excellent total =	**18**	**Good total =**	**25**	**Fair total =**	**15**	**Poor total =**	**0**

Stream type	A1	A2	A3	A4	A5	A6	B1	B2	B3	B4	B5	B6	C1	C2	C3	C4	C5	C6	D3	D4	D5	D6
Good (Stable)	38-43	38-43	54-90	60-95	60-95	50-80	38-45	38-45	40-60	40-64	48-68	40-60	38-50	38-50	60-85	70-90	70-90	60-85	85-107	85-107	85-107	67-98
Fair (Mod. unstable	44-47	44-47	91-129	96-132	96-142	81-110	46-58	46-58	61-78	65-84	69-88	61-78	51-61	51-61	86-105	91-110	91-110	86-105	108-132	108-132	108-132	99-125
Poor (Unstable)	48+	48+	130+	133+	143+	111+	59+	59+	79+	85+	89+	79+	62+	62+	106+	111+	111+	106+	133+	133+	133+	126+

Stream type	DA3	DA4	DA5	DA6	E3	E4	E5	E6	F1	F2	F3	F4	F5	F6	G1	G2	G3	G4	G5	G6
Good (Stable)	40-63	40-63	40-63	40-63	40-63	50-75	50-75	40-63	60-85	60-85	85-110	85-110	90-115	80-95	40-60	40-60	85-107	85-107	90-112	85-107
Fair (Mod. unstable	64-86	64-86	64-86	64-86	64-86	76-96	76-96	64-86	86-105	86-105	111-125	111-125	116-130	96-110	61-78	61-78	108-120	108-120	113-125	108-120
Poor (Unstable)	87+	87+	87+	87+	87+	97+	97+	87+	106+	106+	126+	126+	131+	111+	79+	79+	121+	121+	126+	121+

*Rating is adjusted to potential stream type, not existing.

Grand total =	**58**
Existing stream type =	**C**
***Potential stream type =**	
Modified channel stability rating =	**Good**

Worksheet 3-4. Meander pattern relations used for interpretations for river stability.

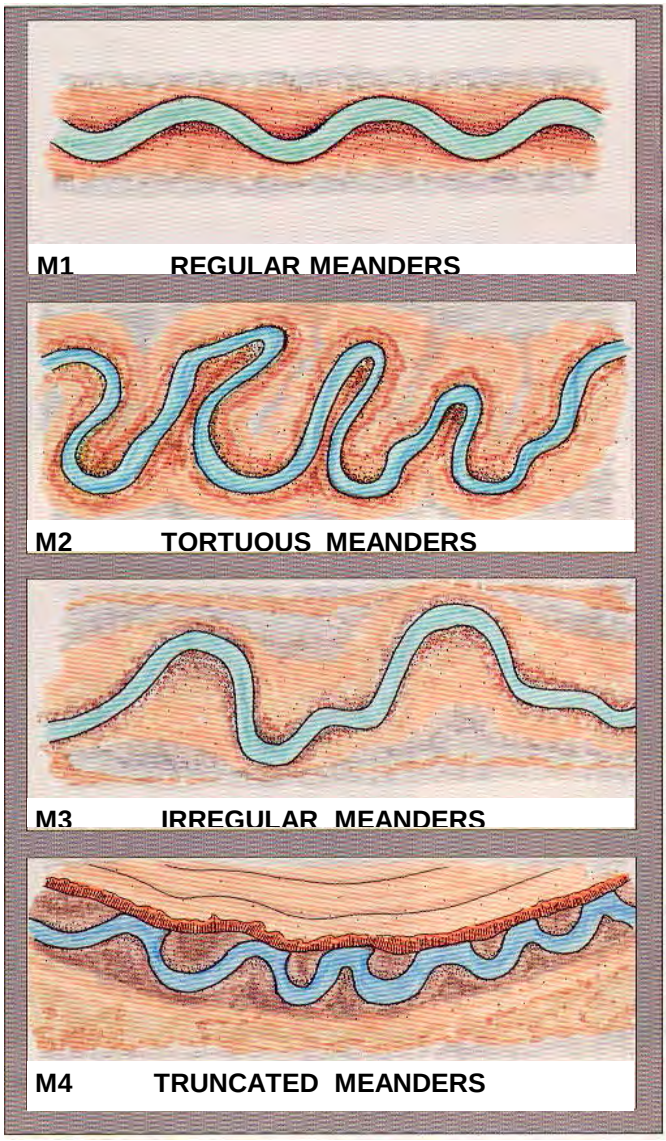
Meander Patterns

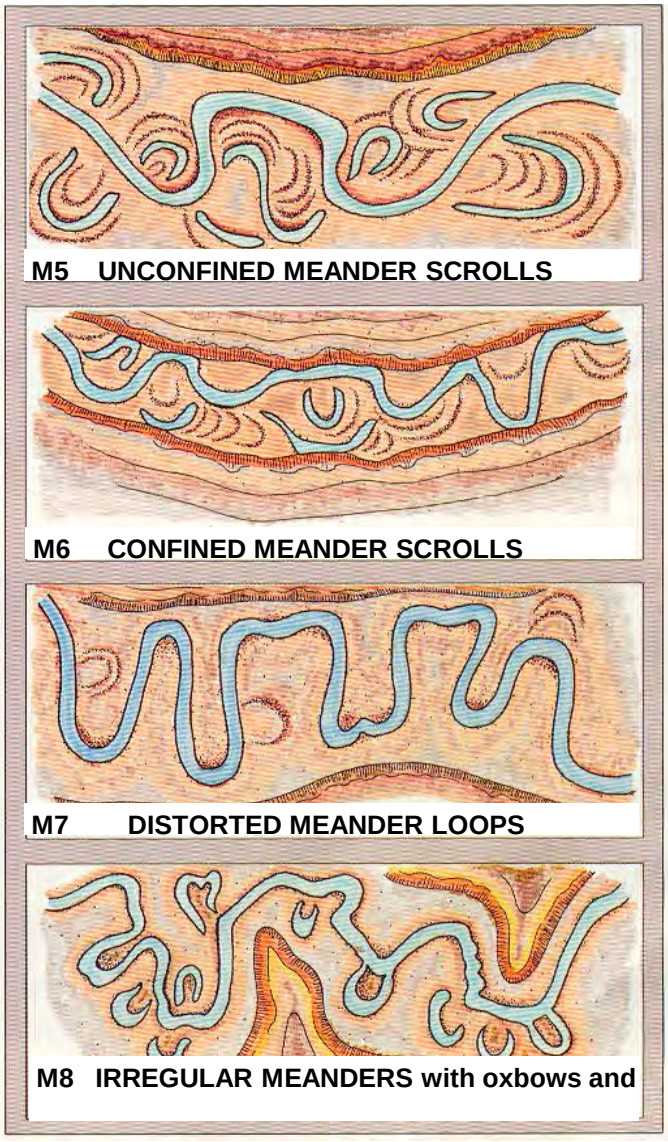
Stream: **Knife River** Reach: **Reach 4**

Observers: **M.Pranckus, B. Wizner, S.Alvar** Date: **12/7/2015**

List ALL CATEGORIES that APPLY ☞	M1	M2	M3		

Various Meander Pattern variables modified from Galay et al. (1973)





Worksheet 3-5. Depositional patterns used for stabiilty assessment interpretations.

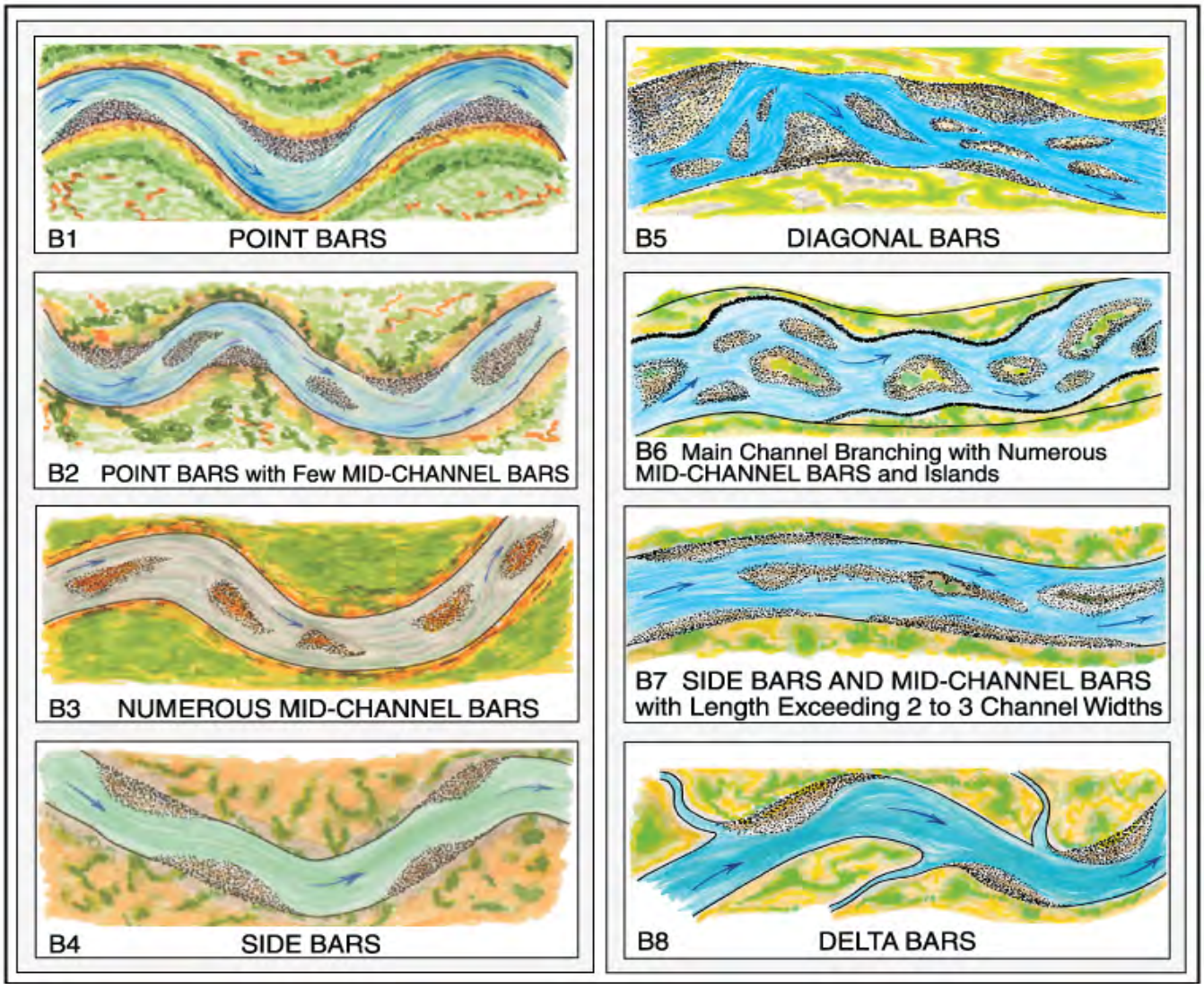
Depositional Patterns

Stream: **Knife River** Reach: **Reach 2**

Observers: **M.Pranckus, B.Wizner, S.Alvar** Date: **12/7/2015**

List ALL CATEGORIES that APPLY ☞	B1	B2	B5		

Various Depositional Features modified from Galay et al. (1973)



Worksheet 3-6. Various categories of in-channel debris, dams and channel blockages used to evaluate channel stability.

Channel Blockages			
Stream: **Knife River**		Location: **Reach 4**	
Observers: **M.Pranckus, B.Wizner, S.Alvar**		Date: **12/7/2015**	
Description/extent		**Materials that upon placement into the active channel or flood-prone area may cause adjustments in channel dimensions or conditions due to influences on the existing flow regime.**	**Check (✓) all that apply**
D1	None	Minor amounts of small, floatable material.	☐
D2	Infrequent	Debris consists of small, easily moved, floatable material, e.g., leaves, needles, small limbs and twigs.	☑
D3	Moderate	Increasing frequency of small- to medium-sized material, such as large limbs, branches and small logs, that when accumulated, affect 10% or less of the active channel cross-section area.	☑
D4	Numerous	Significant build-up of medium- to large-sized materials, e.g., large limbs, branches, small logs or portions of trees that may occupy 10–30% of the active channel cross-section area.	☑
D5	Extensive	Debris "dams" of predominantly larger materials, e.g., branches, logs and trees, occupying 30–50% of the active channel cross-section area, often extending across the width of the active channel.	☐
D6	Dominating	Large, somewhat continuous debris "dams," extensive in nature and occupying over 50% of the active channel cross-section area. Such accumulations may divert water into the flood-prone areas and form fish migration barriers, even when flows are at less than bankfull.	☐
D7	Beaver dams: Few	An infrequent number of dams spaced such that normal streamflow and expected channel conditions exist in the reaches between dams.	☐
D8	Beaver dams: Frequent	Frequency of dams is such that backwater conditions exist for channel reaches between structures where streamflow velocities are reduced and channel dimensions or conditions are influenced.	☐
D9	Beaver dams: Abandoned	Numerous abandoned dams, many of which have filled with sediment and/or breached, initiating a series of channel adjustments, such as bank erosion, lateral migration, avulsion, aggradation and degradation.	☐
D10	Human influences	Structures, facilities or materials related to land uses or development located within the flood-prone area, such as diversions or low-head dams, controlled by-pass channels, velocity control structures and various transportation encroachments that have an influence on the existing flow regime, such that significant channel adjustments occur.	☐

Worksheet 3-10. Pfankuch (1975) channel stability rating procedure, as modified by Rosgen (1996, 2001c, 2006b).

Stream: Knife River **Location:** Reach 4 **Valley Type:** **Observers:** M.Pranckus, B.Wizner **Date:** 12/7/2015

Location	Key	Category	Excellent		Good		Fair		Poor	
			Description	Rating	Description	Rating	Description	Rating	Description	Rating
Upper banks	1	Landform slope	Bank slope gradient <30%.	2	Bank slope gradient 30–40%.	4	Bank slope gradient 40–60%.	6	Bank slope gradient > 60%.	8
	2	Mass erosion	No evidence of past or future mass erosion.	3	Infrequent. Mostly healed over. Low future potential.	6	Frequent or large, causing sediment nearly yearlong.	9	Frequent or large, causing sediment nearly yearlong OR imminent danger of same.	12
	3	Debris jam potential	Essentially absent from immediate channel area.	2	Present, but mostly small twigs and limbs.	4	Moderate to heavy amounts, mostly larger sizes.	6	Moderate to heavy amounts, predominantly larger sizes.	8
	4	Vegetative bank protection	> 90% plant density. Vigor and variety suggest a deep, dense soil-binding root mass.	3	70–90% density. Fewer species or less vigor suggest less dense or deep root mass.	6	50–70% density. Lower vigor and fewer species from a shallow, discontinuous root mass.	9	<50% density plus fewer species and less vigor indicating poor, discontinuous and shallow root mass.	12
Lower banks	5	Channel capacity	Bank heights sufficient to contain the bankfull stage. Width/depth ratio departure from reference width/depth ratio = 1.0. Bank-Height Ratio (BHR) = 1.0.	1	Bankfull stage is contained within banks. Width/depth ratio departure from reference width/depth ratio = 1.0–1.2. Bank-Height Ratio (BHR) = 1.0–1.1.	2	Bankfull stage is not contained. Width/depth ratio departure from reference width/depth ratio = 1.2–1.4. Bank-Height Ratio (BHR) = 1.1–1.3.	3	Bankfull stage is not contained; over-bank flows are common with flows less than bankfull. Width/depth ratio departure from reference width/depth ratio > 1.4. Bank-Height Ratio (BHR) > 1.3.	4
	6	Bank rock content	> 65% with large angular boulders. 12"+ common.	2	40–65%. Mostly boulders and small cobbles 6–12".	4	20–40%. Most in the 3–6" diameter class.	6	<20% rock fragments of gravel sizes, 1–3" or less.	8
	7	Obstructions to flow	Rocks and logs firmly imbedded. Flow pattern w/o cutting or deposition. Stable bed.	2	Some present causing erosive cross currents and minor pool filling. Obstructions fewer and less firm.	4	Moderately frequent, unstable obstructions move with high flows causing bank cutting and pool filling.	6	Frequent obstructions and deflectors cause bank erosion yearlong. Sediment traps full, channel migration occurring.	8
	8	Cutting	Little or none. Infrequent raw banks <6".	4	Some, intermittently at outcurves and constrictions. Raw banks may be up to 12".	6	Significant. Cuts 12–24" high. Root mat overhangs and sloughing evident.	12	Almost continuous cuts, some over 24" high. Failure of overhangs frequent.	16
	9	Deposition	Little or no enlargement of channel or point bars.	4	Some new bar increase, mostly from coarse gravel.	8	Moderate depostion of new gravel and coarse sand on old and some new bars.	12	Extensive deposit of predominantly fine particles. Accelerated bar development.	16
Bottom	10	Rock angularity	Sharp edges and corners. Plane surfaces rough.	1	Rounded corners and edges. Surfaces smooth and flat.	2	Corners and edges well rounded in 2 dimensions.	3	Well rounded in all dimensions, surfaces smooth.	4
	11	Brightness	Surfaces dull, dark or stained. Generally not bright.	1	Mostly dull, but may have <35% bright surfaces.	2	Mixture dull and bright, i.e., 35–65% mixture range.	3	Predominantly bright, > 65%, exposed or scoured surfaces.	4
	12	Consolidation of particles	Assorted sizes tightly packed or overlapping.	2	Moderately packed with some overlapping.	4	Mostly loose assortment with no apparent overlap.	6	No packing evident. Loose assortment, easily moved.	8
	13	Bottom size distribution	No size change evident. Stable material 80–100%.	4	Distribution shift light. Stable material 50–80%.	8	Moderate change in sizes. Stable materials 20–50%.	12	Marked distribution change. Stable materials 0–20%.	16
	14	Scouring and deposition	<5% of bottom affected by scour or deposition.	6	5–30% affected. Scour at constrictions and where grades steepen. Some deposition in pools.	12	30–50% affected. Deposits and scour at obstructions, constrictions and bends. Some filling of pools.	18	More than 50% of the bottom in a state of flux or change nearly yearlong.	24
	15	Aquatic vegetation	Abundant growth moss-like, dark green perennial. In swift water too.	1	Common. Algae forms in low velocity and pool areas. Moss here too.	2	Present but spotty, mostly in backwater. Seasonal algae growth makes rocks slick.	3	Perennial types scarce or absent. Yellow-green, short-term bloom may be present.	4
			Excellent total =		**Good total =**	**14**	**Fair total =**	**47**	**Poor total =**	**60**

Stream type	A1	A2	A3	A4	A5	A6	B1	B2	B3	B4	B5	B6	C1	C2	C3	C4	C5	C6	D3	D4	D5	D6
Good (Stable)	38-43	38-43	54-90	60-95	60-95	50-80	38-45	38-45	40-60	40-64	48-68	40-60	38-50	38-50	60-85	70-90	70-90	60-85	85-107	85-107	85-107	67-98
Fair (Mod. unstable	44-47	44-47	91-129	96-132	96-142	81-110	46-58	46-58	61-78	65-84	69-88	61-78	51-61	51-61	86-105	91-110	91-110	86-105	108-132	108-132	108-132	99-125
Poor (Unstable)	48+	48+	130+	133+	143+	111+	59+	59+	79+	85+	89+	79+	62+	62+	106+	111+	111+	106+	133+	133+	133+	126+

Stream type	DA3	DA4	DA5	DA6	E3	E4	E5	E6	F1	F2	F3	F4	F5	F6	G1	G2	G3	G4	G5	G6
Good (Stable)	40-63	40-63	40-63	40-63	40-63	50-75	50-75	40-63	60-85	60-85	85-110	85-110	90-115	80-95	40-60	40-60	85-107	85-107	90-112	85-107
Fair (Mod. unstable	64-86	64-86	64-86	64-86	64-86	76-96	76-96	64-86	86-105	86-105	111-125	111-125	116-130	96-110	61-78	61-78	108-120	108-120	113-125	108-120
Poor (Unstable)	87+	87+	87+	87+	87+	97+	97+	87+	106+	106+	126+	126+	131+	111+	79+	79+	121+	121+	126+	121+

*Rating is adjusted to potential stream type, not existing.

Grand total =	**121**
Existing stream type =	
***Potential stream type =**	**B/C**
Modified channel stability rating =	**Poor**

Worksheet 3-4. Meander pattern relations used for interpretations for river stability.

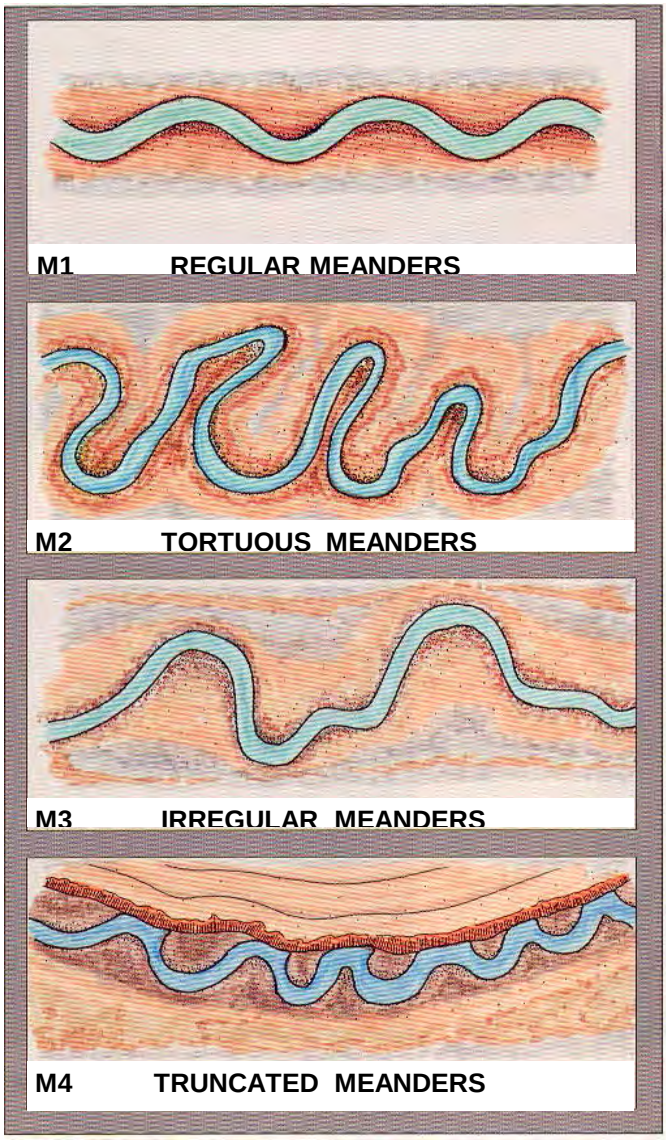
Meander Patterns

Stream: **Knife River** Reach: **Reach 5**

Observers: **A. Steber, M.Pranckus, B.Wizner** Date: **11/25/2015**

List ALL CATEGORIES that APPLY ☞	M1	M3			

Various Meander Pattern variables modified from Galay et al. (1973)

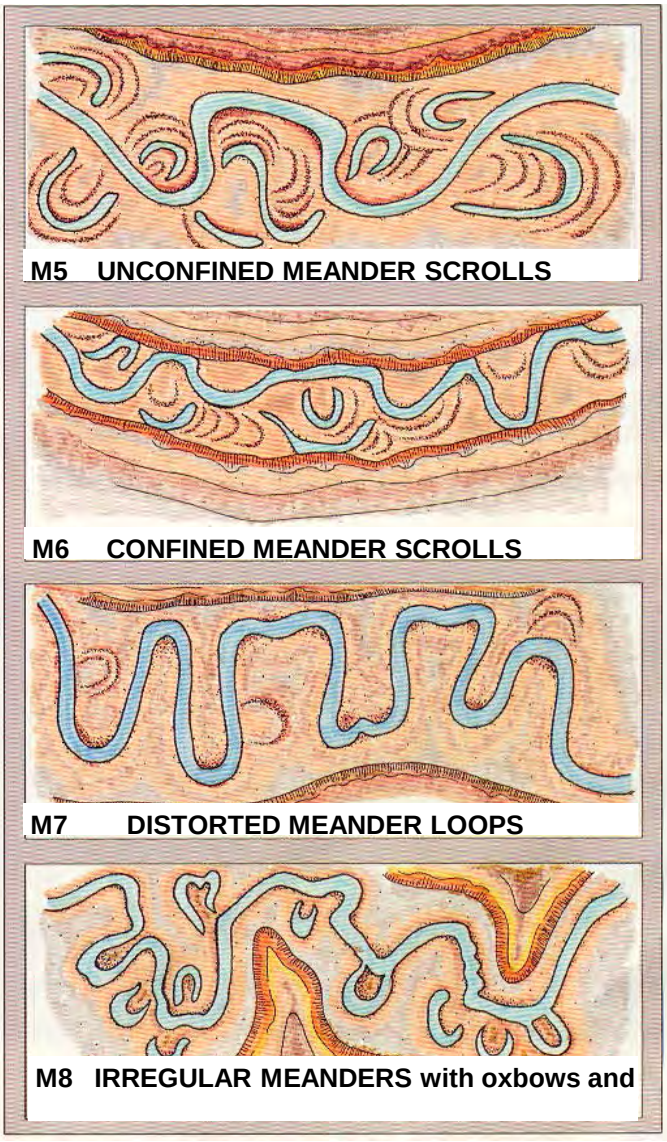


M1 REGULAR MEANDERS

M2 TORTUOUS MEANDERS

M3 IRREGULAR MEANDERS

M4 TRUNCATED MEANDERS



M5 UNCONFINED MEANDER SCROLLS

M6 CONFINED MEANDER SCROLLS

M7 DISTORTED MEANDER LOOPS

M8 IRREGULAR MEANDERS with oxbows and

Worksheet 3-5. Depositional patterns used for stabiilty assessment interpretations.

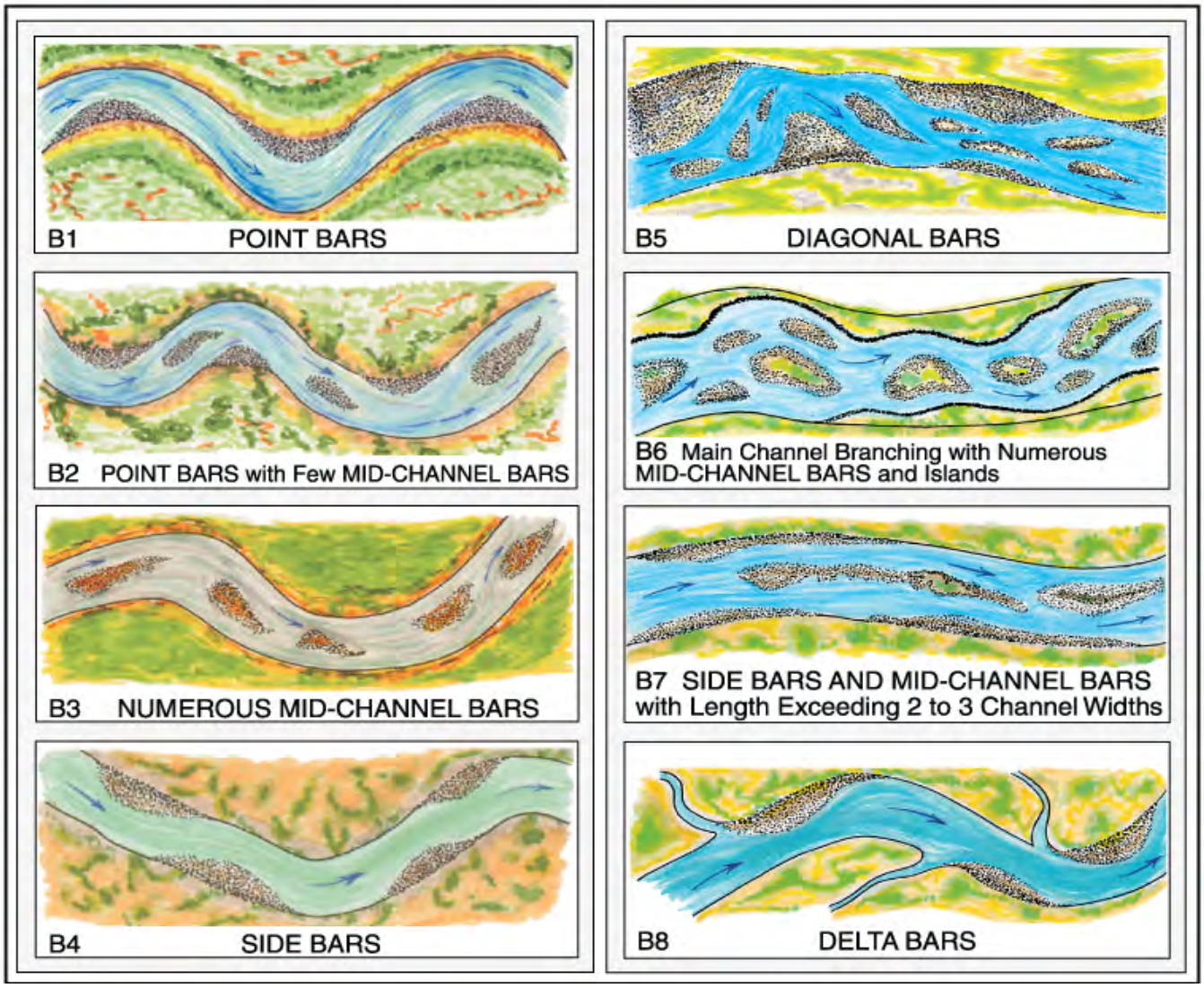
Depositional Patterns

Stream: **Knife River** Reach: **Reach 5**

Observers: **A. Steber, M.Pranckus, B.Wizner** Date: **11/25/2015**

List ALL CATEGORIES that APPLY ☞	B1				

Various Depositional Features modified from Galay et al. (1973)



Worksheet 3-6. Various categories of in-channel debris, dams and channel blockages used to evaluate channel stability.

Channel Blockages			
Stream: **Knife River**		Location: **Reach 5**	
Observers: **A. Steber, M.Pranckus, B.Wizner**		Date: **11/25/2015**	
Description/extent		**Materials that upon placement into the active channel or flood-prone area may cause adjustments in channel dimensions or conditions due to influences on the existing flow regime.**	**Check (✓) all that apply**
D1	None	Minor amounts of small, floatable material.	☑
D2	Infrequent	Debris consists of small, easily moved, floatable material, e.g., leaves, needles, small limbs and twigs.	☑
D3	Moderate	Increasing frequency of small- to medium-sized material, such as large limbs, branches and small logs, that when accumulated, affect 10% or less of the active channel cross-section area.	☐
D4	Numerous	Significant build-up of medium- to large-sized materials, e.g., large limbs, branches, small logs or portions of trees that may occupy 10–30% of the active channel cross-section area.	☐
D5	Extensive	Debris "dams" of predominantly larger materials, e.g., branches, logs and trees, occupying 30–50% of the active channel cross-section area, often extending across the width of the active channel.	☐
D6	Dominating	Large, somewhat continuous debris "dams," extensive in nature and occupying over 50% of the active channel cross-section area. Such accumulations may divert water into the flood-prone areas and form fish migration barriers, even when flows are at less than bankfull.	☐
D7	Beaver dams: Few	An infrequent number of dams spaced such that normal streamflow and expected channel conditions exist in the reaches between dams.	☐
D8	Beaver dams: Frequent	Frequency of dams is such that backwater conditions exist for channel reaches between structures where streamflow velocities are reduced and channel dimensions or conditions are influenced.	☐
D9	Beaver dams: Abandoned	Numerous abandoned dams, many of which have filled with sediment and/or breached, initiating a series of channel adjustments, such as bank erosion, lateral migration, avulsion, aggradation and degradation.	☐
D10	Human influences	Structures, facilities or materials related to land uses or development located within the flood-prone area, such as diversions or low-head dams, controlled by-pass channels, velocity control structures and various transportation encroachments that have an influence on the existing flow regime, such that significant channel adjustments occur.	☐

Worksheet 3-10. Pfankuch (1975) channel stability rating procedure, as modified by Rosgen (1996, 2001c, 2006b).

Stream: Knife River **Location:** Reach 5 **Valley Type:** **Observers:** A.Steber, M.Pranckus **Date:** 11/25/2015

Location	Key	Category	Excellent		Good		Fair		Poor	
			Description	Rating	Description	Rating	Description	Rating	Description	Rating
Upper banks	1	Landform slope	Bank slope gradient <30%.	2	Bank slope gradient 30–40%.	4	Bank slope gradient 40–60%.	6	Bank slope gradient > 60%.	8
	2	Mass erosion	No evidence of past or future mass erosion.	3	Infrequent. Mostly healed over. Low future potential.	6	Frequent or large, causing sediment nearly yearlong.	9	Frequent or large, causing sediment nearly yearlong OR imminent danger of same.	12
	3	Debris jam potential	Essentially absent from immediate channel area.	2	Present, but mostly small twigs and limbs.	4	Moderate to heavy amounts, mostly larger sizes.	6	Moderate to heavy amounts, predominantly larger sizes.	8
	4	Vegetative bank protection	> 90% plant density. Vigor and variety suggest a deep, dense soil-binding root mass.	3	70–90% density. Fewer species or less vigor suggest less dense or deep root mass.	6	50–70% density. Lower vigor and fewer species from a shallow, discontinuous root mass.	9	<50% density plus fewer species and less vigor indicating poor, discontinuous and shallow root mass.	12
Lower banks	5	Channel capacity	Bank heights sufficient to contain the bankfull stage. Width/depth ratio departure from reference width/depth ratio = 1.0. Bank-Height Ratio (BHR) = 1.0.	1	Bankfull stage is contained within banks. Width/depth ratio departure from reference width/depth ratio = 1.0–1.2. Bank-Height Ratio (BHR) = 1.0–1.1.	2	Bankfull stage is not contained. Width/depth ratio departure from reference width/depth ratio = 1.2–1.4. Bank-Height Ratio (BHR) = 1.1–1.3.	3	Bankfull stage is not contained; over-bank flows are common with flows less than bankfull. Width/depth ratio departure from reference width/depth ratio > 1.4. Bank-Height Ratio (BHR) > 1.3.	4
	6	Bank rock content	> 65% with large angular boulders. 12"+ common.	2	40–65%. Mostly boulders and small cobbles 6–12".	4	20–40%. Most in the 3–6" diameter class.	6	<20% rock fragments of gravel sizes, 1–3" or less.	8
	7	Obstructions to flow	Rocks and logs firmly imbedded. Flow pattern w/o cutting or deposition. Stable bed.	2	Some present causing erosive cross currents and minor pool filling. Obstructions fewer and less firm.	4	Moderately frequent, unstable obstructions move with high flows causing bank cutting and pool filling.	6	Frequent obstructions and deflectors cause bank erosion yearlong. Sediment traps full, channel migration occurring.	8
	8	Cutting	Little or none. Infrequent raw banks <6".	4	Some, intermittently at outcurves and constrictions. Raw banks may be up to 12".	6	Significant. Cuts 12–24" high. Root mat overhangs and sloughing evident.	12	Almost continuous cuts, some over 24" high. Failure of overhangs frequent.	16
	9	Deposition	Little or no enlargement of channel or point bars.	4	Some new bar increase, mostly from coarse gravel.	8	Moderate depostion of new gravel and coarse sand on old and some new bars.	12	Extensive deposit of predominantly fine particles. Accelerated bar development.	16
Bottom	10	Rock angularity	Sharp edges and corners. Plane surfaces rough.	1	Rounded corners and edges. Surfaces smooth and flat.	2	Corners and edges well rounded in 2 dimensions.	3	Well rounded in all dimensions, surfaces smooth.	4
	11	Brightness	Surfaces dull, dark or stained. Generally not bright.	1	Mostly dull, but may have <35% bright surfaces.	2	Mixture dull and bright, i.e., 35–65% mixture range.	3	Predominantly bright, > 65%, exposed or scoured surfaces.	4
	12	Consolidation of particles	Assorted sizes tightly packed or overlapping.	2	Moderately packed with some overlapping.	4	Mostly loose assortment with no apparent overlap.	6	No packing evident. Loose assortment, easily moved.	8
	13	Bottom size distribution	No size change evident. Stable material 80–100%.	4	Distribution shift light. Stable material 50–80%.	8	Moderate change in sizes. Stable materials 20–50%.	12	Marked distribution change. Stable materials 0–20%.	16
	14	Scouring and deposition	<5% of bottom affected by scour or deposition.	6	5–30% affected. Scour at constrictions and where grades steepen. Some deposition in pools.	12	30–50% affected. Deposits and scour at obstructions, constrictions and bends. Some filling of pools.	18	More than 50% of the bottom in a state of flux or change nearly yearlong.	24
	15	Aquatic vegetation	Abundant growth moss-like, dark green perennial. In swift water too.	1	Common. Algae forms in low velocity and pool areas. Moss here too.	2	Present but spotty, mostly in backwater. Seasonal algae growth makes rocks slick.	3	Perennial types scarce or absent. Yellow-green, short-term bloom may be present.	4
			Excellent total =	**19**	**Good total =**	**35**	**Fair total =**	**0**	**Poor total =**	**8**

Stream type	A1	A2	A3	A4	A5	A6	B1	B2	B3	B4	B5	B6	C1	C2	C3	C4	C5	C6	D3	D4	D5	D6
Good (Stable)	38-43	38-43	54-90	60-95	60-95	50-80	38-45	38-45	40-60	40-64	48-68	40-60	38-50	38-50	60-85	70-90	70-90	60-85	85-107	85-107	85-107	67-98
Fair (Mod. unstable	44-47	44-47	91-129	96-132	96-142	81-110	46-58	46-58	61-78	65-84	69-88	61-78	51-61	51-61	86-105	91-110	91-110	86-105	108-132	108-132	108-132	99-125
Poor (Unstable)	48+	48+	130+	133+	143+	111+	59+	59+	79+	85+	89+	79+	62+	62+	106+	111+	111+	106+	133+	133+	133+	126+

Stream type	DA3	DA4	DA5	DA6	E3	E4	E5	E6	F1	F2	F3	F4	F5	F6	G1	G2	G3	G4	G5	G6
Good (Stable)	40-63	40-63	40-63	40-63	40-63	50-75	50-75	40-63	60-85	60-85	85-110	85-110	90-115	80-95	40-60	40-60	85-107	85-107	90-112	85-107
Fair (Mod. unstable	64-86	64-86	64-86	64-86	64-86	76-96	76-96	64-86	86-105	86-105	111-125	111-125	116-130	96-110	61-78	61-78	108-120	108-120	113-125	108-120
Poor (Unstable)	87+	87+	87+	87+	87+	97+	97+	87+	106+	106+	126+	126+	131+	111+	79+	79+	121+	121+	126+	121+

Grand total =	**62**
Existing stream type =	**B/C**
***Potential stream type =**	
Modified channel stability rating =	**Good**

*Rating is adjusted to potential stream type, not existing.

Worksheet 3-4. Meander pattern relations used for interpretations for river stability.

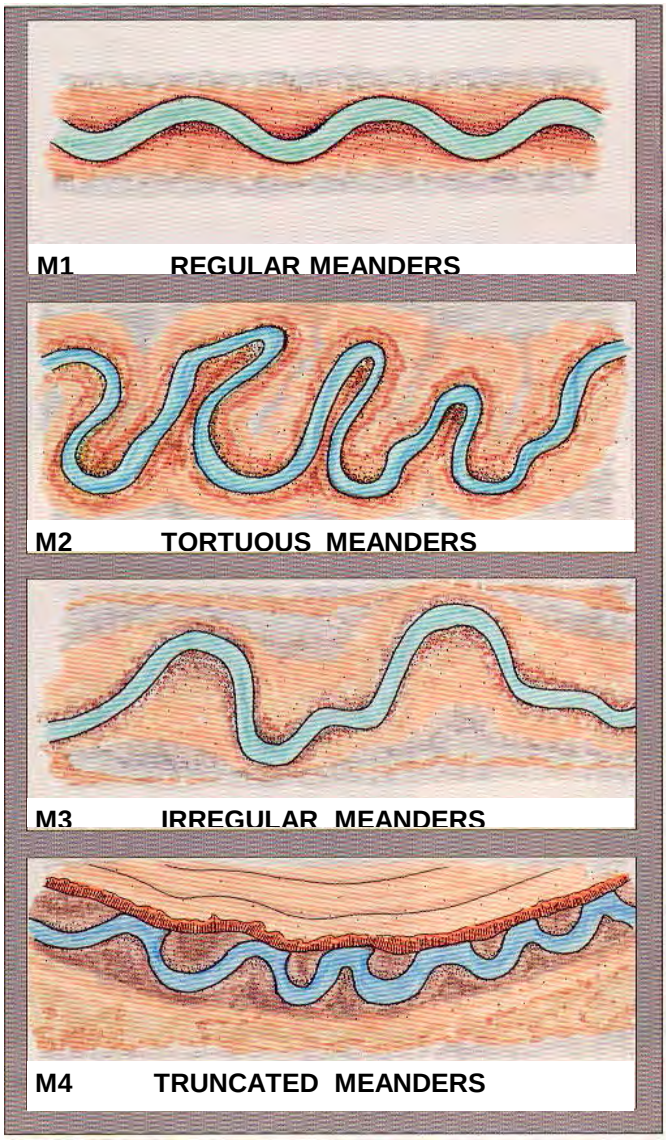
Meander Patterns

Stream: **Knife River** Reach: **Reach 7**

Observers: **M.Pranckus, B.Wizner, S. Alvar** Date: **12/15/2015**

List ALL CATEGORIES that APPLY ☞	M1	M3	M8		

Various Meander Pattern variables modified from Galay et al. (1973)

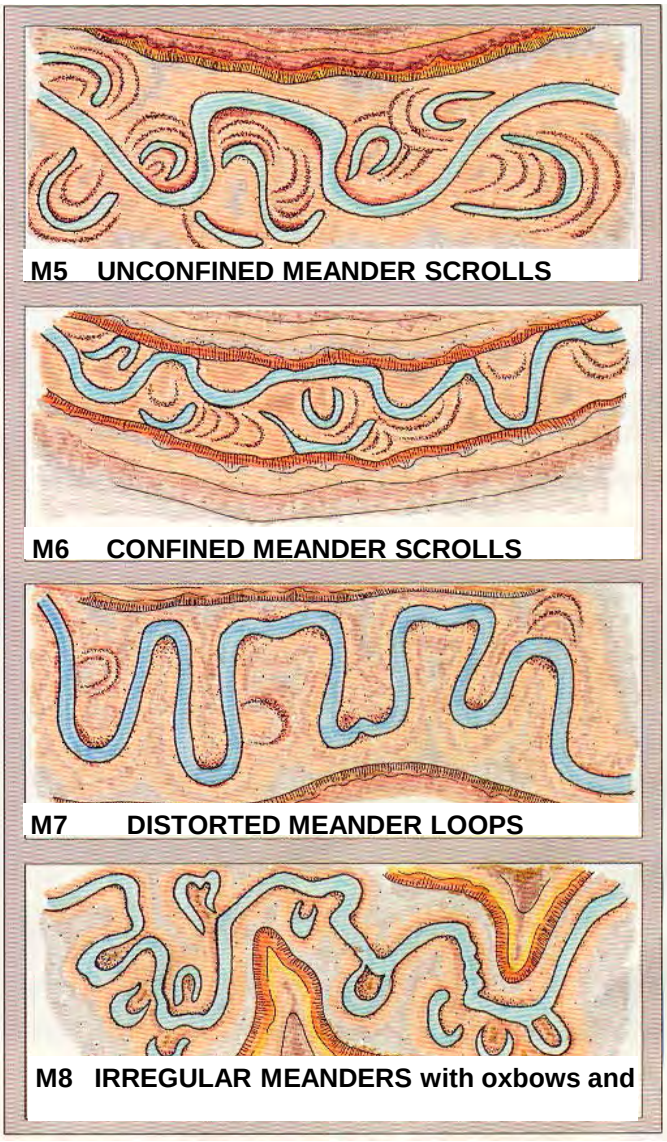


M1 REGULAR MEANDERS

M2 TORTUOUS MEANDERS

M3 IRREGULAR MEANDERS

M4 TRUNCATED MEANDERS



M5 UNCONFINED MEANDER SCROLLS

M6 CONFINED MEANDER SCROLLS

M7 DISTORTED MEANDER LOOPS

M8 IRREGULAR MEANDERS with oxbows and

Worksheet 3-5. Depositional patterns used for stabiilty assessment interpretations.

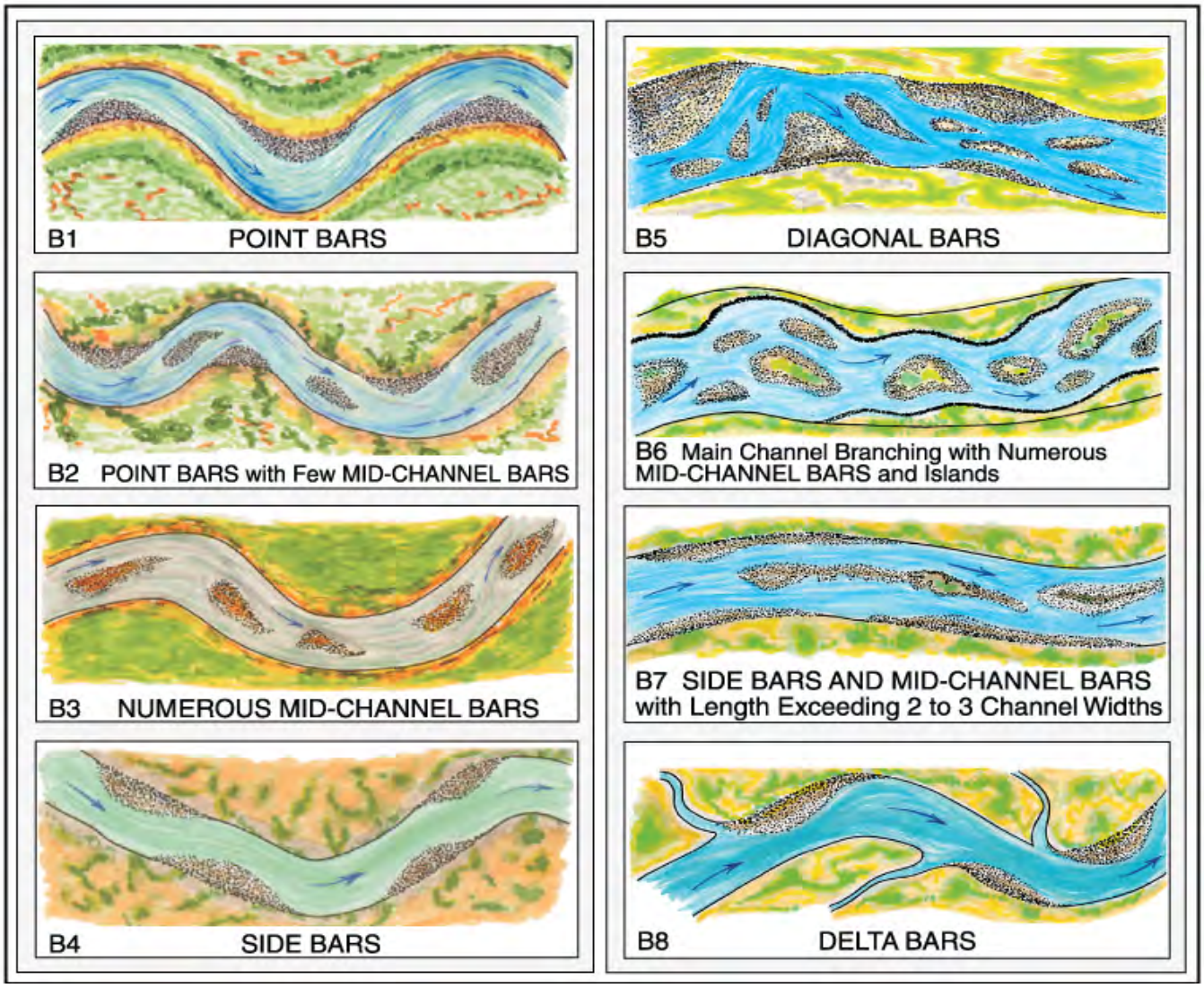
Depositional Patterns

Stream: **Knife River** Reach: **Reach 7**

Observers: **M.Pranckus, B.Wizner, S.Alvar** Date: **12/15/2015**

List ALL CATEGORIES that APPLY ☞	B1	B2	B4		

Various Depositional Features modified from Galay et al. (1973)



Worksheet 3-6. Various categories of in-channel debris, dams and channel blockages used to evaluate channel stability.

Channel Blockages			
Stream: **Knife River**		Location: **Reach 7**	
Observers: **M.Pranckus, B.Wizner, S. Alvar**		Date: **12/15/2015**	
Description/extent		**Materials that upon placement into the active channel or flood-prone area may cause adjustments in channel dimensions or conditions due to influences on the existing flow regime.**	**Check (✓) all that apply**
D1	None	Minor amounts of small, floatable material.	☐
D2	Infrequent	Debris consists of small, easily moved, floatable material, e.g., leaves, needles, small limbs and twigs.	☑
D3	Moderate	Increasing frequency of small- to medium-sized material, such as large limbs, branches and small logs, that when accumulated, affect 10% or less of the active channel cross-section area.	☐
D4	Numerous	Significant build-up of medium- to large-sized materials, e.g., large limbs, branches, small logs or portions of trees that may occupy 10–30% of the active channel cross-section area.	☑
D5	Extensive	Debris "dams" of predominantly larger materials, e.g., branches, logs and trees, occupying 30–50% of the active channel cross-section area, often extending across the width of the active channel.	☐
D6	Dominating	Large, somewhat continuous debris "dams," extensive in nature and occupying over 50% of the active channel cross-section area. Such accumulations may divert water into the flood-prone areas and form fish migration barriers, even when flows are at less than bankfull.	☑
D7	Beaver dams: Few	An infrequent number of dams spaced such that normal streamflow and expected channel conditions exist in the reaches between dams.	☐
D8	Beaver dams: Frequent	Frequency of dams is such that backwater conditions exist for channel reaches between structures where streamflow velocities are reduced and channel dimensions or conditions are influenced.	☐
D9	Beaver dams: Abandoned	Numerous abandoned dams, many of which have filled with sediment and/or breached, initiating a series of channel adjustments, such as bank erosion, lateral migration, avulsion, aggradation and degradation.	☐
D10	Human influences	Structures, facilities or materials related to land uses or development located within the flood-prone area, such as diversions or low-head dams, controlled by-pass channels, velocity control structures and various transportation encroachments that have an influence on the existing flow regime, such that significant channel adjustments occur.	☐

Worksheet 3-10. Pfankuch (1975) channel stability rating procedure, as modified by Rosgen (1996, 2001c, 2006b).

Stream: Knife River **Location:** Reach 7 **Valley Type:** **Observers:** M.Pranckus, B.Wizner **Date:** 12/15/2015

Location	Key	Category	Excellent		Good		Fair		Poor	
			Description	Rating	Description	Rating	Description	Rating	Description	Rating
Upper banks	1	Landform slope	Bank slope gradient <30%.	2	Bank slope gradient 30–40%.	4	Bank slope gradient 40–60%.	6	Bank slope gradient > 60%.	8
	2	Mass erosion	No evidence of past or future mass erosion.	3	Infrequent. Mostly healed over. Low future potential.	6	Frequent or large, causing sediment nearly yearlong.	9	Frequent or large, causing sediment nearly yearlong OR imminent danger of same.	12
	3	Debris jam potential	Essentially absent from immediate channel area.	2	Present, but mostly small twigs and limbs.	4	Moderate to heavy amounts, mostly larger sizes.	6	Moderate to heavy amounts, predominantly larger sizes.	8
	4	Vegetative bank protection	> 90% plant density. Vigor and variety suggest a deep, dense soil-binding root mass.	3	70–90% density. Fewer species or less vigor suggest less dense or deep root mass.	6	50–70% density. Lower vigor and fewer species from a shallow, discontinuous root mass.	9	<50% density plus fewer species and less vigor indicating poor, discontinuous and shallow root mass.	12
Lower banks	5	Channel capacity	Bank heights sufficient to contain the bankfull stage. Width/depth ratio departure from reference width/depth ratio = 1.0. Bank-Height Ratio (BHR) = 1.0.	1	Bankfull stage is contained within banks. Width/depth ratio departure from reference width/depth ratio = 1.0–1.2. Bank-Height Ratio (BHR) = 1.0–1.1.	2	Bankfull stage is not contained. Width/depth ratio departure from reference width/depth ratio = 1.2–1.4. Bank-Height Ratio (BHR) = 1.1–1.3.	3	Bankfull stage is not contained; over-bank flows are common with flows less than bankfull. Width/depth ratio departure from reference width/depth ratio > 1.4. Bank-Height Ratio (BHR) > 1.3.	4
	6	Bank rock content	> 65% with large angular boulders. 12"+ common.	2	40–65%. Mostly boulders and small cobbles 6–12".	4	20–40%. Most in the 3–6" diameter class.	6	<20% rock fragments of gravel sizes, 1–3" or less.	8
	7	Obstructions to flow	Rocks and logs firmly imbedded. Flow pattern w/o cutting or deposition. Stable bed.	2	Some present causing erosive cross currents and minor pool filling. Obstructions fewer and less firm.	4	Moderately frequent, unstable obstructions move with high flows causing bank cutting and pool filling.	6	Frequent obstructions and deflectors cause bank erosion yearlong. Sediment traps full, channel migration occurring.	8
	8	Cutting	Little or none. Infrequent raw banks <6".	4	Some, intermittently at outcurves and constrictions. Raw banks may be up to 12".	6	Significant. Cuts 12–24" high. Root mat overhangs and sloughing evident.	12	Almost continuous cuts, some over 24" high. Failure of overhangs frequent.	16
	9	Deposition	Little or no enlargement of channel or point bars.	4	Some new bar increase, mostly from coarse gravel.	8	Moderate depostion of new gravel and coarse sand on old and some new bars.	12	Extensive deposit of predominantly fine particles. Accelerated bar development.	16
Bottom	10	Rock angularity	Sharp edges and corners. Plane surfaces rough.	1	Rounded corners and edges. Surfaces smooth and flat.	2	Corners and edges well rounded in 2 dimensions.	3	Well rounded in all dimensions, surfaces smooth.	4
	11	Brightness	Surfaces dull, dark or stained. Generally not bright.	1	Mostly dull, but may have <35% bright surfaces.	2	Mixture dull and bright, i.e., 35–65% mixture range.	3	Predominantly bright, > 65%, exposed or scoured surfaces.	4
	12	Consolidation of particles	Assorted sizes tightly packed or overlapping.	2	Moderately packed with some overlapping.	4	Mostly loose assortment with no apparent overlap.	6	No packing evident. Loose assortment, easily moved.	8
	13	Bottom size distribution	No size change evident. Stable material 80–100%.	4	Distribution shift light. Stable material 50–80%.	8	Moderate change in sizes. Stable materials 20–50%.	12	Marked distribution change. Stable materials 0–20%.	16
	14	Scouring and deposition	<5% of bottom affected by scour or deposition.	6	5–30% affected. Scour at constrictions and where grades steepen. Some deposition in pools.	12	30–50% affected. Deposits and scour at obstructions, constrictions and bends. Some filling of pools.	18	More than 50% of the bottom in a state of flux or change nearly yearlong.	24
	15	Aquatic vegetation	Abundant growth moss-like, dark green perennial. In swift water too.	1	Common. Algae forms in low velocity and pool areas. Moss here too.	2	Present but spotty, mostly in backwater. Seasonal algae growth makes rocks slick.	3	Perennial types scarce or absent. Yellow-green, short-term bloom may be present.	4
			Excellent total =	**0**	**Good total =**	**41**	**Fair total =**	**40**	**Poor total =**	**16**

Stream type	A1	A2	A3	A4	A5	A6	B1	B2	B3	B4	B5	B6	C1	C2	C3	C4	C5	C6	D3	D4	D5	D6
Good (Stable)	38-43	38-43	54-90	60-95	60-95	50-80	38-45	38-45	40-60	40-64	48-68	40-60	38-50	38-50	60-85	70-90	70-90	60-85	85-107	85-107	85-107	67-98
Fair (Mod. unstable	44-47	44-47	91-129	96-132	96-142	81-110	46-58	46-58	61-78	65-84	69-88	61-78	51-61	51-61	86-105	91-110	91-110	86-105	108-132	108-132	108-132	99-125
Poor (Unstable)	48+	48+	130+	133+	143+	111+	59+	59+	79+	85+	89+	79+	62+	62+	106+	111+	111+	106+	133+	133+	133+	126+

Stream type	DA3	DA4	DA5	DA6	E3	E4	E5	E6	F1	F2	F3	F4	F5	F6	G1	G2	G3	G4	G5	G6
Good (Stable)	40-63	40-63	40-63	40-63	40-63	50-75	50-75	40-63	60-85	60-85	85-110	85-110	90-115	80-95	40-60	40-60	85-107	85-107	90-112	85-107
Fair (Mod. unstable	64-86	64-86	64-86	64-86	64-86	76-96	76-96	64-86	86-105	86-105	111-125	111-125	116-130	96-110	61-78	61-78	108-120	108-120	113-125	108-120
Poor (Unstable)	87+	87+	87+	87+	87+	97+	97+	87+	106+	106+	126+	126+	131+	111+	79+	79+	121+	121+	126+	121+

*Rating is adjusted to potential stream type, not existing.

Grand total =	**97**
Existing stream type =	**C**
***Potential stream type =**	
Modified channel stability rating =	**Fair**

Worksheet 3-4. Meander pattern relations used for interpretations for river stability.

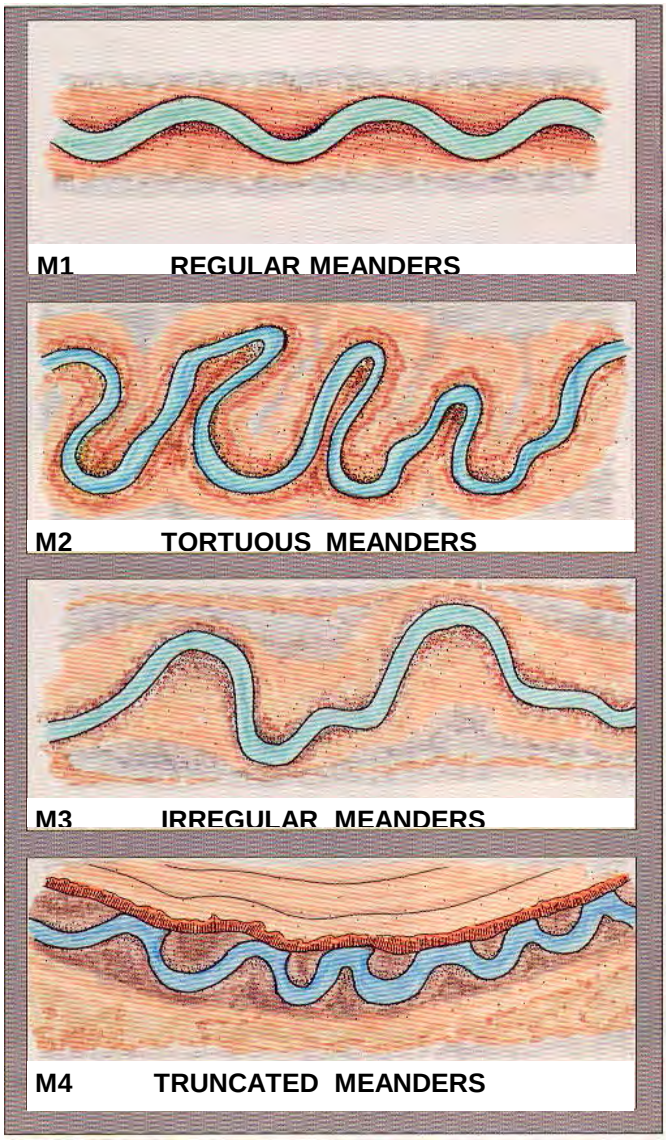
Meander Patterns

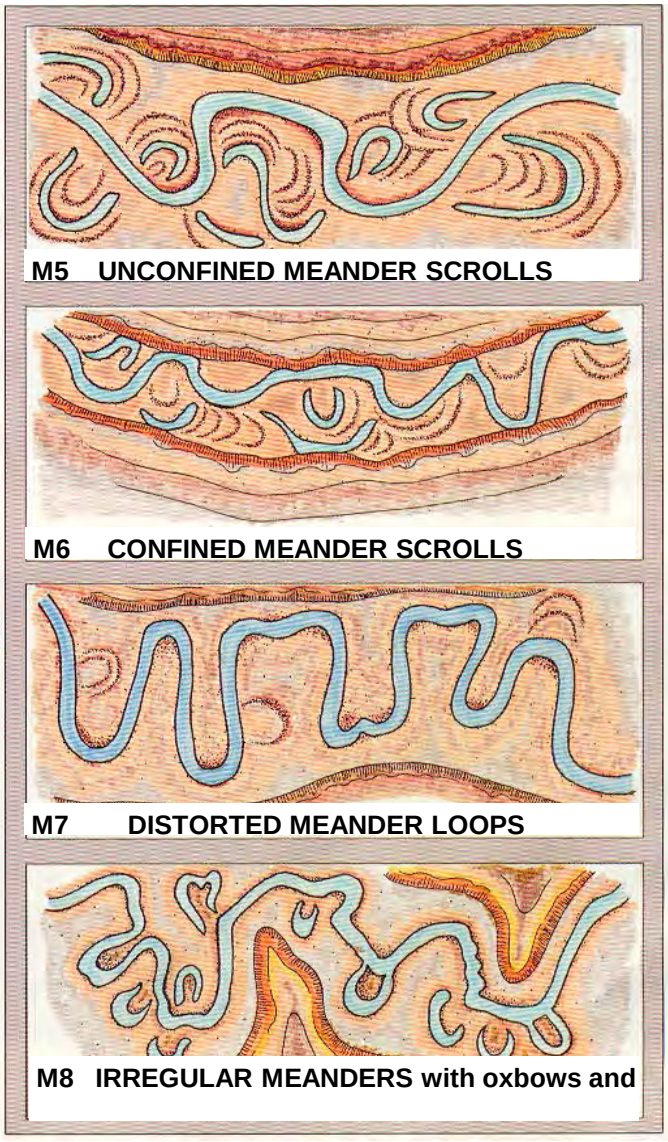
Stream: **Knife River** Reach: **Reach 9**

Observers: **A. Steber, M.Pranckus, B. Wizner** Date: **11/24/2015**

List ALL CATEGORIES that APPLY ☞	M3				

Various Meander Pattern variables modified from Galay et al. (1973)





Worksheet 3-5. Depositional patterns used for stabiilty assessment interpretations.

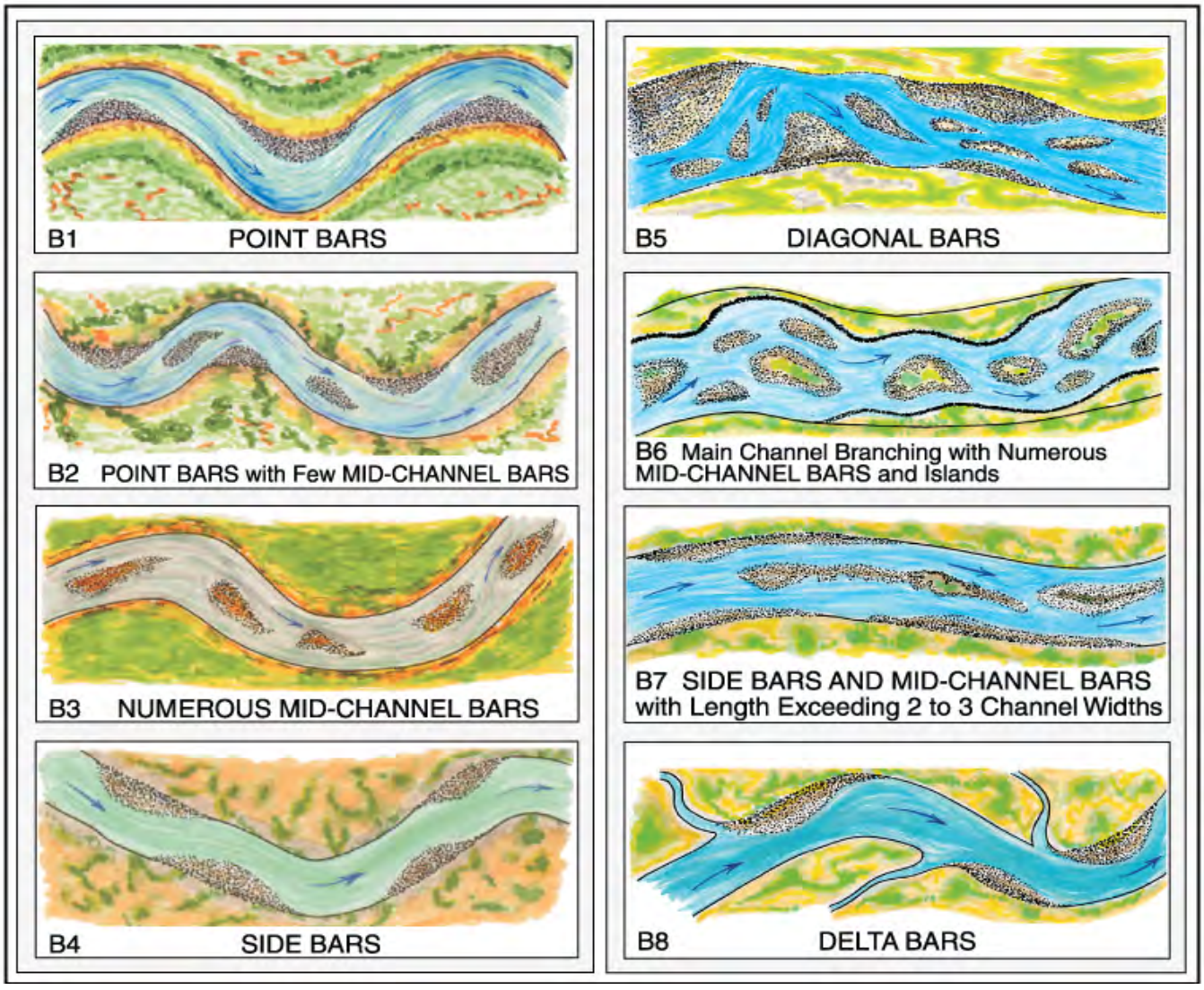
Depositional Patterns

Stream: **Knife River** Reach: **Reach 9**

Observers: **A. Steber, B. Wizner, M.Pranckus** Date: **11/24/2015**

List ALL CATEGORIES that APPLY ☞	B1	B4			

Various Depositional Features modified from Galay et al. (1973)



Worksheet 3-6. Various categories of in-channel debris, dams and channel blockages used to evaluate channel stability.

Channel Blockages			
Stream: **Knife River**		Location: **Reach 9**	
Observers: **A. Steber, M.Pranckus, B. Wizner**		Date: **11/24/2015**	
Description/extent		**Materials that upon placement into the active channel or flood-prone area may cause adjustments in channel dimensions or conditions due to influences on the existing flow regime.**	**Check (✓) all that apply**
D1	None	Minor amounts of small, floatable material.	☑
D2	Infrequent	Debris consists of small, easily moved, floatable material, e.g., leaves, needles, small limbs and twigs.	☑
D3	Moderate	Increasing frequency of small- to medium-sized material, such as large limbs, branches and small logs, that when accumulated, affect 10% or less of the active channel cross-section area.	☐
D4	Numerous	Significant build-up of medium- to large-sized materials, e.g., large limbs, branches, small logs or portions of trees that may occupy 10–30% of the active channel cross-section area.	☐
D5	Extensive	Debris "dams" of predominantly larger materials, e.g., branches, logs and trees, occupying 30–50% of the active channel cross-section area, often extending across the width of the active channel.	☐
D6	Dominating	Large, somewhat continuous debris "dams," extensive in nature and occupying over 50% of the active channel cross-section area. Such accumulations may divert water into the flood-prone areas and form fish migration barriers, even when flows are at less than bankfull.	☐
D7	Beaver dams: Few	An infrequent number of dams spaced such that normal streamflow and expected channel conditions exist in the reaches between dams.	☐
D8	Beaver dams: Frequent	Frequency of dams is such that backwater conditions exist for channel reaches between structures where streamflow velocities are reduced and channel dimensions or conditions are influenced.	☐
D9	Beaver dams: Abandoned	Numerous abandoned dams, many of which have filled with sediment and/or breached, initiating a series of channel adjustments, such as bank erosion, lateral migration, avulsion, aggradation and degradation.	☐
D10	Human influences	Structures, facilities or materials related to land uses or development located within the flood-prone area, such as diversions or low-head dams, controlled by-pass channels, velocity control structures and various transportation encroachments that have an influence on the existing flow regime, such that significant channel adjustments occur.	☐

Worksheet 3-10. Pfankuch (1975) channel stability rating procedure, as modified by Rosgen (1996, 2001c, 2006b).

Stream: Knife River **Location:** Reach 9 **Valley Type:** **Observers:** A. Steber, M.Pranckus **Date:** 11/24/2015

Location	Key	Category	Excellent		Good		Fair		Poor	
			Description	Rating	Description	Rating	Description	Rating	Description	Rating
Upper banks	1	Landform slope	Bank slope gradient <30%.	2	Bank slope gradient 30–40%.	4	Bank slope gradient 40–60%.	6	Bank slope gradient > 60%.	8
	2	Mass erosion	No evidence of past or future mass erosion.	3	Infrequent. Mostly healed over. Low future potential.	6	Frequent or large, causing sediment nearly yearlong.	9	Frequent or large, causing sediment nearly yearlong OR imminent danger of same.	12
	3	Debris jam potential	Essentially absent from immediate channel area.	2	Present, but mostly small twigs and limbs.	4	Moderate to heavy amounts, mostly larger sizes.	6	Moderate to heavy amounts, predominantly larger sizes.	8
	4	Vegetative bank protection	> 90% plant density. Vigor and variety suggest a deep, dense soil-binding root mass.	3	70–90% density. Fewer species or less vigor suggest less dense or deep root mass.	6	50–70% density. Lower vigor and fewer species from a shallow, discontinuous root mass.	9	<50% density plus fewer species and less vigor indicating poor, discontinuous and shallow root mass.	12
Lower banks	5	Channel capacity	Bank heights sufficient to contain the bankfull stage. Width/depth ratio departure from reference width/depth ratio = 1.0. Bank-Height Ratio (BHR) = 1.0.	1	Bankfull stage is contained within banks. Width/depth ratio departure from reference width/depth ratio = 1.0–1.2. Bank-Height Ratio (BHR) = 1.0–1.1.	2	Bankfull stage is not contained. Width/depth ratio departure from reference width/depth ratio = 1.2–1.4. Bank-Height Ratio (BHR) = 1.1–1.3.	3	Bankfull stage is not contained; over-bank flows are common with flows less than bankfull. Width/depth ratio departure from reference width/depth ratio > 1.4. Bank-Height Ratio (BHR) > 1.3.	4
	6	Bank rock content	> 65% with large angular boulders. 12"+ common.	2	40–65%. Mostly boulders and small cobbles 6–12".	4	20–40%. Most in the 3–6" diameter class.	6	<20% rock fragments of gravel sizes, 1–3" or less.	8
	7	Obstructions to flow	Rocks and logs firmly imbedded. Flow pattern w/o cutting or deposition. Stable bed.	2	Some present causing erosive cross currents and minor pool filling. Obstructions fewer and less firm.	4	Moderately frequent, unstable obstructions move with high flows causing bank cutting and pool filling.	6	Frequent obstructions and deflectors cause bank erosion yearlong. Sediment traps full, channel migration occurring.	8
	8	Cutting	Little or none. Infrequent raw banks <6".	4	Some, intermittently at outcurves and constrictions. Raw banks may be up to 12".	6	Significant. Cuts 12–24" high. Root mat overhangs and sloughing evident.	12	Almost continuous cuts, some over 24" high. Failure of overhangs frequent.	16
	9	Deposition	Little or no enlargement of channel or point bars.	4	Some new bar increase, mostly from coarse gravel.	8	Moderate depostion of new gravel and coarse sand on old and some new bars.	12	Extensive deposit of predominantly fine particles. Accelerated bar development.	16
Bottom	10	Rock angularity	Sharp edges and corners. Plane surfaces rough.	1	Rounded corners and edges. Surfaces smooth and flat.	2	Corners and edges well rounded in 2 dimensions.	3	Well rounded in all dimensions, surfaces smooth.	4
	11	Brightness	Surfaces dull, dark or stained. Generally not bright.	1	Mostly dull, but may have <35% bright surfaces.	2	Mixture dull and bright, i.e., 35–65% mixture range.	3	Predominantly bright, > 65%, exposed or scoured surfaces.	4
	12	Consolidation of particles	Assorted sizes tightly packed or overlapping.	2	Moderately packed with some overlapping.	4	Mostly loose assortment with no apparent overlap.	6	No packing evident. Loose assortment, easily moved.	8
	13	Bottom size distribution	No size change evident. Stable material 80–100%.	4	Distribution shift light. Stable material 50–80%.	8	Moderate change in sizes. Stable materials 20–50%.	12	Marked distribution change. Stable materials 0–20%.	16
	14	Scouring and deposition	<5% of bottom affected by scour or deposition.	6	5–30% affected. Scour at constrictions and where grades steepen. Some deposition in pools.	12	30–50% affected. Deposits and scour at obstructions, constrictions and bends. Some filling of pools.	18	More than 50% of the bottom in a state of flux or change nearly yearlong.	24
	15	Aquatic vegetation	Abundant growth moss-like, dark green perennial. In swift water too.	1	Common. Algae forms in low velocity and pool areas. Moss here too.	2	Present but spotty, mostly in backwater. Seasonal algae growth makes rocks slick.	3	Perennial types scarce or absent. Yellow-green, short-term bloom may be present.	4
			Excellent total =	**0**	**Good total =**	**11.5**	**Fair total =**	**79.5**	**Poor total =**	**24**

Stream type	A1	A2	A3	A4	A5	A6	B1	B2	B3	B4	B5	B6	C1	C2	C3	C4	C5	C6	D3	D4	D5	D6
Good (Stable)	38-43	38-43	54-90	60-95	60-95	50-80	38-45	38-45	40-60	40-64	48-68	40-60	38-50	38-50	60-85	70-90	70-90	60-85	85-107	85-107	85-107	67-98
Fair (Mod. unstable	44-47	44-47	91-129	96-132	96-142	81-110	46-58	46-58	61-78	65-84	69-88	61-78	51-61	51-61	86-105	91-110	91-110	86-105	108-132	108-132	108-132	99-125
Poor (Unstable)	48+	48+	130+	133+	143+	111+	59+	59+	79+	85+	89+	79+	62+	62+	106+	111+	111+	106+	133+	133+	133+	126+

Stream type	DA3	DA4	DA5	DA6	E3	E4	E5	E6	F1	F2	F3	F4	F5	F6	G1	G2	G3	G4	G5	G6
Good (Stable)	40-63	40-63	40-63	40-63	40-63	50-75	50-75	40-63	60-85	60-85	85-110	85-110	90-115	80-95	40-60	40-60	85-107	85-107	90-112	85-107
Fair (Mod. unstable	64-86	64-86	64-86	64-86	64-86	76-96	76-96	64-86	86-105	86-105	111-125	111-125	116-130	96-110	61-78	61-78	108-120	108-120	113-125	108-120
Poor (Unstable)	87+	87+	87+	87+	87+	97+	97+	87+	106+	106+	126+	126+	131+	111+	79+	79+	121+	121+	126+	121+

Grand total =	**115**
Existing stream type =	**C**
***Potential stream type =**	
Modified channel stability rating =	**Poor**

*Rating is adjusted to potential stream type, not existing.

Worksheet 3-10. Pfankuch (1975) channel stability rating procedure, as modified by Rosgen (1996, 2001c, 2006b).

Stream: Knife River **Location:** Reach 12 **Valley Type:** **Observers:** A. Steber, M.Pranckus **Date:** 11/24/2015

Location	Key	Category	Excellent		Good		Fair		Poor	
			Description	Rating	Description	Rating	Description	Rating	Description	Rating
Upper banks	1	Landform slope	Bank slope gradient <30%.	2	Bank slope gradient 30–40%.	4	Bank slope gradient 40–60%.	6	Bank slope gradient > 60%.	8
	2	Mass erosion	No evidence of past or future mass erosion.	3	Infrequent. Mostly healed over. Low future potential.	6	Frequent or large, causing sediment nearly yearlong.	9	Frequent or large, causing sediment nearly yearlong OR imminent danger of same.	12
	3	Debris jam potential	Essentially absent from immediate channel area.	2	Present, but mostly small twigs and limbs.	4	Moderate to heavy amounts, mostly larger sizes.	6	Moderate to heavy amounts, predominantly larger sizes.	8
	4	Vegetative bank protection	> 90% plant density. Vigor and variety suggest a deep, dense soil-binding root mass.	3	70–90% density. Fewer species or less vigor suggest less dense or deep root mass.	6	50–70% density. Lower vigor and fewer species from a shallow, discontinuous root mass.	9	<50% density plus fewer species and less vigor indicating poor, discontinuous and shallow root mass.	12
Lower banks	5	Channel capacity	Bank heights sufficient to contain the bankfull stage. Width/depth ratio departure from reference width/depth ratio = 1.0. Bank-Height Ratio (BHR) = 1.0.	1	Bankfull stage is contained within banks. Width/depth ratio departure from reference width/depth ratio = 1.0–1.2. Bank-Height Ratio (BHR) = 1.0–1.1.	2	Bankfull stage is not contained. Width/depth ratio departure from reference width/depth ratio = 1.2–1.4. Bank-Height Ratio (BHR) = 1.1–1.3.	3	Bankfull stage is not contained; over-bank flows are common with flows less than bankfull. Width/depth ratio departure from reference width/depth ratio > 1.4. Bank-Height Ratio (BHR) > 1.3.	4
	6	Bank rock content	> 65% with large angular boulders. 12"+ common.	2	40–65%. Mostly boulders and small cobbles 6–12".	4	20–40%. Most in the 3–6" diameter class.	6	<20% rock fragments of gravel sizes, 1–3" or less.	8
	7	Obstructions to flow	Rocks and logs firmly imbedded. Flow pattern w/o cutting or deposition. Stable bed.	2	Some present causing erosive cross currents and minor pool filling. Obstructions fewer and less firm.	4	Moderately frequent, unstable obstructions move with high flows causing bank cutting and pool filling.	6	Frequent obstructions and deflectors cause bank erosion yearlong. Sediment traps full, channel migration occurring.	8
	8	Cutting	Little or none. Infrequent raw banks <6".	4	Some, intermittently at outcurves and constrictions. Raw banks may be up to 12".	6	Significant. Cuts 12–24" high. Root mat overhangs and sloughing evident.	12	Almost continuous cuts, some over 24" high. Failure of overhangs frequent.	16
	9	Deposition	Little or no enlargement of channel or point bars.	4	Some new bar increase, mostly from coarse gravel.	8	Moderate depostion of new gravel and coarse sand on old and some new bars.	12	Extensive deposit of predominantly fine particles. Accelerated bar development.	16
Bottom	10	Rock angularity	Sharp edges and corners. Plane surfaces rough.	1	Rounded corners and edges. Surfaces smooth and flat.	2	Corners and edges well rounded in 2 dimensions.	3	Well rounded in all dimensions, surfaces smooth.	4
	11	Brightness	Surfaces dull, dark or stained. Generally not bright.	1	Mostly dull, but may have <35% bright surfaces.	2	Mixture dull and bright, i.e., 35–65% mixture range.	3	Predominantly bright, > 65%, exposed or scoured surfaces.	4
	12	Consolidation of particles	Assorted sizes tightly packed or overlapping.	2	Moderately packed with some overlapping.	4	Mostly loose assortment with no apparent overlap.	6	No packing evident. Loose assortment, easily moved.	8
	13	Bottom size distribution	No size change evident. Stable material 80–100%.	4	Distribution shift light. Stable material 50–80%.	8	Moderate change in sizes. Stable materials 20–50%.	12	Marked distribution change. Stable materials 0–20%.	16
	14	Scouring and deposition	<5% of bottom affected by scour or deposition.	6	5–30% affected. Scour at constrictions and where grades steepen. Some deposition in pools.	12	30–50% affected. Deposits and scour at obstructions, constrictions and bends. Some filling of pools.	18	More than 50% of the bottom in a state of flux or change nearly yearlong.	24
	15	Aquatic vegetation	Abundant growth moss-like, dark green perennial. In swift water too.	1	Common. Algae forms in low velocity and pool areas. Moss here too.	2	Present but spotty, mostly in backwater. Seasonal algae growth makes rocks slick.	3	Perennial types scarce or absent. Yellow-green, short-term bloom may be present.	4
			Excellent total =		**Good total =**	**30**	**Fair total =**	**33**	**Poor total =**	**48**

Stream type	A1	A2	A3	A4	A5	A6	B1	B2	B3	B4	B5	B6	C1	C2	C3	C4	C5	C6	D3	D4	D5	D6
Good (Stable)	38-43	38-43	54-90	60-95	60-95	50-80	38-45	38-45	40-60	40-64	48-68	40-60	38-50	38-50	60-85	70-90	70-90	60-85	85-107	85-107	85-107	67-98
Fair (Mod. unstable	44-47	44-47	91-129	96-132	96-142	81-110	46-58	46-58	61-78	65-84	69-88	61-78	51-61	51-61	86-105	91-110	91-110	86-105	108-132	108-132	108-132	99-125
Poor (Unstable)	48+	48+	130+	133+	143+	111+	59+	59+	79+	85+	89+	79+	62+	62+	106+	111+	111+	106+	133+	133+	133+	126+

Stream type	DA3	DA4	DA5	DA6	E3	E4	E5	E6	F1	F2	F3	F4	F5	F6	G1	G2	G3	G4	G5	G6
Good (Stable)	40-63	40-63	40-63	40-63	40-63	50-75	50-75	40-63	60-85	60-85	85-110	85-110	90-115	80-95	40-60	40-60	85-107	85-107	90-112	85-107
Fair (Mod. unstable	64-86	64-86	64-86	64-86	64-86	76-96	76-96	64-86	86-105	86-105	111-125	111-125	116-130	96-110	61-78	61-78	108-120	108-120	113-125	108-120
Poor (Unstable)	87+	87+	87+	87+	87+	97+	97+	87+	106+	106+	126+	126+	131+	111+	79+	79+	121+	121+	126+	121+

*Rating is adjusted to potential stream type, not existing.

Grand total =	**111**
Existing stream type =	**B/C**
***Potential stream type =**	
Modified channel stability rating =	**Poor**

Worksheet 3-4. Meander pattern relations used for interpretations for river stability.

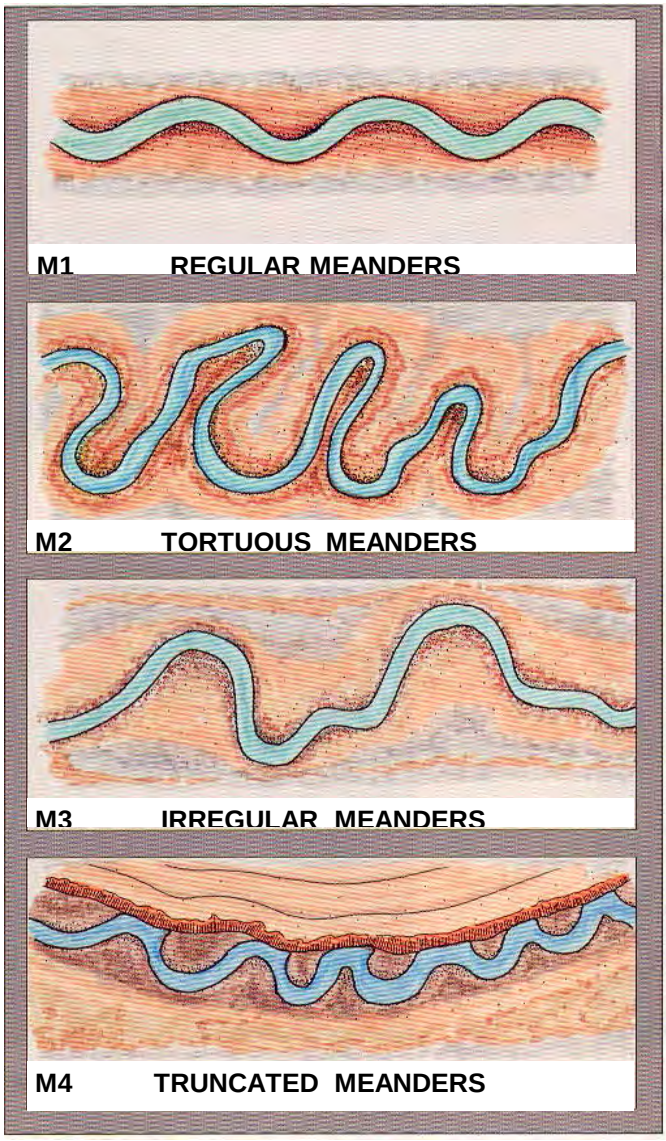
Meander Patterns

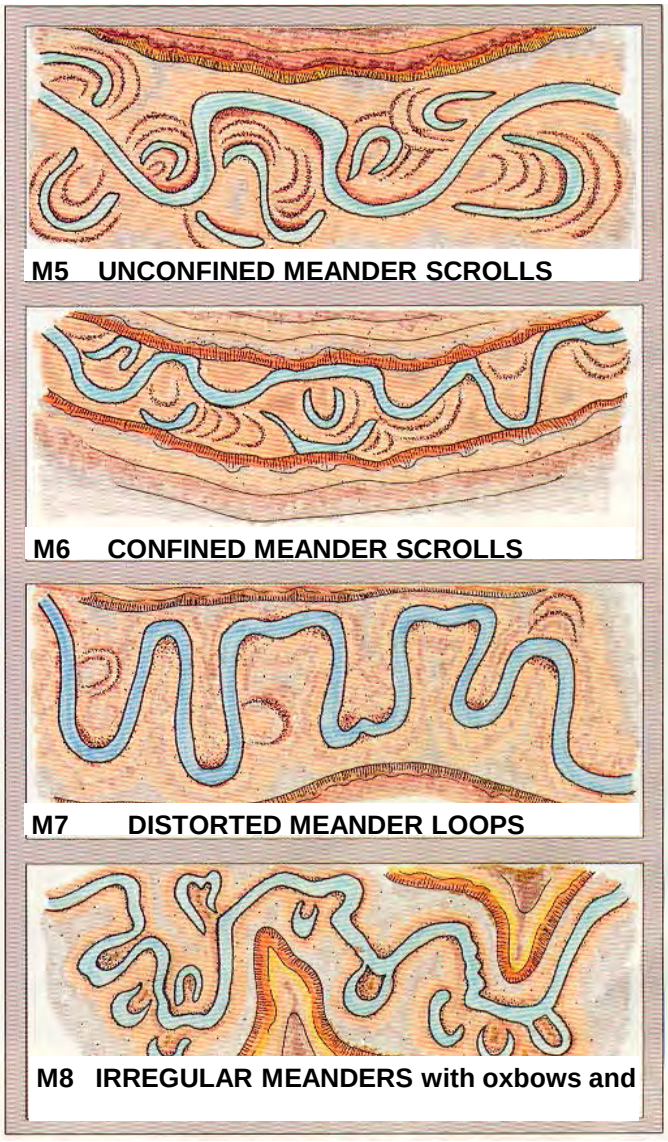
Stream: **Knife River** Reach: **Reach 12**

Observers: **A. Steber, M.Pranckus, B. Wizner** Date: **11/24/2015**

List ALL CATEGORIES that APPLY ☞	M1	M3			

Various Meander Pattern variables modified from Galay et al. (1973)





Worksheet 3-5. Depositional patterns used for stabiilty assessment interpretations.

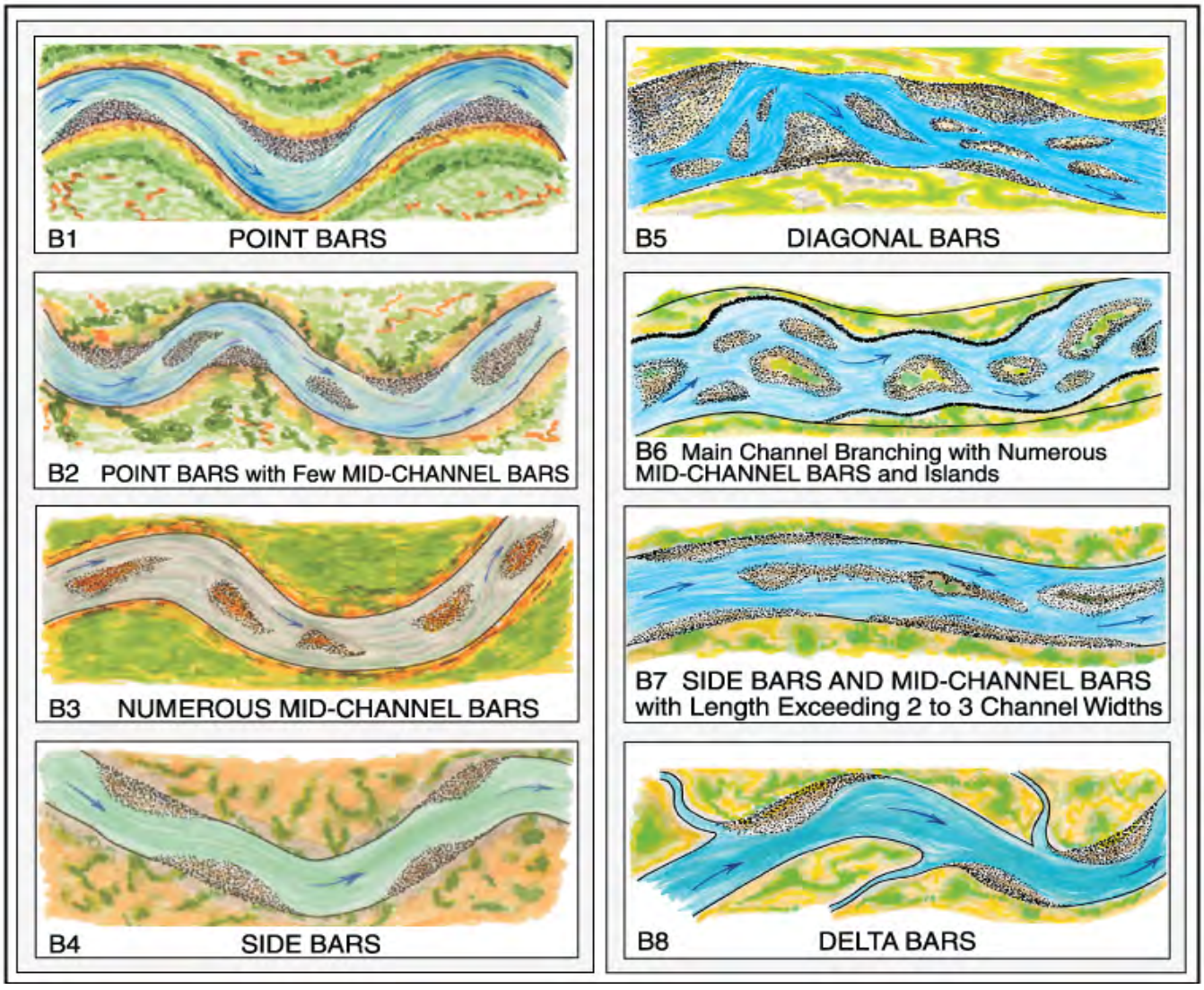
Depositional Patterns

Stream: **Knife River** Reach: **Reach 12**

Observers: **A. Steber, B. Wizner, M.Pranckus** Date: **11/24/2015**

List ALL CATEGORIES that APPLY ☞	B1	B4			

Various Depositional Features modified from Galay et al. (1973)



Worksheet 3-6. Various categories of in-channel debris, dams and channel blockages used to evaluate channel stability.

Channel Blockages			
Stream: **Knife River**		Location: **Reach 12**	
Observers: **A. Steber, M.Pranckus, B. Wizner**		Date: **11/24/2015**	
Description/extent		**Materials that upon placement into the active channel or flood-prone area may cause adjustments in channel dimensions or conditions due to influences on the existing flow regime.**	**Check (✓) all that apply**
D1	None	Minor amounts of small, floatable material.	☑
D2	Infrequent	Debris consists of small, easily moved, floatable material, e.g., leaves, needles, small limbs and twigs.	☐
D3	Moderate	Increasing frequency of small- to medium-sized material, such as large limbs, branches and small logs, that when accumulated, affect 10% or less of the active channel cross-section area.	☐
D4	Numerous	Significant build-up of medium- to large-sized materials, e.g., large limbs, branches, small logs or portions of trees that may occupy 10–30% of the active channel cross-section area.	☐
D5	Extensive	Debris "dams" of predominantly larger materials, e.g., branches, logs and trees, occupying 30–50% of the active channel cross-section area, often extending across the width of the active channel.	☐
D6	Dominating	Large, somewhat continuous debris "dams," extensive in nature and occupying over 50% of the active channel cross-section area. Such accumulations may divert water into the flood-prone areas and form fish migration barriers, even when flows are at less than bankfull.	☐
D7	Beaver dams: Few	An infrequent number of dams spaced such that normal streamflow and expected channel conditions exist in the reaches between dams.	☐
D8	Beaver dams: Frequent	Frequency of dams is such that backwater conditions exist for channel reaches between structures where streamflow velocities are reduced and channel dimensions or conditions are influenced.	☐
D9	Beaver dams: Abandoned	Numerous abandoned dams, many of which have filled with sediment and/or breached, initiating a series of channel adjustments, such as bank erosion, lateral migration, avulsion, aggradation and degradation.	☐
D10	Human influences	Structures, facilities or materials related to land uses or development located within the flood-prone area, such as diversions or low-head dams, controlled by-pass channels, velocity control structures and various transportation encroachments that have an influence on the existing flow regime, such that significant channel adjustments occur.	☐