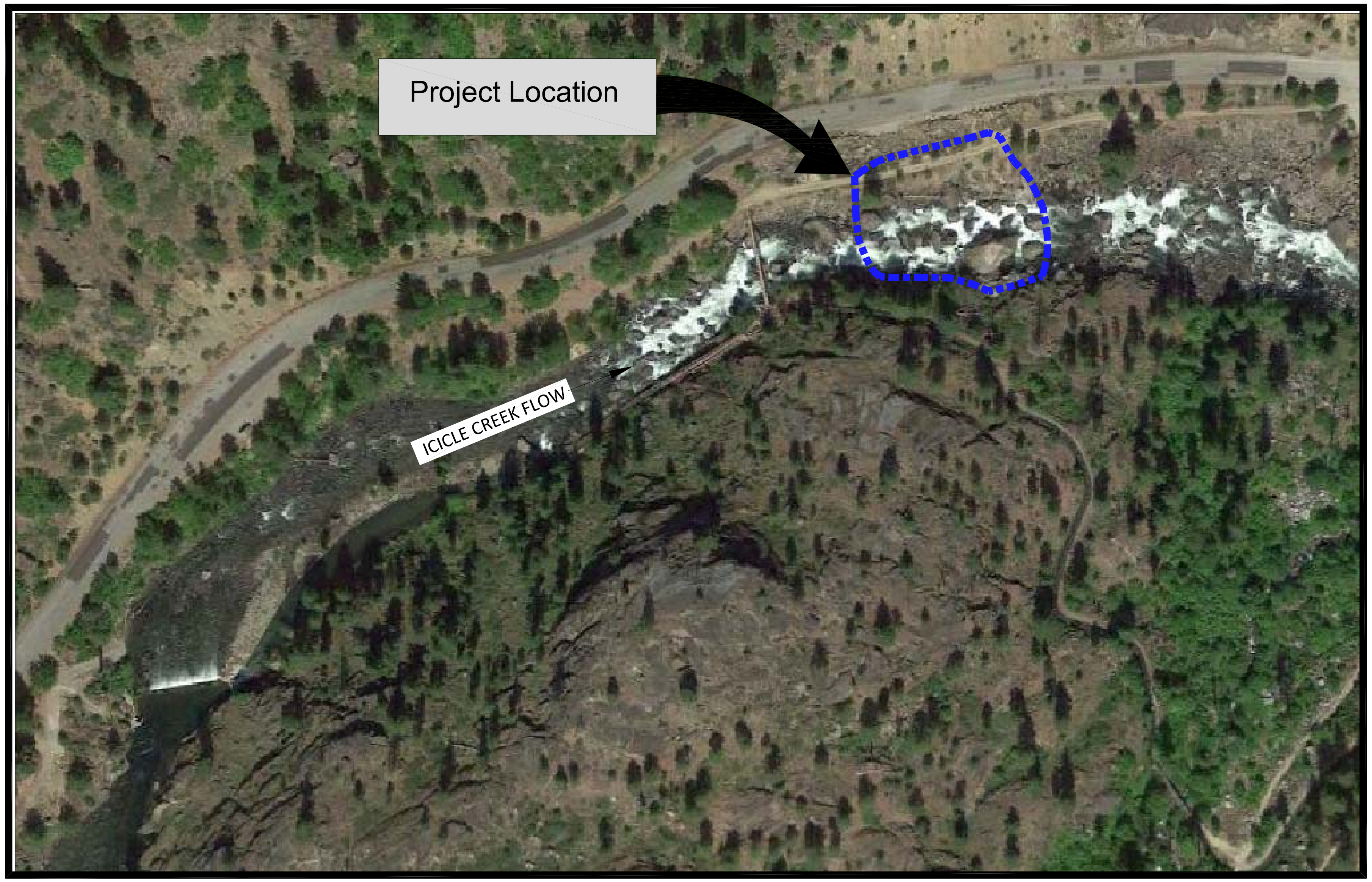
APPENDIX A – BOULDER FIELD EXISTING AND DESIGN DRAWINGS AND COST ESTIMATE

Preliminary Design - Option 4b - Step Pool Fishway

Icicle Boulder Field Passage Design

Project Number 13-1342



VICINITY MAP
Scale 1" = 200'

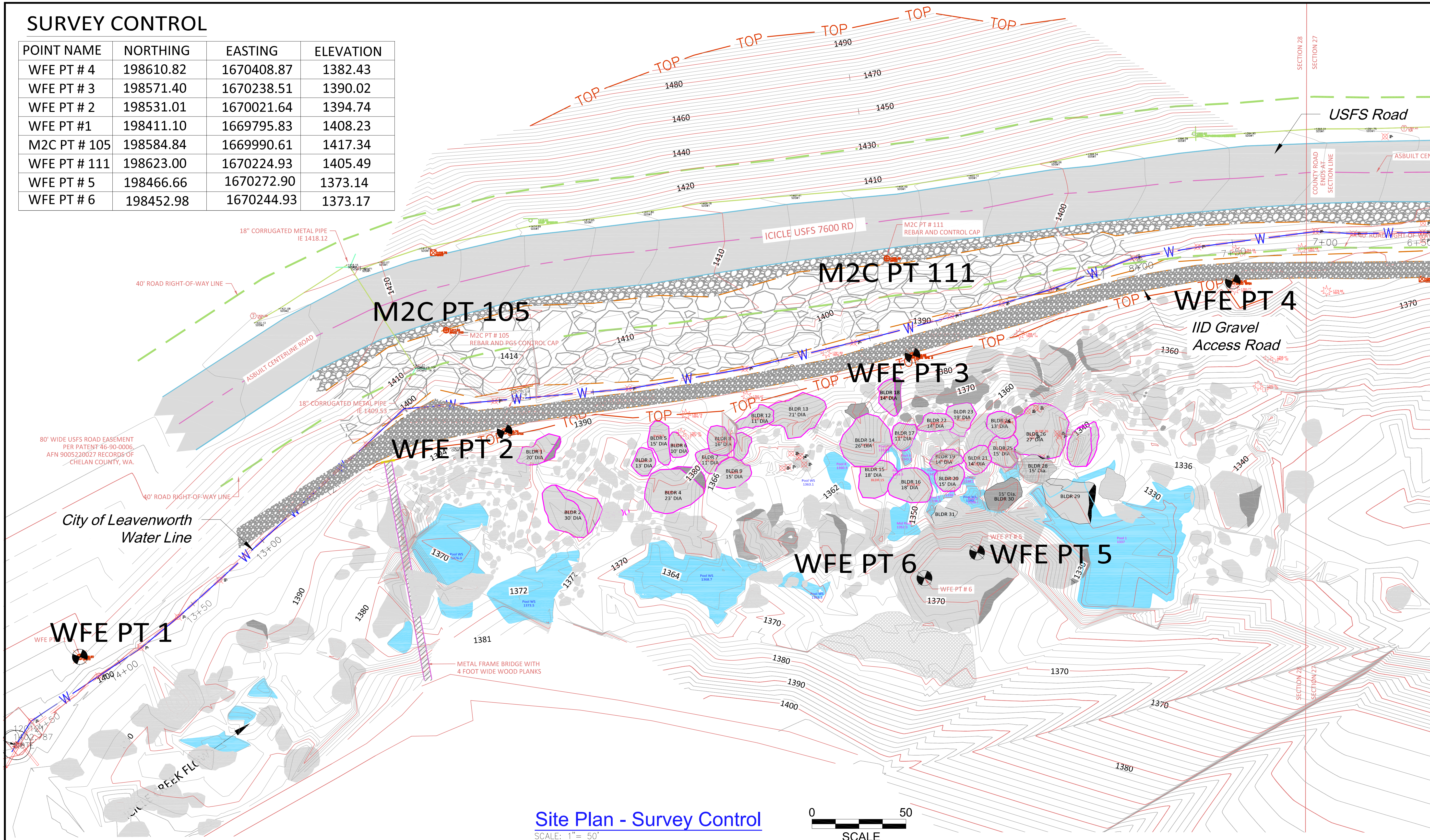
DRAWING INDEX:

TROUT UNLIMITED	Icicle Boulder Field Passage Design	REV	DATE	BY	APP'D	DESCRIPTION	DESIGN BY: Waterfall Engineering DRAWN BY: RiverSide Drafting DATE: 05/24/2015	Cover Sheet	1 SHEET OF 17

SCALE VERIFICATION
BAR IS ONE INCH ON ORIGINAL DRAWING. 0 1"
IF NOT ONE INCH ON THIS SHEET, ADJUST SCALES ACCORDINGLY.

SURVEY CONTROL

POINT NAME	NORTHING	EASTING	ELEVATION
WFE PT # 4	198610.82	1670408.87	1382.43
WFE PT # 3	198571.40	1670238.51	1390.02
WFE PT # 2	198531.01	1670021.64	1394.74
WFE PT #1	198411.10	1669795.83	1408.23
M2C PT # 105	198584.84	1669990.61	1417.34
WFE PT # 111	198623.00	1670224.93	1405.49
WFE PT # 5	198466.66	1670272.90	1373.14
WFE PT # 6	198452.98	1670244.93	1373.17



Site Plan - Survey Control

SCALE: 1" = 50'

0 50
SCALE

Icicle Boulder Field Passage Design

REV	DATE	BY	APP'D	DESCRIPTION

SCALE VERIFICATION

BAR IS ONE INCH ON ORIGINAL DRAWING. 0 1"

IF NOT ONE INCH ON THIS SHEET, ADJUST SCALES ACCORDINGLY.

DESIGN BY:
Waterfall Engineering

DRAWN BY:
RiverSide Drafting

DATE:
05/24/2015

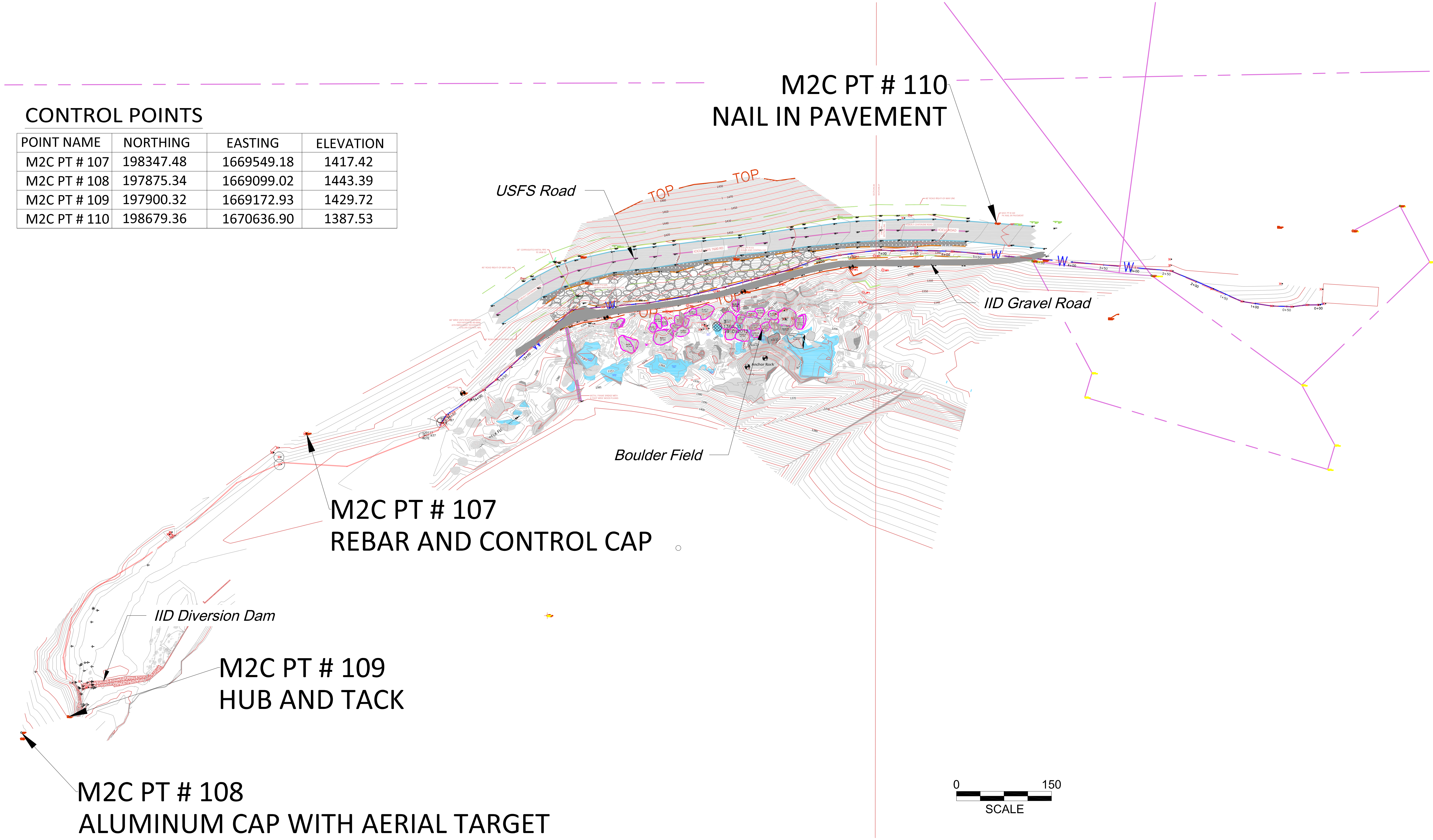
Site Plan
Survey Control

2 SHEET 17 OF

TROUT UNLIMITED

CONTROL POINTS

POINT NAME	NORTHING	EASTING	ELEVATION
M2C PT # 107	198347.48	1669549.18	1417.42
M2C PT # 108	197875.34	1669099.02	1443.39
M2C PT # 109	197900.32	1669172.93	1429.72
M2C PT # 110	198679.36	1670636.90	1387.53



TROUT UNLIMITED

Icicle Boulder Field Passage Design

REV	DATE	BY	APP'D	DESCRIPTION

SCALE VERIFICATION

BAR IS ONE INCH ON ORIGINAL DRAWING. 0 1"

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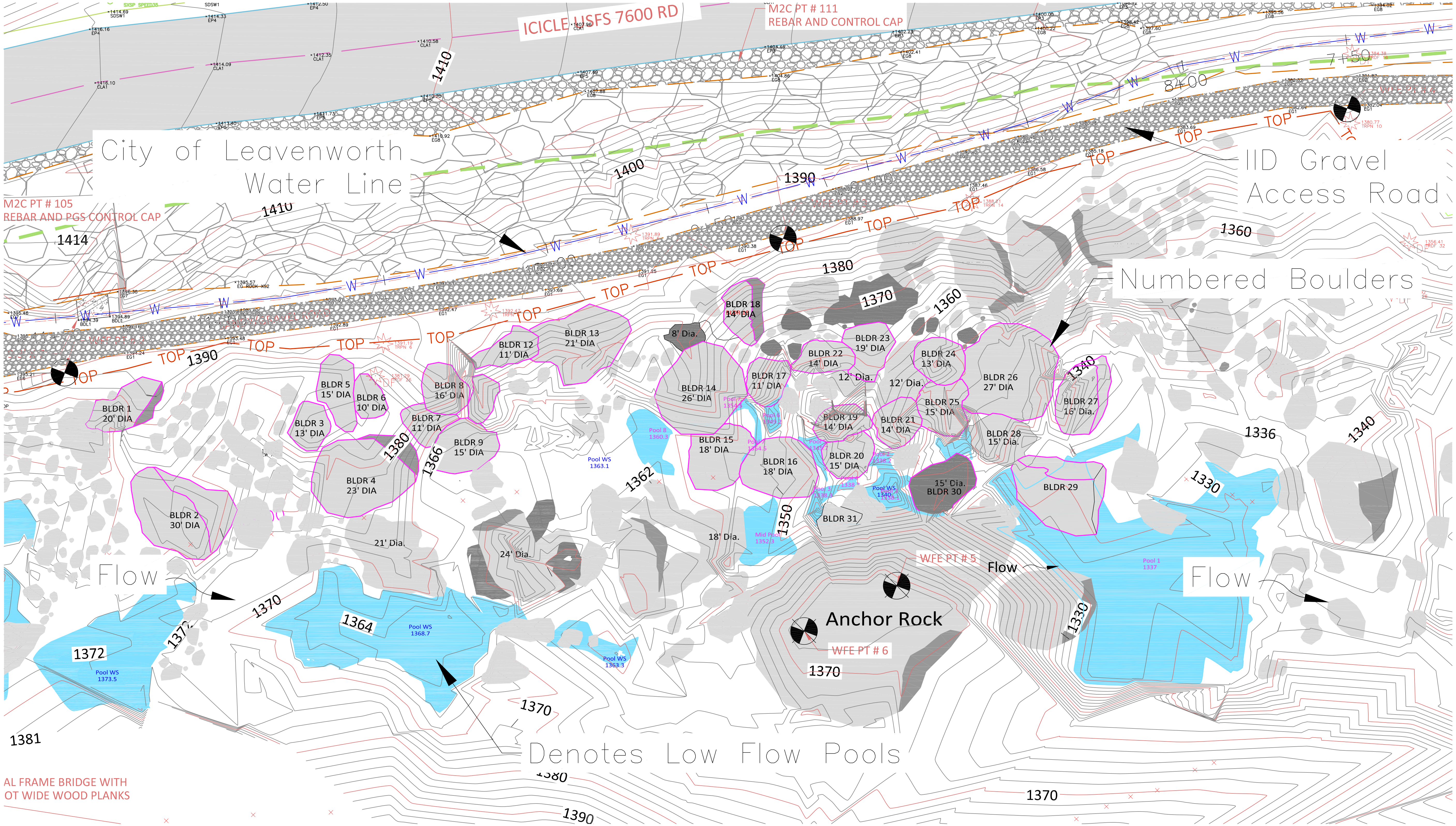
DESIGN BY: Waterfall Engineering

DRAWN BY: RiverSide Drafting

DATE: 05/24/2015

Location of Control Points

3 SHEET 17 OF



Site Plan - Existing

SCALE: 1"= 30'

0 30

SCALE

Icicle Boulder Field Passage Design

REV	DATE	BY	APP'D	DESCRIPTION

SCALE VERIFICATION

BAR IS ONE INCH ON ORIGINAL DRAWING.

0 1"

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DESIGN BY: Waterfall Engineering

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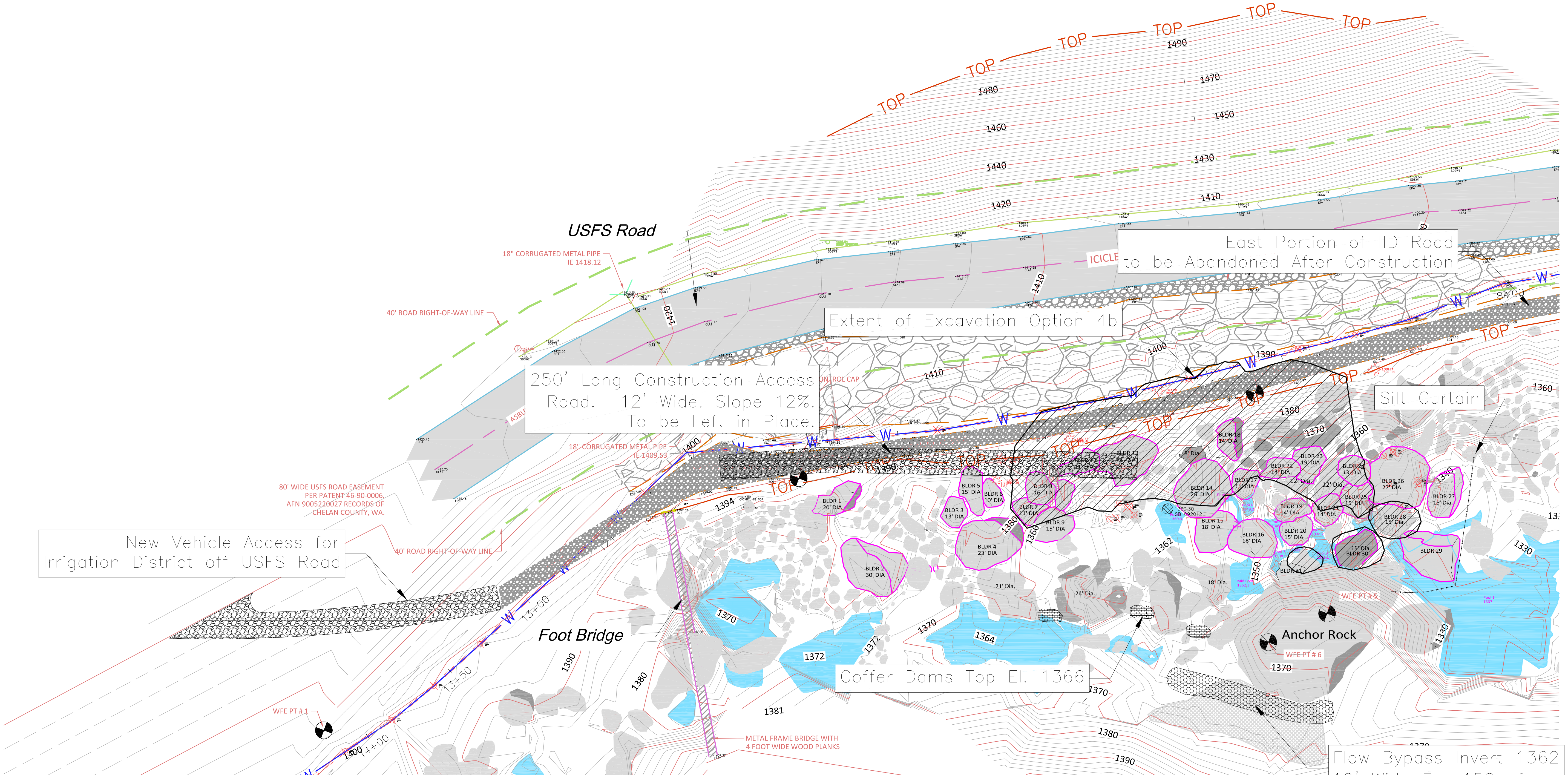
DATE: 05/24/2015

Site Plan - Existing

4 SHEET 17 OF



Site Plan

SCALE: 1"= 50'

Hatch Denotes Area of Proposed Construction

TROUT UNLIMITED	Icicle Boulder Field Passage Design

REV	DATE	BY	APP'D	DESCRIPTION

SCALE VERIFICATION — BAR IS ONE INCH ON ORIGINAL DRAWING. 0 — 1" — IF NOT ONE INCH ON THIS SHEET, ADJUST SCALES ACCORDINGLY.

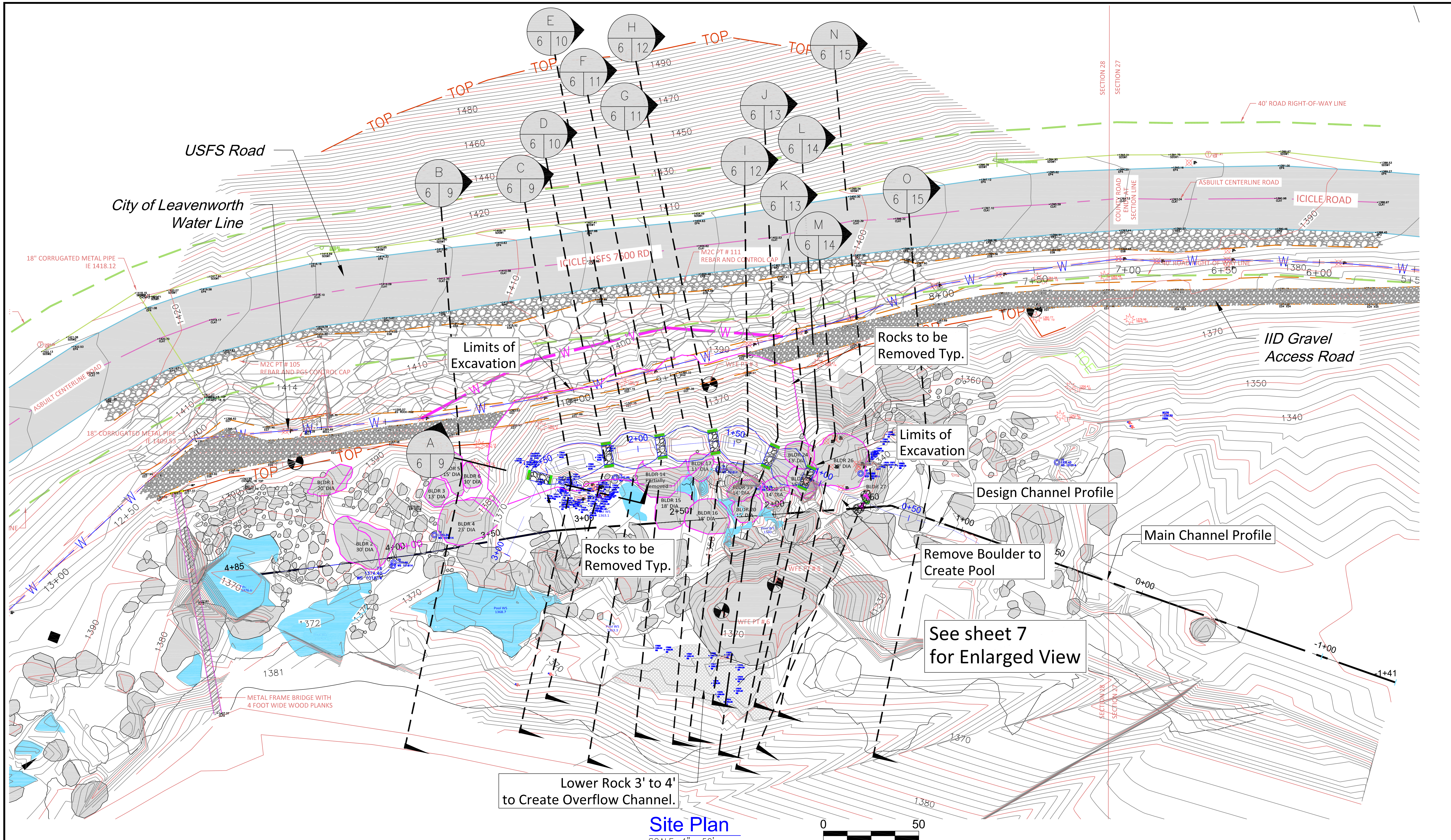
DESIGN BY: Waterfall Engineering

DRAWN BY: RiverSide Drafting

DATE: 10/2/15

Construction Access Dewatering Plan

SHEET 5 OF 17



Icicle Boulder Field Passage Design

REV	DATE	BY	APP'D	DESCRIPTION

SCALE VERIFICATION

BAR IS ONE INCH ON ORIGINAL DRAWING.

0 1"

IF NOT ONE INCH ON THIS SHEET, ADJUST SCALES ACCORDINGLY.

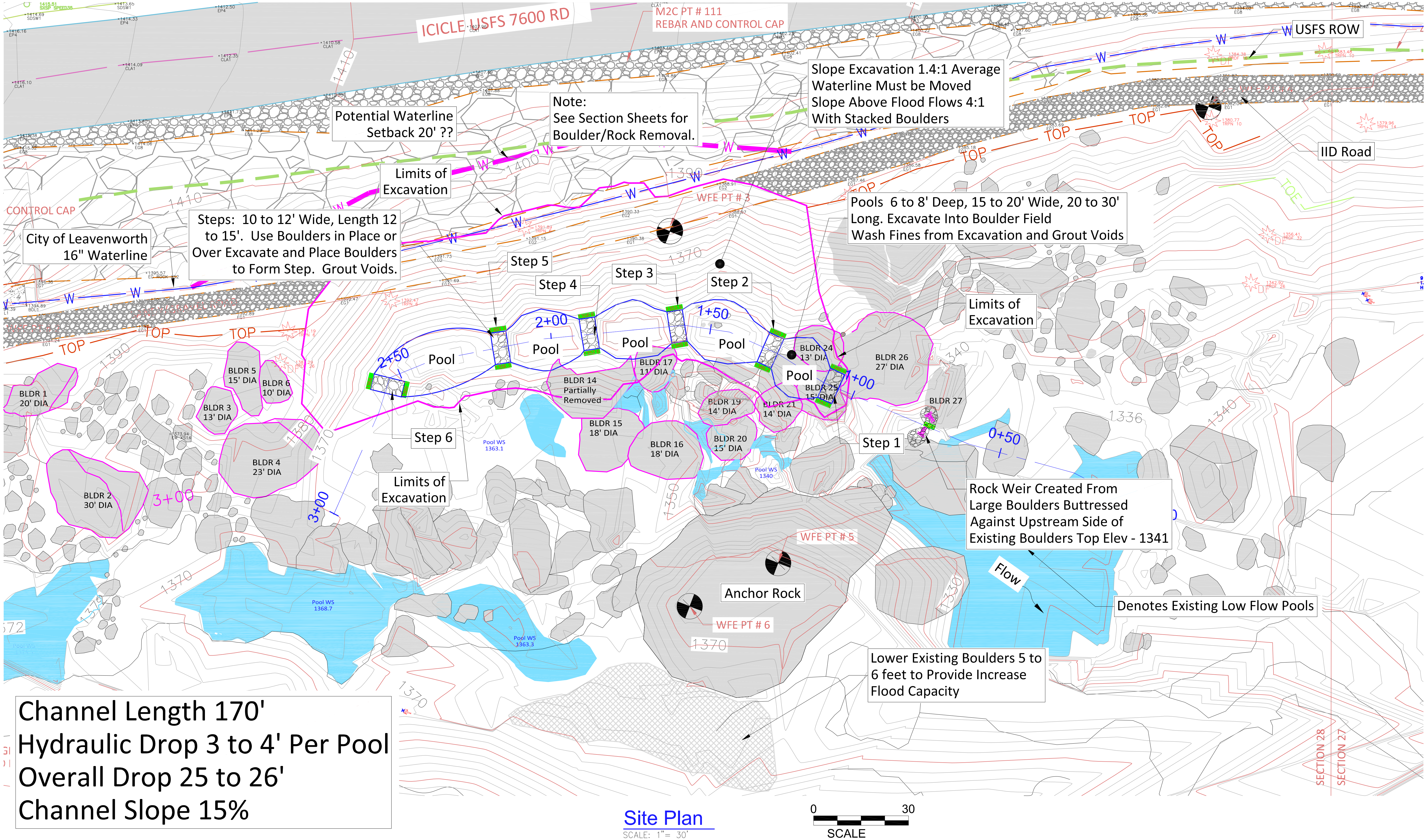
DESIGN BY: Waterfall Engineering

DRAWN BY: RiverSide Drafting

DATE: 05/24/2015

Site Plan - Option 4b

6 SHEET 17 OF



Site Plan
SCALE: 1" = 30'

Icicle Boulder Field Passage Design

REV	DATE	BY	APP'D	DESCRIPTION

SCALE VERIFICATION
BAR IS ONE INCH ON ORIGINAL DRAWING. 0 1"
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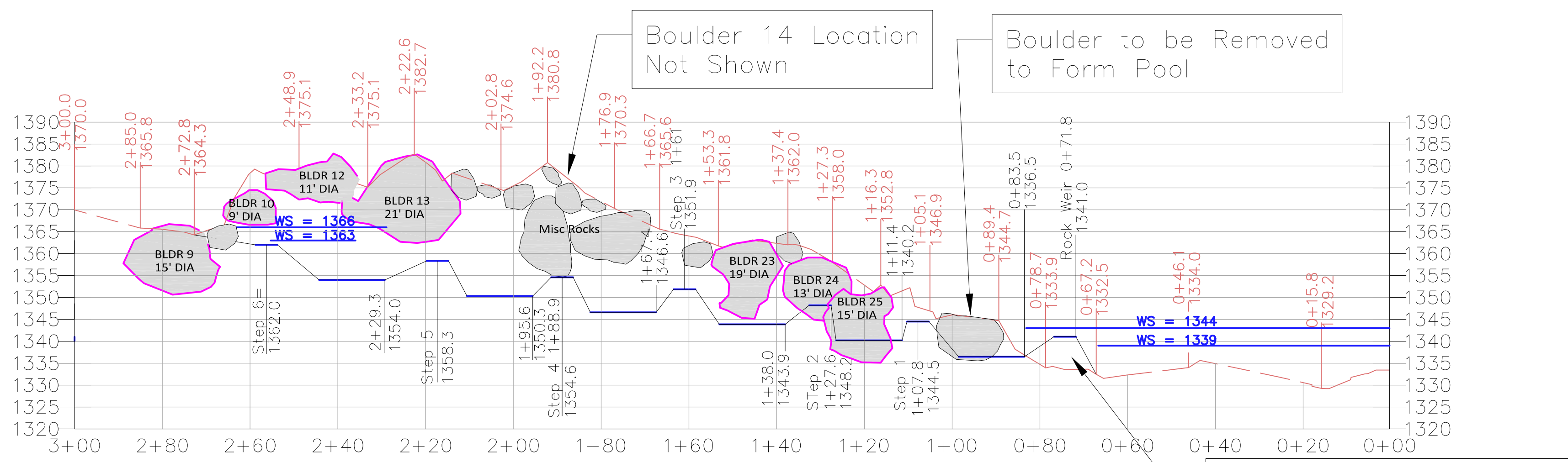
DESIGN BY: Waterfall Engineering
DRAWN BY: RiverSide Drafting
DATE: 10/2/15

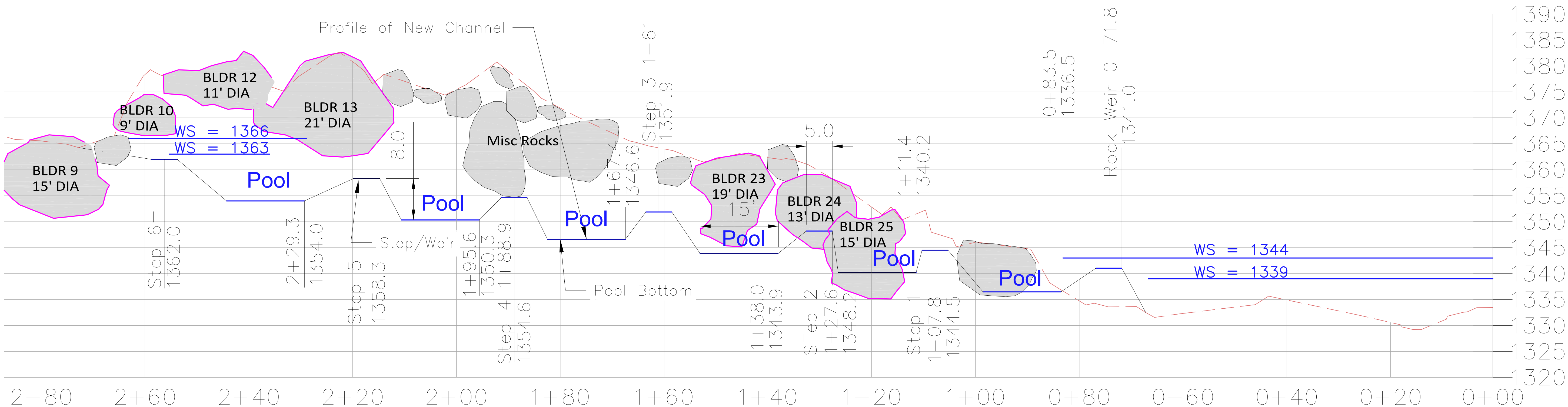
Site Plan - Option 4b
Enlarged View

TROUT UNLIMITED



Option 4b - Overall Channel Profile

SCALE: 1"= 40'



Option 4b - Channel Profile - Enlarged View

SCALE: 1"= 20'

TROUT UNLIMITED

Icicle Boulder Field Passage Design

REV	DATE	BY	APP'D	DESCRIPTION

SCALE VERIFICATION

BAR IS ONE INCH ON ORIGINAL DRAWING. 0 1"

IF NOT ONE INCH ON THIS SHEET, ADJUST SCALES ACCORDINGLY.

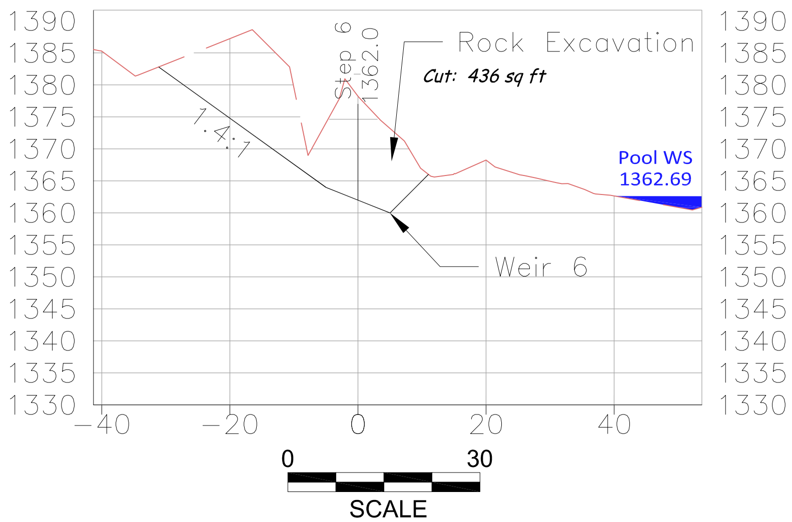
DESIGN BY: Waterfall Engineering

DRAWN BY: RiverSide Drafting

DATE: 10/2/15

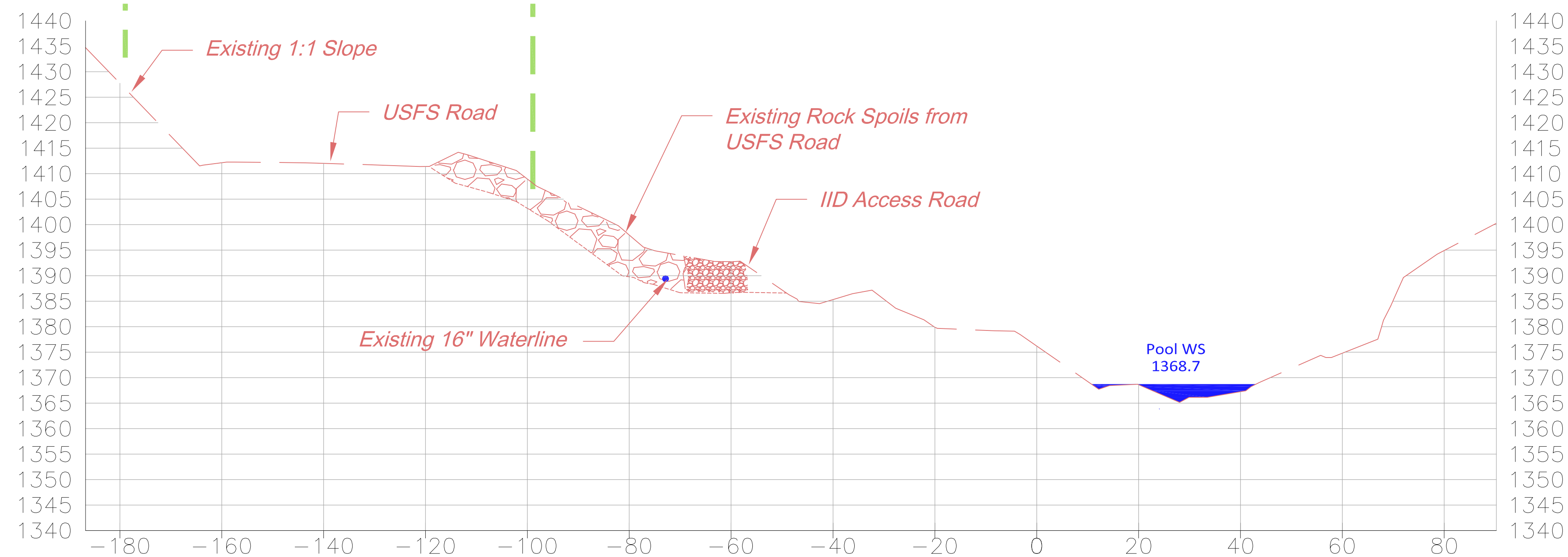
Channel Profile

8 SHEET 17 OF



Channel Section A (View Downstream)

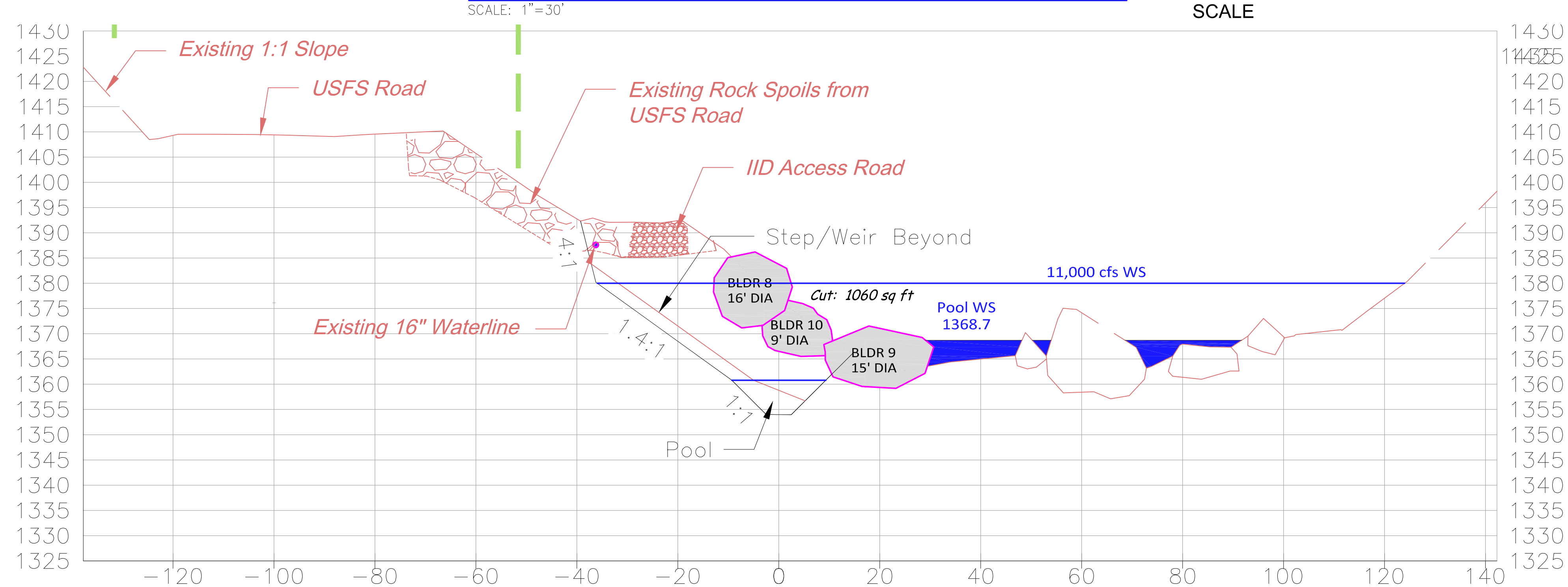
SCALE: 1"=30'



Typical Channel Section B (View Downstream)

SCALE: 1"=30'

0 30
SCALE



Channel Section C (View Downstream)

SCALE: 1"=30'

0 30
SCALE

TROUT UNLIMITED

Icicle Boulder Field Passage Design

REV	DATE	BY	APP'D	DESCRIPTION

SCALE VERIFICATION

BAR IS ONE INCH ON ORIGINAL DRAWING. 0 1"

IF NOT ONE INCH ON THIS SHEET, ADJUST SCALES ACCORDINGLY.

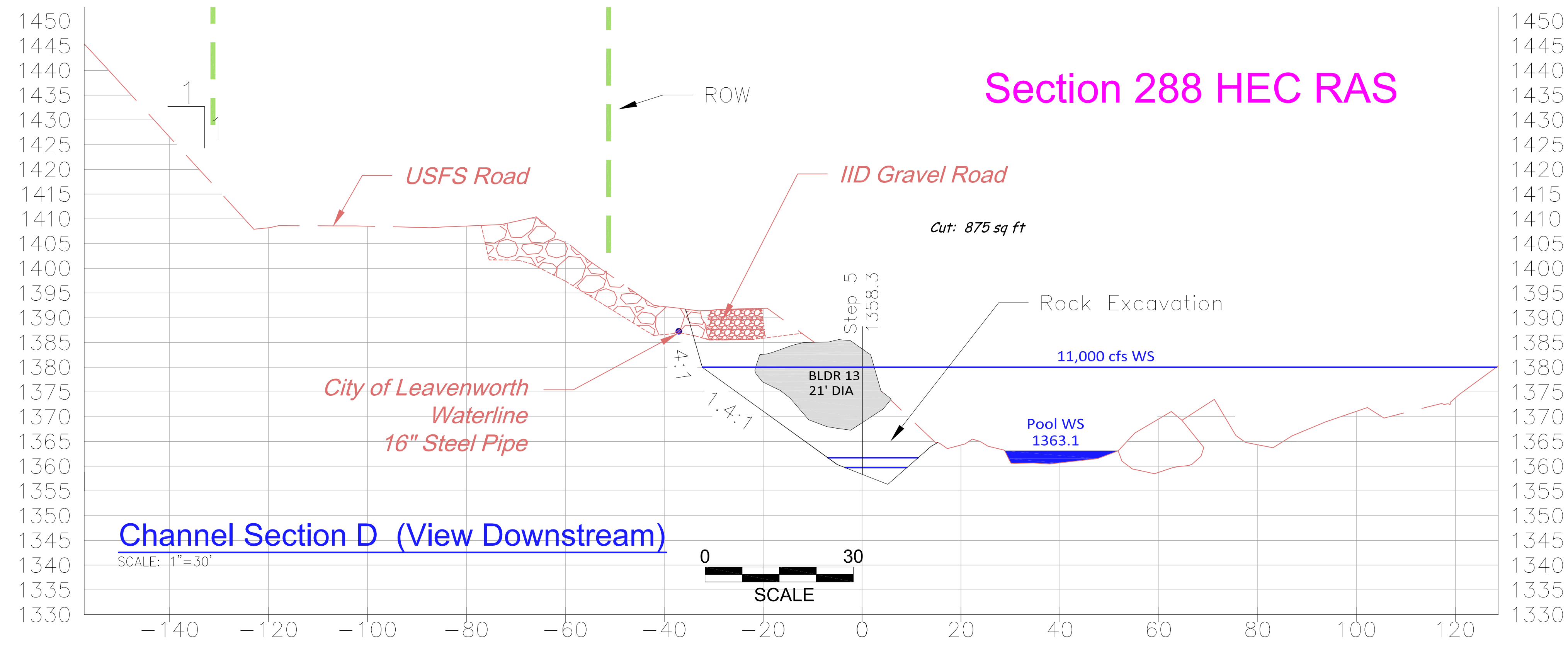
DESIGN BY: Waterfall Engineering

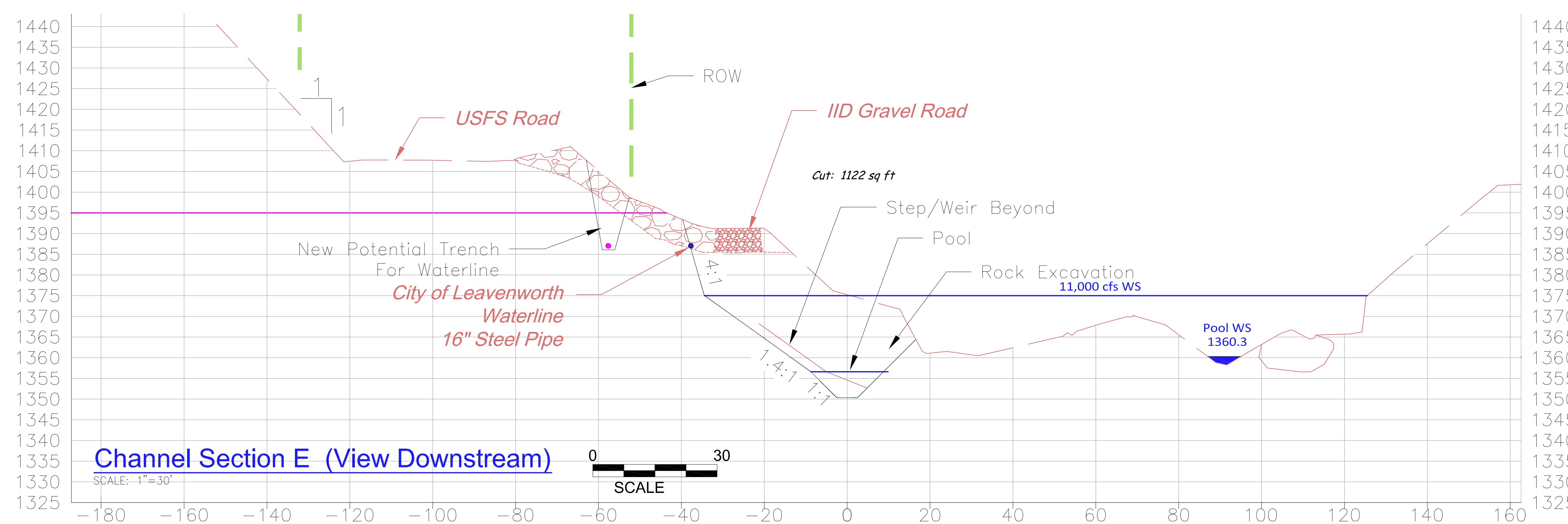
DRAWN BY: RiverSide Drafting

DATE: 05/24/2015

Section A to C

9 SHEET 17 OF





Icicle Boulder Field Passage Design

REV	DATE	BY	APP'D	DESCRIPTION

SCALE VERIFICATION

BAR IS ONE INCH ON ORIGINAL DRAWING. 0 1"

IF NOT ONE INCH ON THIS SHEET, ADJUST SCALES ACCORDINGLY.

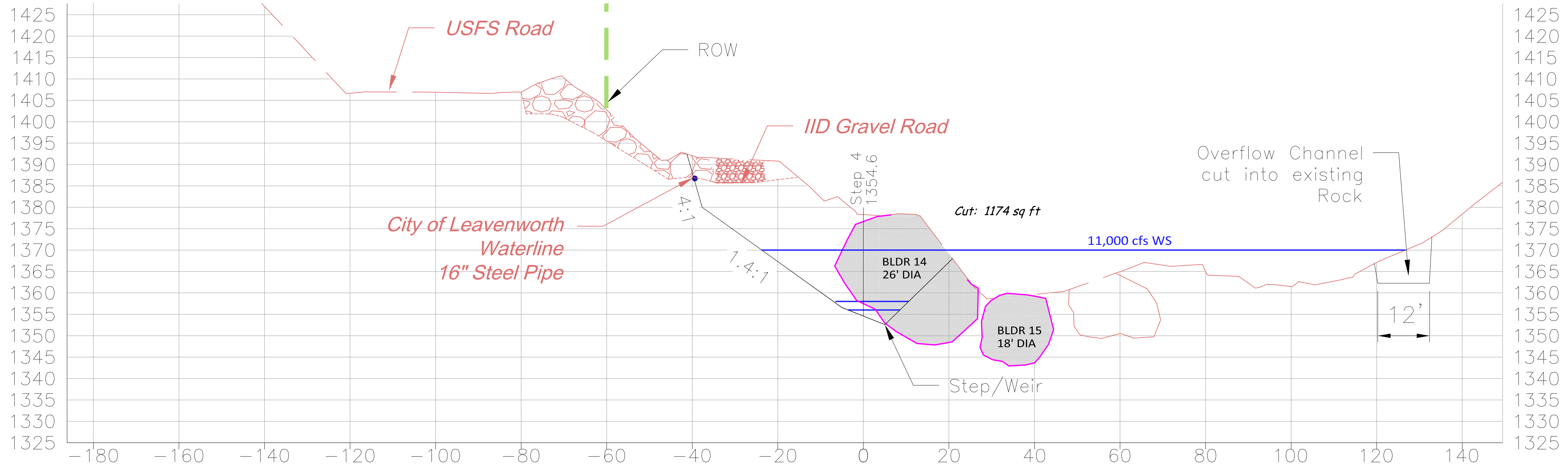
DESIGN BY: Waterfall Engineering

DRAWN BY: RiverSide Drafting

DATE: 05/24/2015

Sections D and E

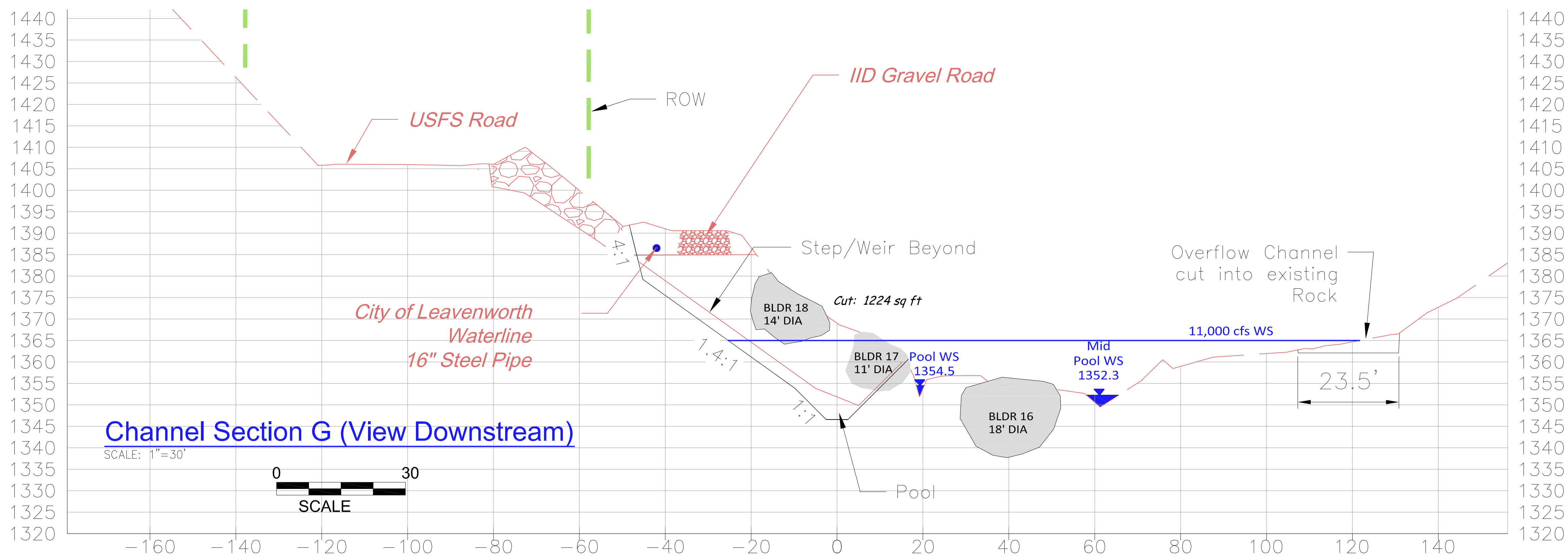
10 SHEET 17 OF



Channel Section F (View Downstream)

SCALE: 1"=30'

0 30
SCALE



Channel Section G (View Downstream)

SCALE: 1"=30'

0 30
SCALE

TROUT UNLIMITED

Icicle Boulder Field Passage Design

REV	DATE	BY	APP'D	DESCRIPTION

SCALE VERIFICATION

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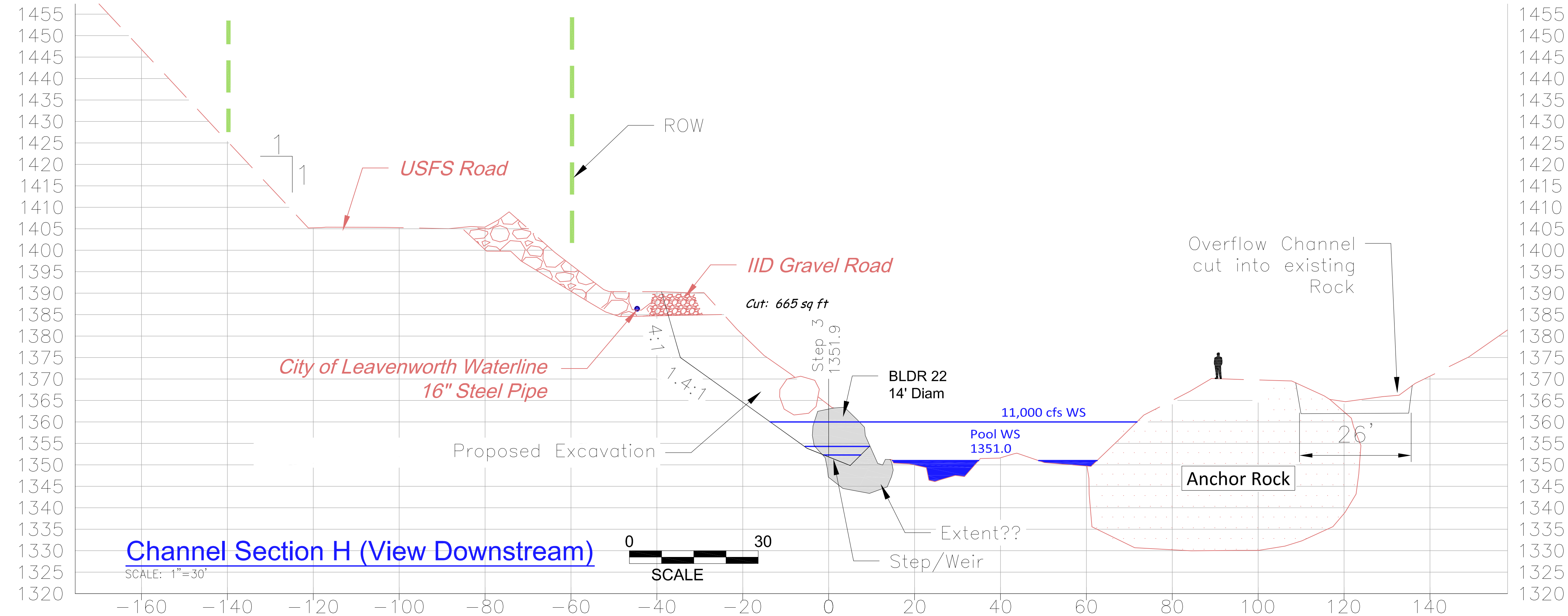
DESIGN BY: Waterfall Engineering

DRAWN BY: RiverSide Drafting

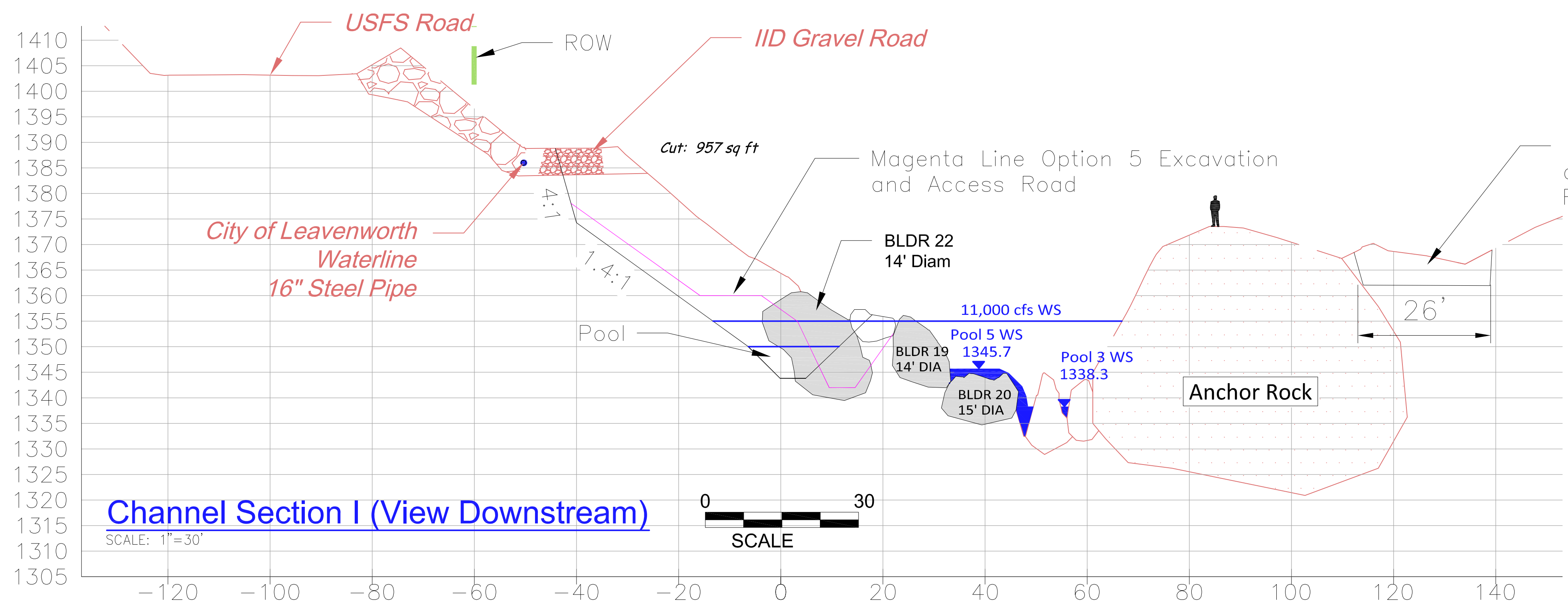
DATE: 05/24/2015

Sections F AND G

11 SHEET 17 OF



Channel Section H (View Downstream)



Channel Section I (View Downstream)

TROUT UNLIMITED

Icicle Boulder Field Passage Design

REV	DATE	BY	APP'D	DESCRIPTION

SCALE VERIFICATION

BAR IS ONE INCH ON ORIGINAL DRAWING. 0 1"

IF NOT ONE INCH ON THIS SHEET, ADJUST SCALES ACCORDINGLY.

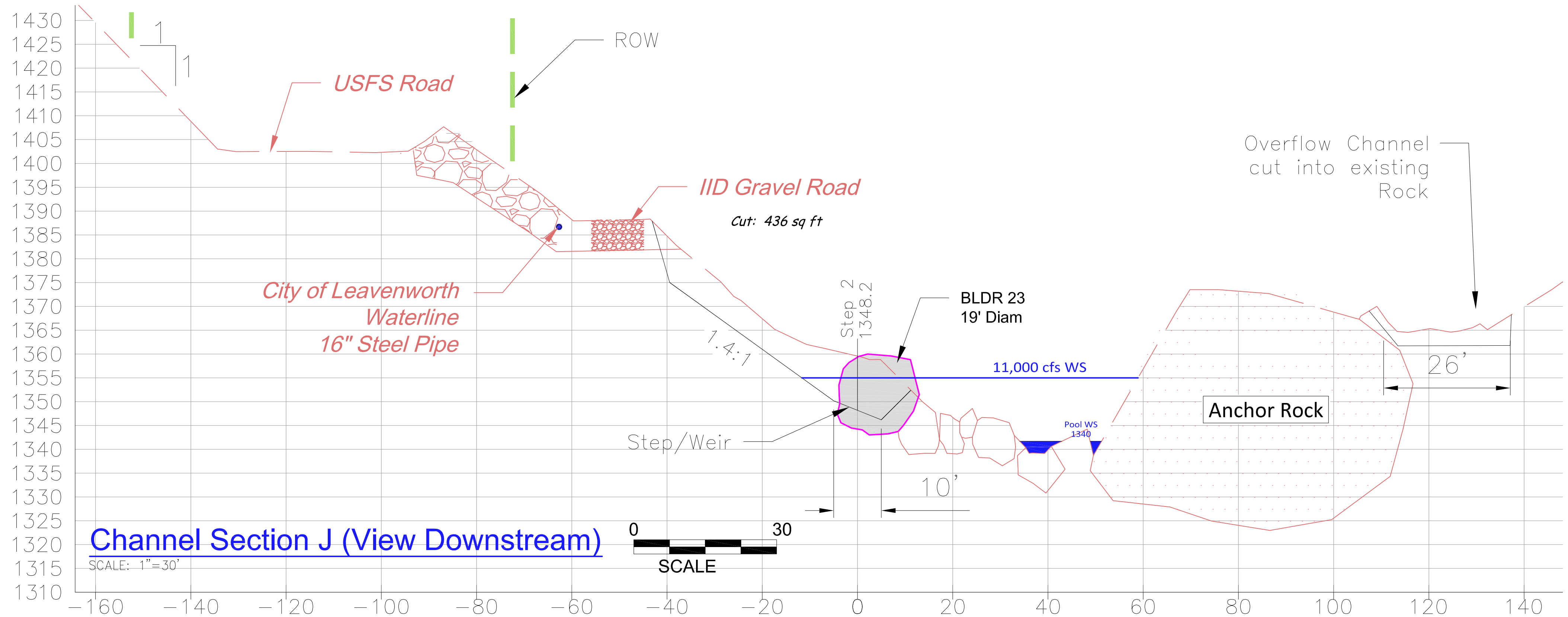
DESIGN BY: Waterfall Engineering

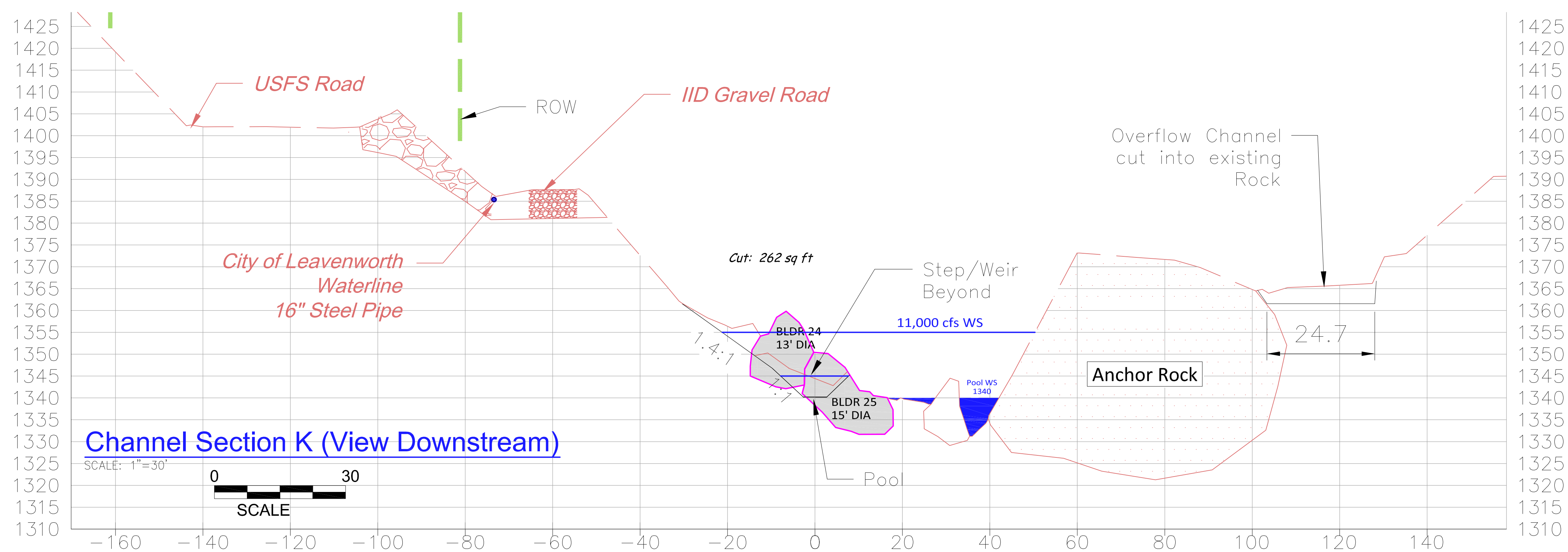
DRAWN BY: RiverSide Drafting

DATE: 10/2/15

Sections H and I

12 SHEET 17 OF





TROUT UNLIMITED

Icicle Boulder Field Passage Design

REV	DATE	BY	APP'D	DESCRIPTION

SCALE VERIFICATION

BAR IS ONE INCH ON ORIGINAL DRAWING. 0 1"

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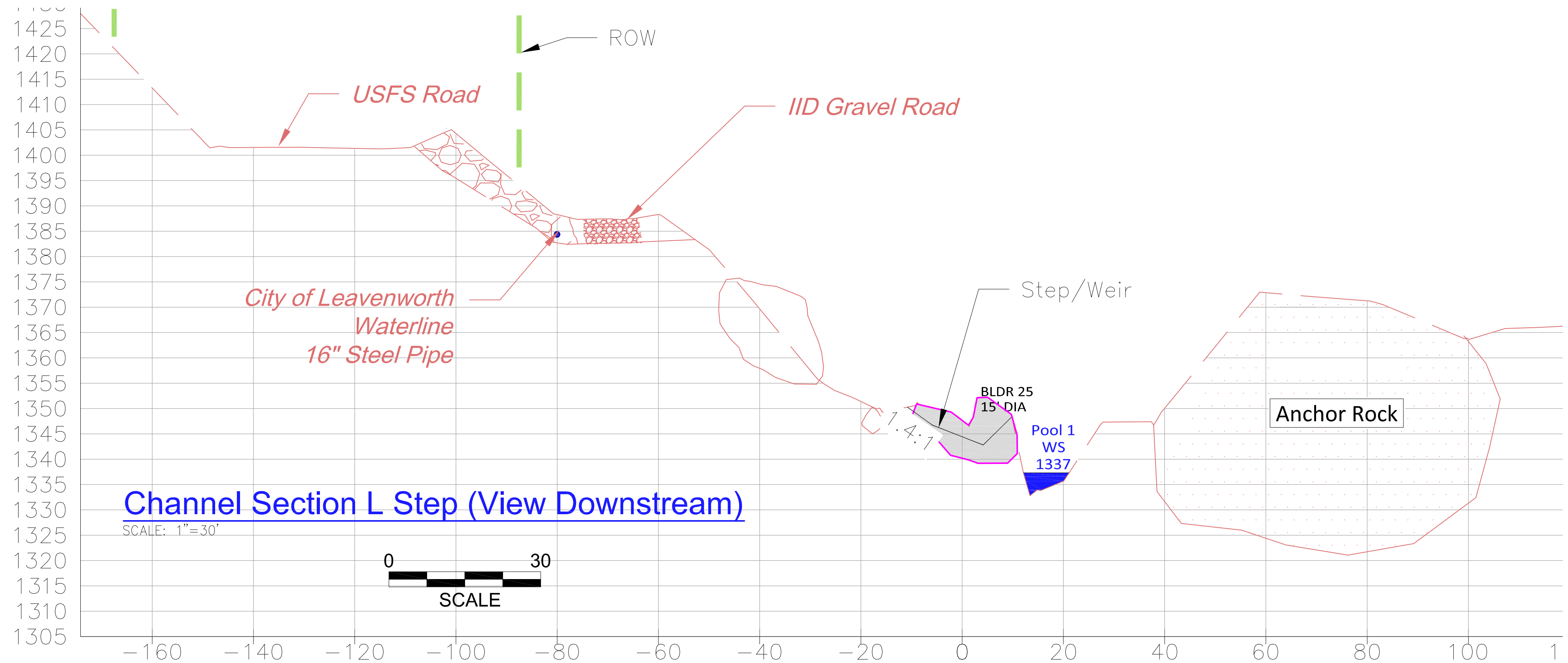
DESIGN BY: Waterfall Engineering

DRAWN BY: RiverSide Drafting

DATE: 10/2/15

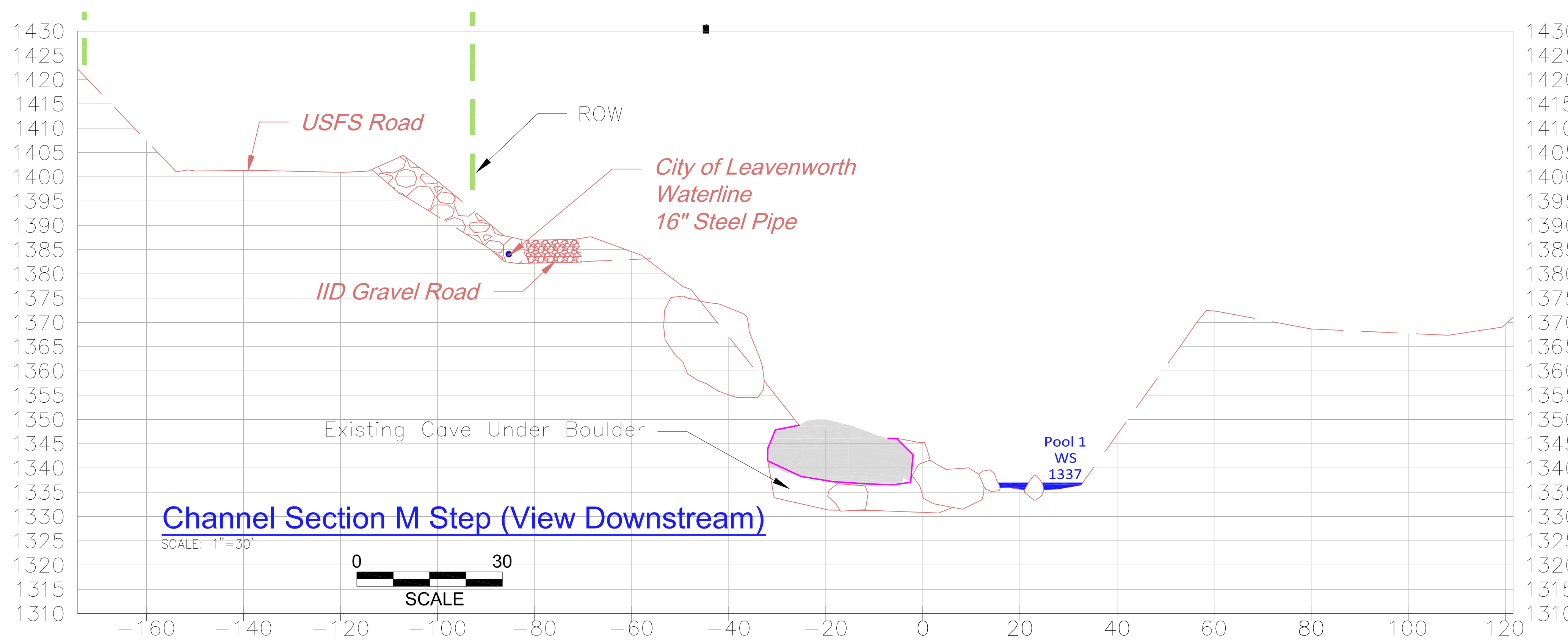
Section J and K

13 SHEET 17 OF



Channel Section L Step (View Downstream)

SCALE: 1"=30'



Channel Section M Step (View Downstream)

SCALE: 1"=30'

TROUT UNLIMITED

Icicle Boulder Field Passage Design

REV	DATE	BY	APP'D	DESCRIPTION

SCALE VERIFICATION

BAR IS ONE INCH ON ORIGINAL DRAWING. 0 1"

IF NOT ONE INCH ON THIS SHEET, ADJUST SCALES ACCORDINGLY.

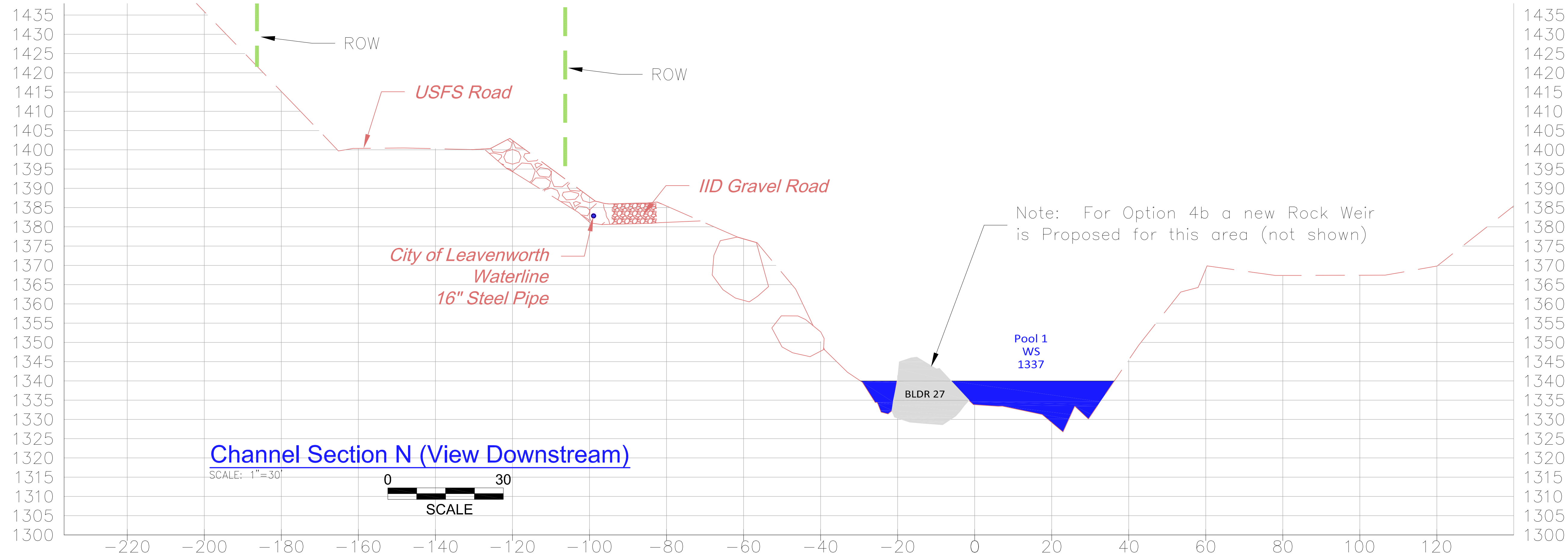
DESIGN BY: Waterfall Engineering

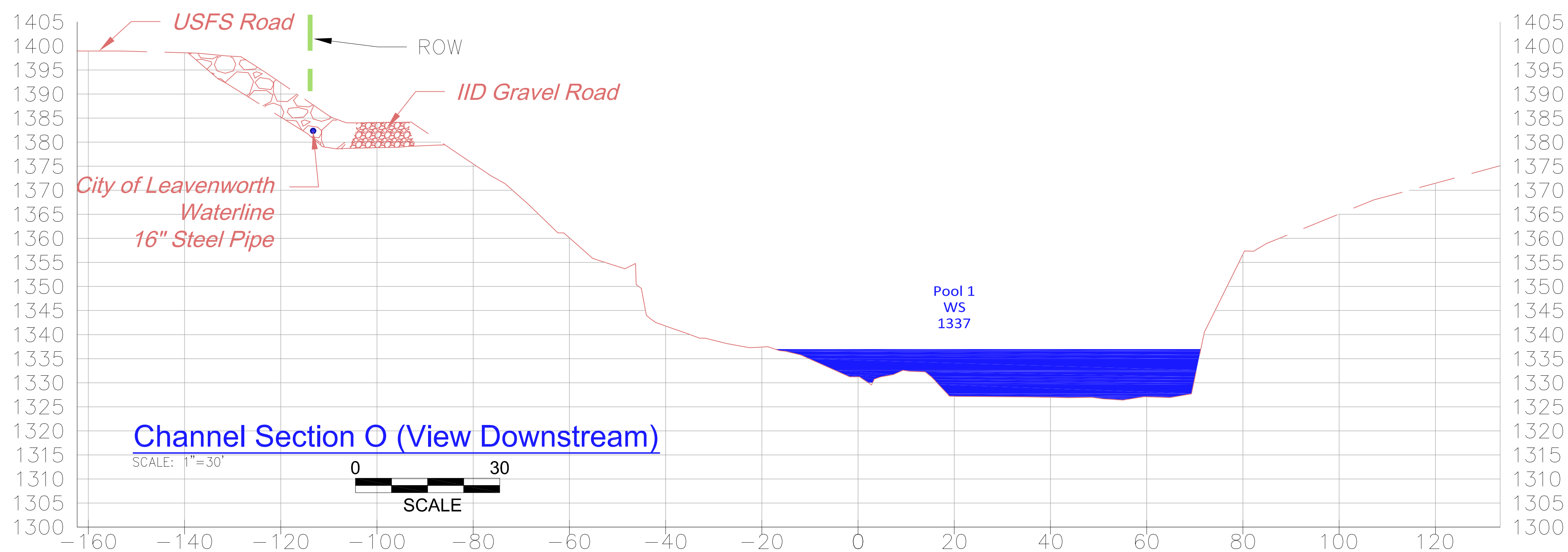
DRAWN BY: RiverSide Drafting

DATE: 05/24/2015

Section L and M

14 SHEET 17 OF





TROUT UNLIMITED

Icicle Boulder Field Passage Design

REV	DATE	BY	APP'D	DESCRIPTION

SCALE VERIFICATION

BAR IS ONE INCH ON ORIGINAL DRAWING.

0 1"

IF NOT ONE INCH ON THIS SHEET, ADJUST SCALES ACCORDINGLY.

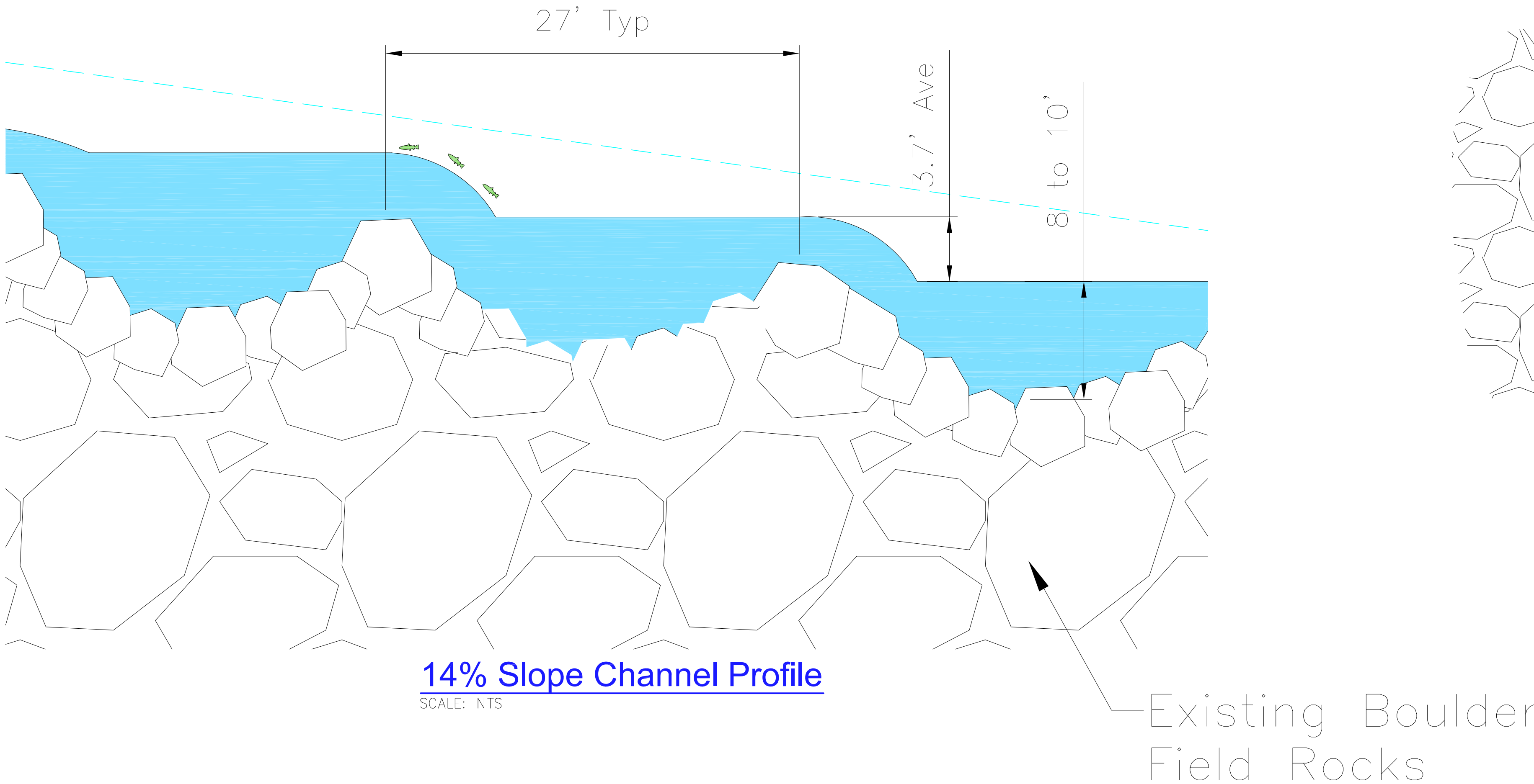
DESIGN BY:
Waterfall Engineering

DRAWN BY:
RiverSide Drafting

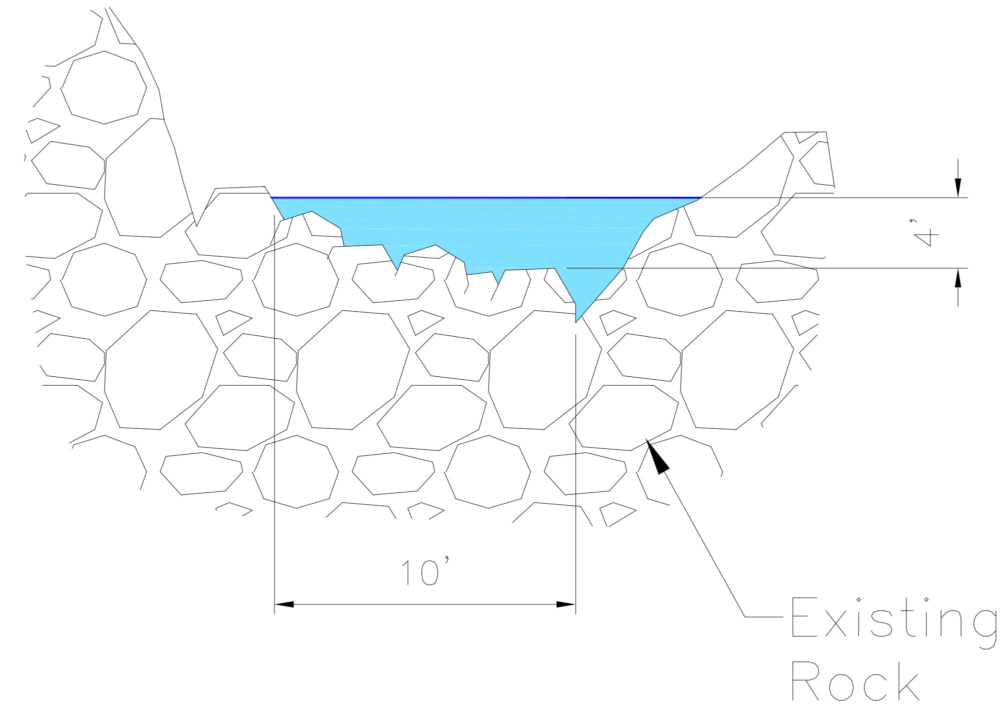
DATE:
10/2/15

Section N & O

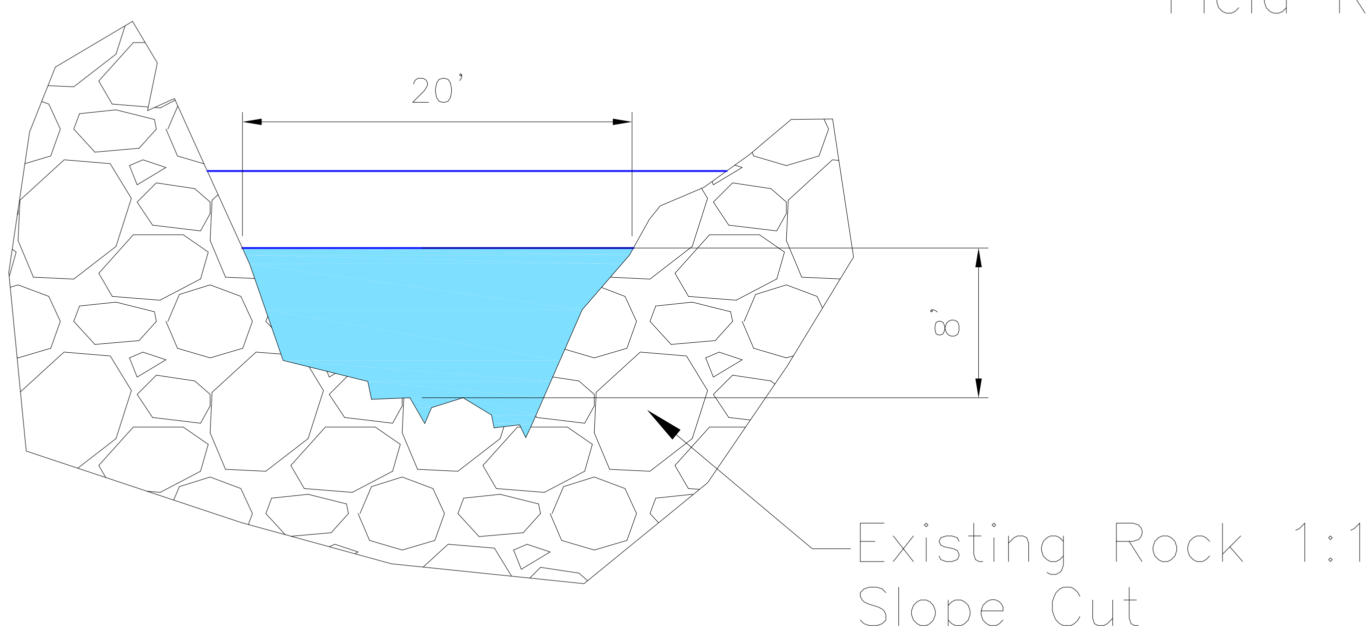
15 SHEET 17 OF



14% Slope Channel Profile
SCALE: NTS



Typical Step/Weir (View D/S)
SCALE: NTS



Typical Pool Detail
SCALE: 1"= 10'

Icicle Boulder Field Passage Design

REV	DATE	BY	APP'D	DESCRIPTION

SCALE VERIFICATION
BAR IS ONE INCH ON ORIGINAL DRAWING.
0 1"
IF NOT ONE INCH ON THIS SHEET, ADJUST SCALES ACCORDINGLY.

DESIGN BY:
Waterfall Engineering
DRAWN BY:
RiverSide Drafting
DATE:
10/2/15

Fishway Details

17 SHEET 17 OF

Icicle Creek Boulder Field Passage Design — Yellow Color Denotes Calculation

Site: Boulder Field
Date: 8/24/15
Estimate By: Waterfall Engineering
Design Level: 70% Channel, 10% Waterline

Proposed Correction: *Design Option 4b: Remove 350' of Access Road, Relocate 300' of 16" Waterline Construct a 160' long, 14% sloped Step/Pool Rock Fishway with Six drops each 3.7', Steps 10' Wide, Pools 20' Wide by 25' Long. Make Rock Blasting Modifications to the Main Spill Channel Adjacent to the*

Description	Unit	CAD Qty	Mult	Bid Qty	Cost	Amount	Sub Total	Notes
Mobilize								
Mobilize	L.S.	1			$120,000	$120,000		
Access	L.S.	1			$15,000	$15,000		Build Road Down to Site From USFS Road
Stream Bypass	L.S.	1			$0	$0		Not Possible Too Much Flow
Dewater (Pumps, Etc)	L.S.	1			$20,000	$20,000		Cofferdams and Pumping
Fish Removal	L.S.	1			$5,000	$5,000		
SUBTOTAL							$160,000	
Channel Excavation and Form Steps								
Total Excavation		**5148**						Total Excavation is 5148 cu yds
Large Exposed Boulder Blasting	C.Y.	740	1.2	888	$200.00	$177,600		15 Boulders Larger Than 10' Diameter
Additional Buried Boulder Blasting	C.Y.	2349	1.2	2818.6	$200.00	$563,712		
General Rock Excavation	C.Y.	2059	1.2	2471	$60.00	$148,262		
Loading Trucks	C.Y.	5148	1.2	6177.6	$15.00	$92,664		3 cu yd size, 66" Diam Approx
Disposal	C.Y.	5148	1.2	6177.6	$10.00	$61,776		Rock Disposed of Within 5 Miles
Step Construction (6)	C.Y.	375	1.2		$150.00	$67,500		Use Boulders From Excavation Includes Grout
Concrete/Grout Seal	C.Y.	40	1.2		$1,000.00	$48,000		Low Flow Channel Seal
Additional Rock Removal	C.Y.	50	1.2		$200.00	$12,000		Rock in Spill Area to Redirect Flow
15' High Rock Wall	L.S.	1			$80,000	$80,000		Needs to be Designed
SUBTOTAL							$1,251,514	
Waterline Relocation								
Temp. Relocation During Constructio	L.S.	1			$45,000.00	$45,000		
Excavation/Disposal	C.Y.	1000	1.2		$200.00	$240,000		***Note: The waterline relocation plan has not been aproved by the City of Leavenworth. This estimate is conceptual only and requires further design and discussion with the USFS and the City of Leavenworth. Relocation area may be on the USFS ROW.***
16" Ductile Iron Pipe	FT.	300	1.2		$180.00	$64,800		
30" HDPE Casing	FT.	300	1.2		$73.00	$26,280		
Connections	L.S.	1			$10,000.00	$10,000		
Backfill/Compaction	C.Y.	300	1.2		$45.00	$16,200		
SUBTOTAL							$402,280	
CONSTRUCTION SUB TOTAL							$1,813,794	
Contingencies	25%						$453,449	
Sales Tax	8.0%						$181,379	
CONSTRUCTION TOTAL							$2,448,622	

Opinions of Probable Construction Cost
In providing opinions of probable construction cost, the Client understands that the Consultant (Waterfall Engineering, L.L.C.) has no control over the cost or availability of labor, equipment or materials, or over market condition or the Contractor's method of pricing, and the consultant's opinions of probable construction costs are made on the basis of the Consultant's professional judgment and experience. The Consultant makes no warranty, express of implied that the bids or the negotiated cost of the Work will not vary from the Consultant's opinion of probable construction cost.

APPENDIX B – DIVERSION DAM DESIGN DRAWINGS AND COST ESTIMATE

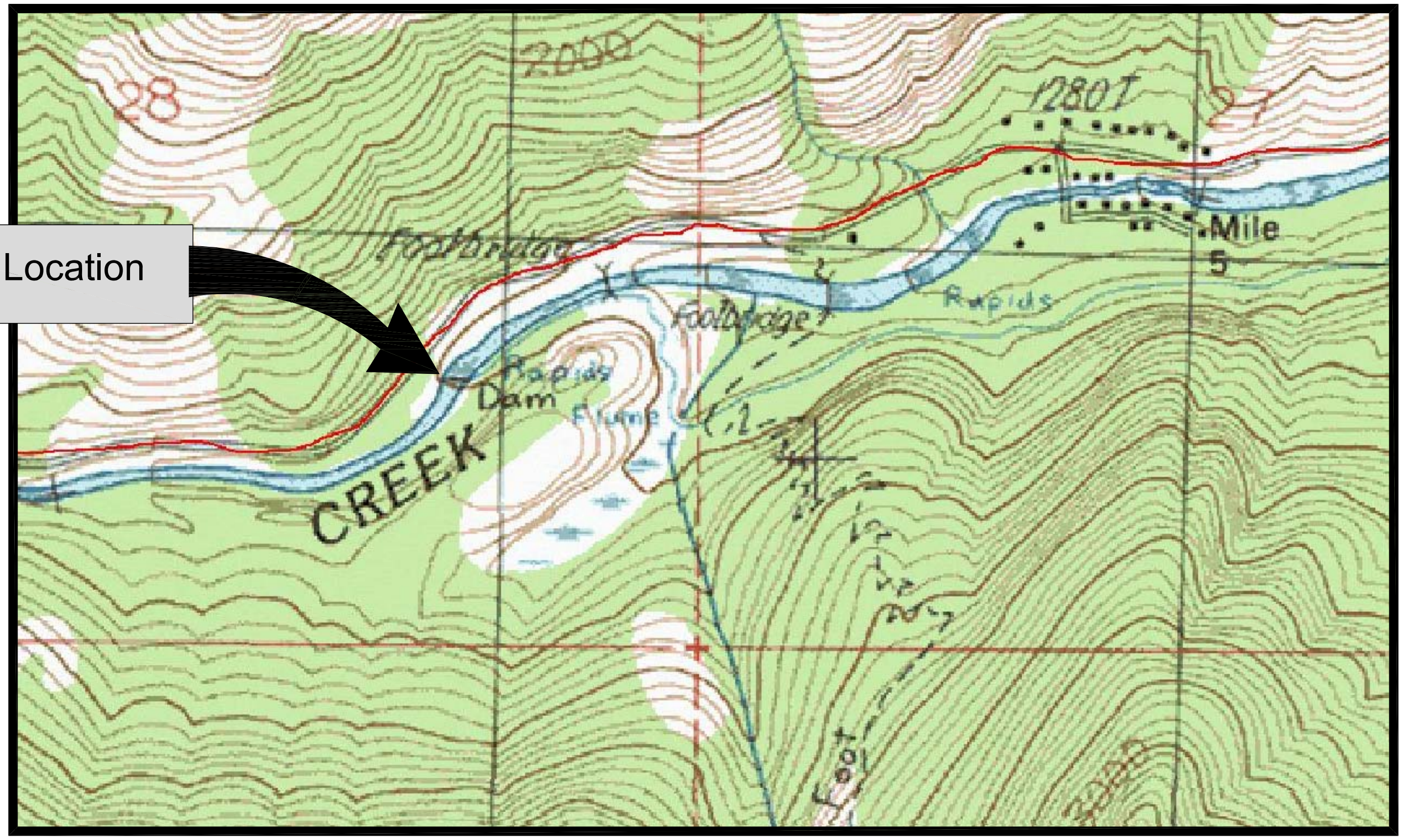
Preliminary Design Documents

Icicle Creek - Diversion Dam Pool and Chute Fishway

Project Number 13-1342

DRAWING INDEX:

Project Location



VICINITY MAP
NOT TO SCALE

Example of Pool and Chute Fishway on Yakima River

REV	DATE	BY	APP'D	DESCRIPTION

SCALE VERIFICATION: BAR IS ONE INCH ON ORIGINAL DRAWING. 0 — 1". IF NOT ONE INCH ON THIS SHEET, ADJUST SCALES ACCORDINGLY.

Icicle Creek Diversion Dam Pool and Chute Fishway

DESIGN BY: Waterfall Engineering
DRAWN BY: RiverSide Drafting and Design
DATE: 10/2/15

Cover Sheet

1 SHEET 4 OF

TROUT UNLIMITED

Icicle Creek Diversion Dam
Pool and Chute Fishway

REV	DATE	BY	APP'D	DESCRIPTION

SCALE VERIFICATION

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IF NOT ONE INCH ON THIS SHEET, ADJUST SCALES ACCORDINGLY.

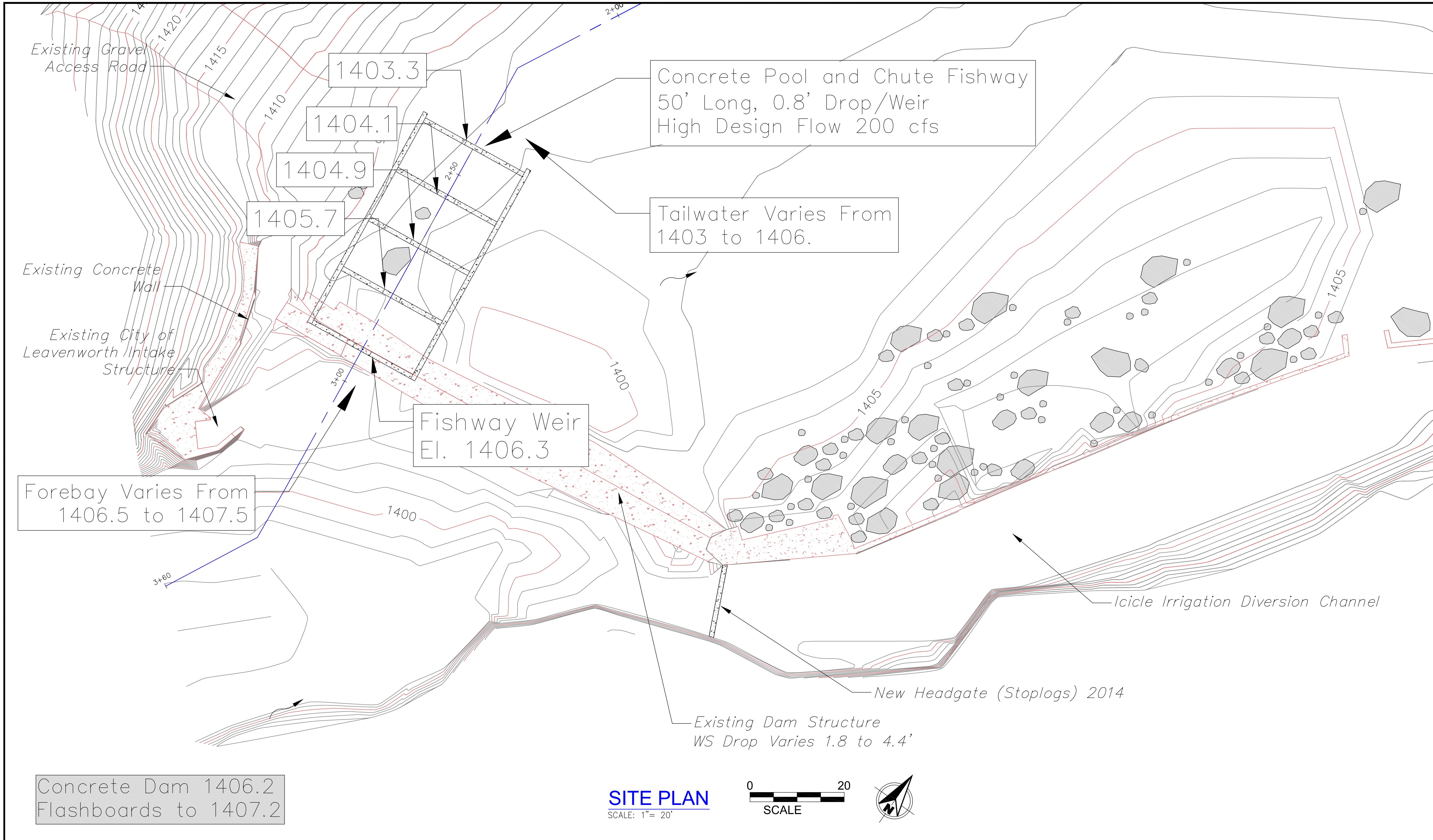
DESIGN BY: Waterfall Engineering

DRAWN BY: RiverSide Drafting and Design

DATE: 10/2/15

Site Plan

SHEET 2 OF 4



TROUT UNLIMITED

Icicle Creek Diversion Dam Pool and Chute Fishway

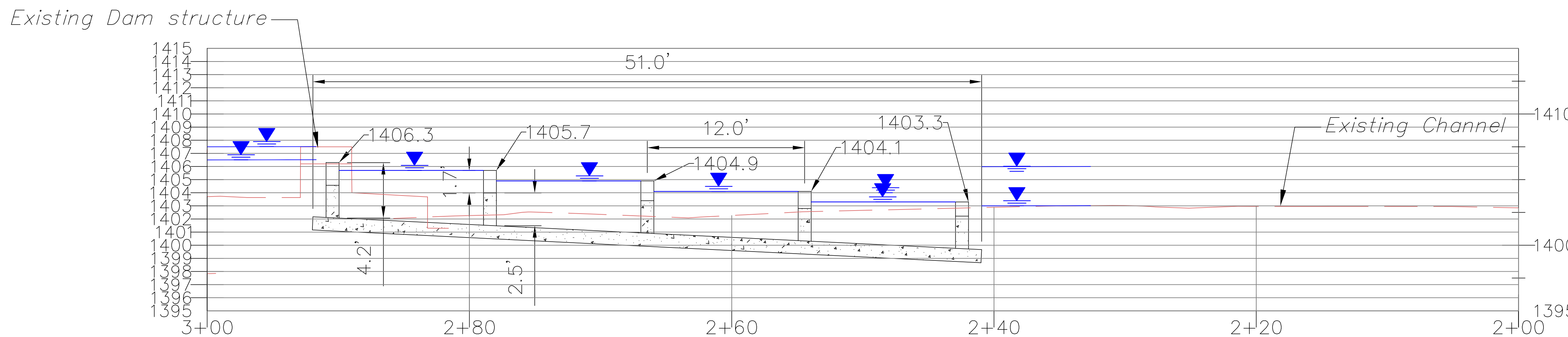
REV	DATE	BY	APP'D	DESCRIPTION

SCALE VERIFICATION — BAR IS ONE INCH ON ORIGINAL DRAWING. 0 1" IF NOT ONE INCH ON THIS SHEET, ADJUST SCALES ACCORDINGLY.

DESIGN BY: Waterfall Engineering
DRAWN BY: RiverSide Drafting and Design
DATE: 10/2/15

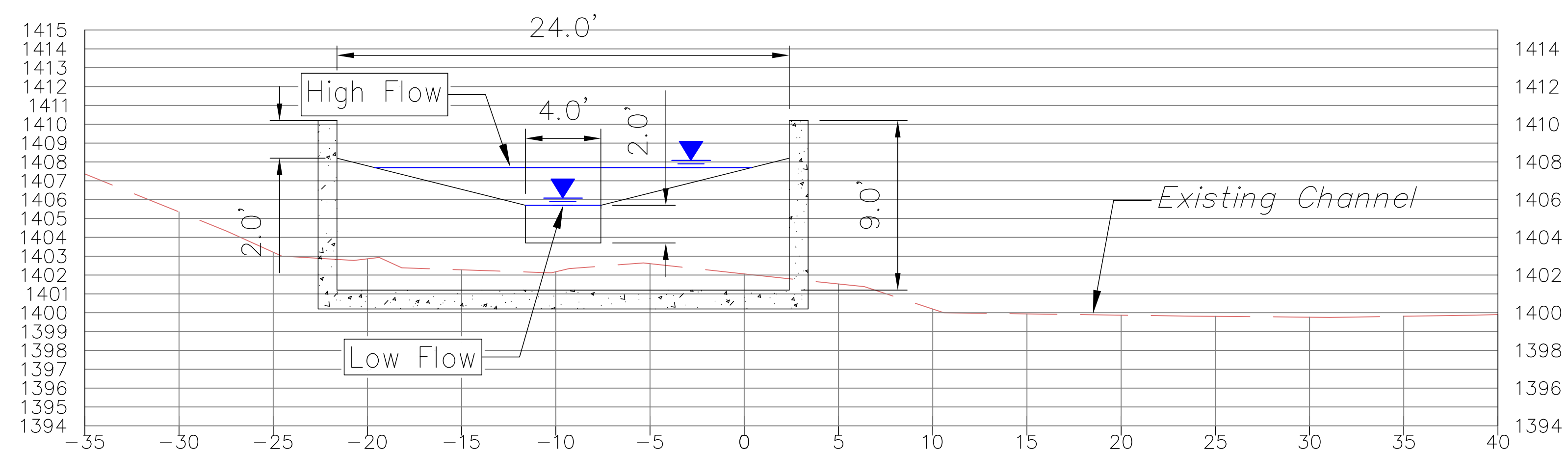
Site Plan

3 SHEET 4 OF



Channel Profile

SCALE: 1"= 10'



Channel Section A (View Downstream)

SCALE: 1"=30'

TROUT UNLIMITED

Icicle Creek Diversion Dam Pool and Chute Fishway

REV	DATE	BY	APP'D	DESCRIPTION

SCALE VERIFICATION

BAR IS ONE INCH ON ORIGINAL DRAWING.

0 1"

IF NOT ONE INCH ON THIS SHEET, ADJUST SCALES ACCORDINGLY.

Waterfall Engineering

DRAWN BY: RiverSide Drafting and Design

DATE: 10/2/15

Profile and Section

4 SHEET 4 OF

Estimate By: Waterfall Engineering
Design Level: 70%

Proposed Correction: Construct a Pool and Chute Concrete Fishway by Removing a section of the dam.

Description	Unit	Calc Quantity	Mult	Cost	Amount	Sub Total	Notes
Mobilize	L.S.	1		$20,000.00	$20,000		
Access	L.S.	1		$8,000.00	$8,000		
Stream Bypass	L.S.	1		$6,000.00	$6,000		
Dewater (Pumps, Etc)	L.S.	1		$6,000.00	$6,000		
Fish Removal	L.S.	1		$1,200.00	$1,200		
Excavation, Rock	C.Y.	220	1.2	$35.00	$9,240		Dispose Along Stream Banks
Steel Plates	L.S.	1		$10,000.00	$10,000		Tops of Weirs
Concrete Walls and Weirs	C.Y.	125	1.1	$1,200.00	$165,000		
Excavation Disposal	C.Y.	220	1.2	$12.00	$3,168		
Partial Dam Removal	L.S.	1		$15,000.00	$15,000		
CONSTRUCTION SUB TOTAL						$243,608	
Contingencies	15%					$36,541	
Sales Tax	8.0%					$22,412	
CONSTRUCTION TOTAL						$302,561	

Opinions of Probable Construction Cost

In providing opinions of probable construction cost, the Client understands that the Consultant (Waterfall Engineering, L.L.C.) has no control over the cost or availability of labor, equipment or materials, or over market condition or the Contractor's method of pricing, an the consultant's opinions of probable construction costs are made on the basis of the Consultant's professional judgment and experience. The Consultant makes no warranty, express of implied that the bids or the negotiated cost of the Work will not vary from the Consultant's opinion of probable construction cost.

APPENDIX C: GEOTECHNICAL ASSESSMENT OF THE ICICLE CREEK BOULDER FIELD STUDY REACH

Geotechnical Assessment of the Icicle Creek Boulder Field Study Reach

Technical Report
SRFB Project #13-1342
October 4, 2015

Geotechnical Assessment of the Icicle Creek Boulder Field Study Reach

Prepared For:

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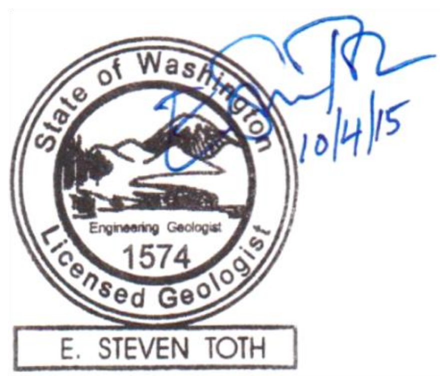

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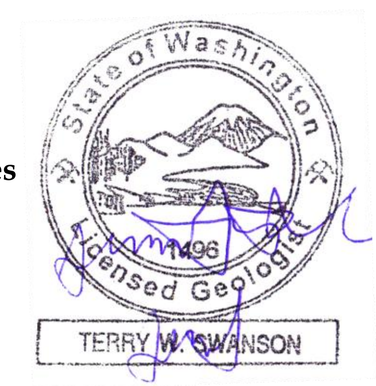

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1.0 Introduction

Trout Unlimited is sponsoring the development of fish passage designs for the Icicle Creek Boulder Field located approximately five miles upstream from the City of Leavenworth. The project site is situated on the north bank of Icicle Creek on Icicle Creek Irrigation District (IID) property. Mr. Patrick Powers, P.E. of Waterfall Engineering is developing preliminary designs for a step-pool fishway on the north bank of Icicle Creek just upstream of the Snow Creek trailhead parking lot. The site is accessed by the IID road, a portion of which would be abandoned as part of the proposed project. The City of Leavenworth has a water supply pipeline located within the road prism that conveys water to their water treatment plant adjacent to the Snow Creek parking lot. The water supply pipeline would likely need to be relocated, at least in part, to construct the proposed fishway.

Toth (2013) previously prepared a geologic assessment of the boulder field for Trout Unlimited. The purpose of this report is to provide a more detailed geologic and geotechnical assessment of the rock and sub-surface conditions in specific portions of the Boulder Field project area. The IID access road was constructed in 1934 as part of the original Icicle Creek Road (Rieman 2001). The current road that accesses upper Icicle Creek, the U.S. Forest Service 7600 Road, was constructed upslope of the original road during the 1960s. In both cases, rock was blasted along the north bank of Icicle Creek when the road grades were constructed. The scope of work for this assessment focused on characterizing rock and sub-surface conditions below the IID access road on the north bank of Icicle Creek.

We had initially planned to excavate temporary test pits along the Irrigation District access road. The purpose of the test pits was to characterize the variability of rocks and overburden under the access road, ascertain the presence of bedrock, and gain insight into potential challenges of excavation for the step-pool fishway. All of the necessary permits were secured to start working, but unfortunately, the location of the City of Leavenworth's water supply line on the inboard side of the road precluded any excavation into the road prism material. The potentially fragile nature of the old pipeline did not allow for any disturbance of the road prism area.

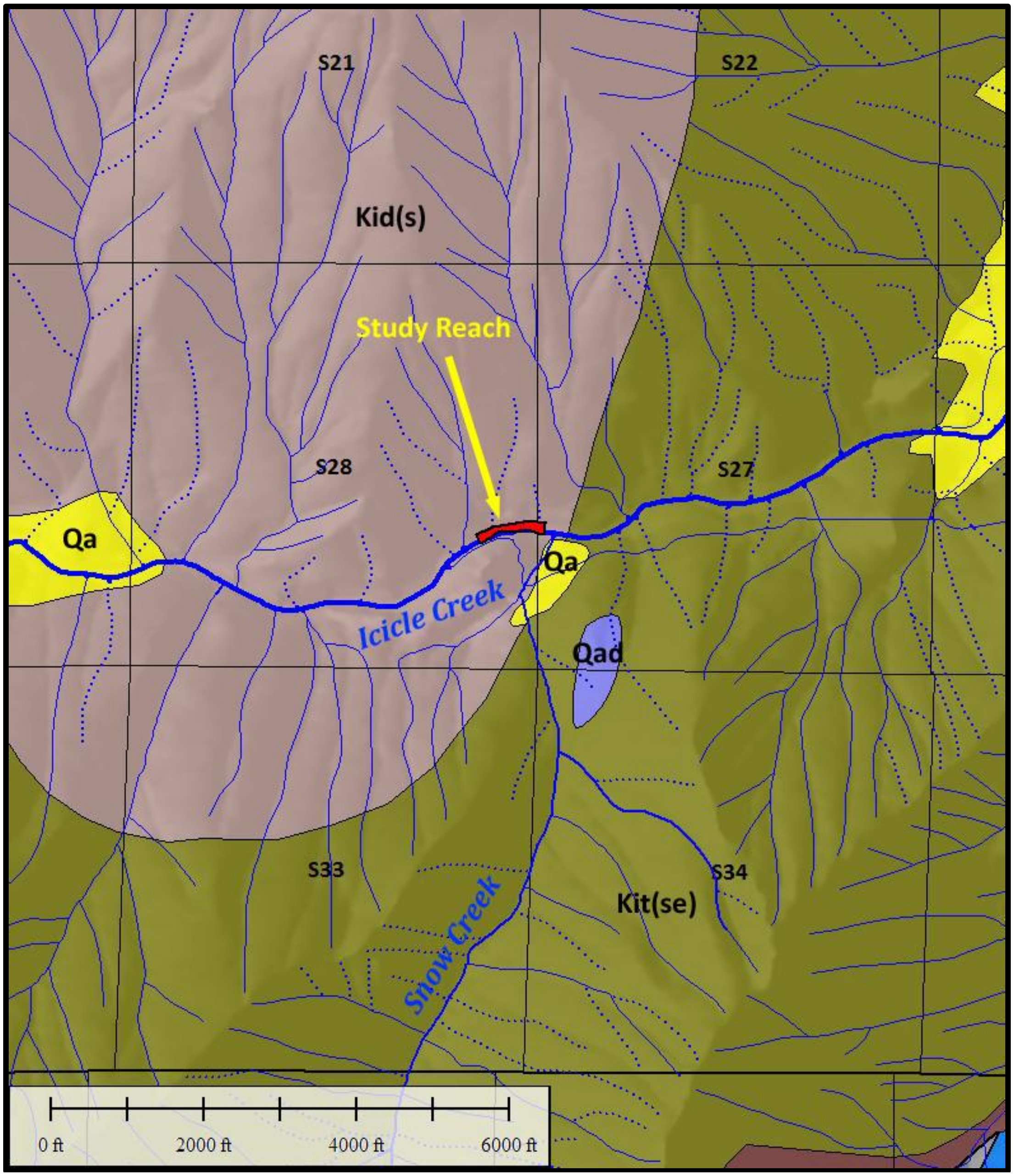
The assessment, therefore, utilized a more detailed geologic and geotechnical investigation of the boulder field area to determine rock characteristics and the likelihood of bedrock outcropping along the proposed route of the step-pool fishway. Field investigations included climbing between large boulders along the road prism and the Icicle Creek channel to assess sub-surface conditions. Rock samples were collected and brought back to the office for further testing of engineering properties. Rock hardness was also evaluated in the field using a Schmidt hammer to estimate the compressive strength of selected boulders. Finally, various rock-breaking methods were tested on sample boulders to identify the most effective procedures.

2.0 Icicle Creek Basin Geology

Most of the Icicle Creek basin is located within the Mount Stuart granitic batholith. The Mount Stuart batholith is a granodiorite pluton that intruded the local metamorphic rocks approximately 60 million years ago (Tabor et al. 1987). The Mount Stuart Batholith consists predominantly of medium-grained, granular hornblende-biotite tonalite or quartz diorite, with a considerable amount of granodiorite east of the project reach along Icicle Ridge. Isotopic tests of Mount Stuart Batholith rocks indicate the age of the eastern pluton at about 93 million years ago and the western pluton at about 85 million years ago (Tabor et al., 1987; Dragovich et al. 2002). The bedrock in the project reach has been mapped by Tabor et al. (1987) and Dragovich et al. (2002) as pre-Tertiary diorite and gabbro and is near the contact with pre-Tertiary tonalite (Figure 1). The rocks are medium-grained hornblende diorite and gabbro, with the hornblende filling in and around plagioclase crystals. The contact with the tonalite is gradational and locally irregular (Tabor et al. 1987). The tonalite is differentiated by quartz crystals in addition to the plagioclase. The diorite, granodiorite, and tonalite of the project area are highly resistant to weathering. Long-term average weathering rates of granitic rock surfaces in the Icicle Creek area have been estimated at about 2 mm per 1,000 years (Porter and Swanson 2008).

Porter and Swanson (2008) did an extensive investigation of the advance and retreat of alpine glaciers in the Icicle Creek valley during the late Pleistocene (between 12,000 and 120,000 years ago). A sequence of five glacial moraines near the junction of the Wenatchee River and Icicle Creek provides evidence of multiple advances of a large east-flowing Cascade Range glacier system (Figure 2, Porter and Swanson 2008). A dozen steep northern tributary ice streams also flowed from an ice cap on the crest of Icicle Ridge. An equal number of southern tributary glaciers, including the Snow Creek drainage, flowed from cirques along the crest of the Stuart Range (Figure 2). At the time of the Last Glacial Maximum (Leavenworth Glaciation I), the ice is estimated to have been over 1,200 feet (380 m) thick in the main valley (Figure 2). Sub-rounded granitic boulders up to 25 feet (8 meters) or more in diameter are present in lateral moraines along the Icicle Creek valley.

During Late Glacial time (12,000 to 14,000 years ago) glaciers re-advanced into the southerly tributary drainages and terminated near their junction with Icicle Creek (Porter and Swanson 2008). Rat Creek, the drainage located directly west of Snow Creek, is the type location for moraines deposited during Late Glacial time (Figure 2). Similar to the Rat Creek drainage, the Snow Creek glacier deposited small loop moraines across Icicle Creek that have since been truncated by fluvial erosion following original deposition (Figure 3). The Snow Creek trailhead parking lot and colluvium observed on the lower, southerly valley sidewall is comprised of matrix-supported till deposited within the original moraines (Figure 4). Post-glacial fluvial erosion removed the fine till matrix within the Icicle Creek channel leaving the large remnant boulders comprising the boulder field within the study area. Similar boulders fields (e.g., Rat Creek and Eight Mile Creeks) are observed along the reaches of the Icicle Creek where Late Glacial moraines were deposited within the main channel and subsequently eroded by glaciofluvial and/or fluvial processes.



ALL BOUNDARIES ARE APPROXIMATE AND MAY NOT BE TO SCALE.

Key: *Kid(s)* – Diorite; Kit(se) – Tonalite; Qad – Alpine glacial drift*;* Qa –Alluvium

Figure 1. Geology map of the Icicle Creek Boulder Field project area (Dragovich 2002).

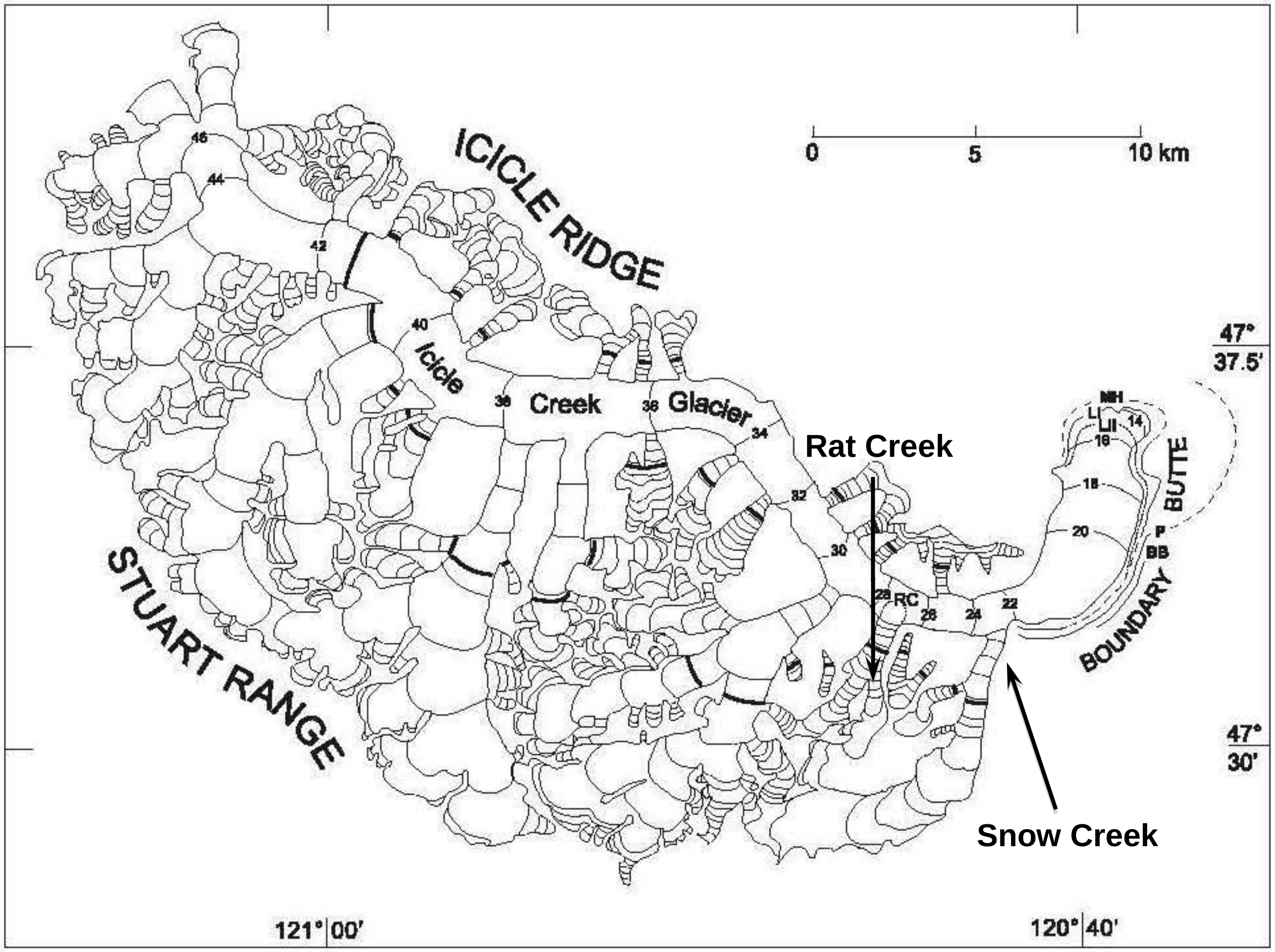


Figure 2: Topographic reconstruction of the Icicle Creek glacier during the Last Glacial Maximum (Leavenworth Glaciation I) 20,000-23,000 years ago. Snow Creek (drainage denoted with black arrow) was one of the southerly tributary glaciers that coalesced with main Icicle Creek glacier during its maximum extent. Crests of major moraines mapped in the lower reaches of the valley include (from oldest to youngest glacial moraine): Boundary Butte (BB), Peshastin (P), Mountain Home (MH), Leavenworth I and II (LI and LII). The type location, Rat Creek (RC), for the Late Glacial advance (12,000 – 14,000 years ago), is the adjacent drainage west of Snow Creek. The reconstructed glacier contour interval is 200 feet (61 meters). Figure 2 adapted from Porter and Swanson (2008).

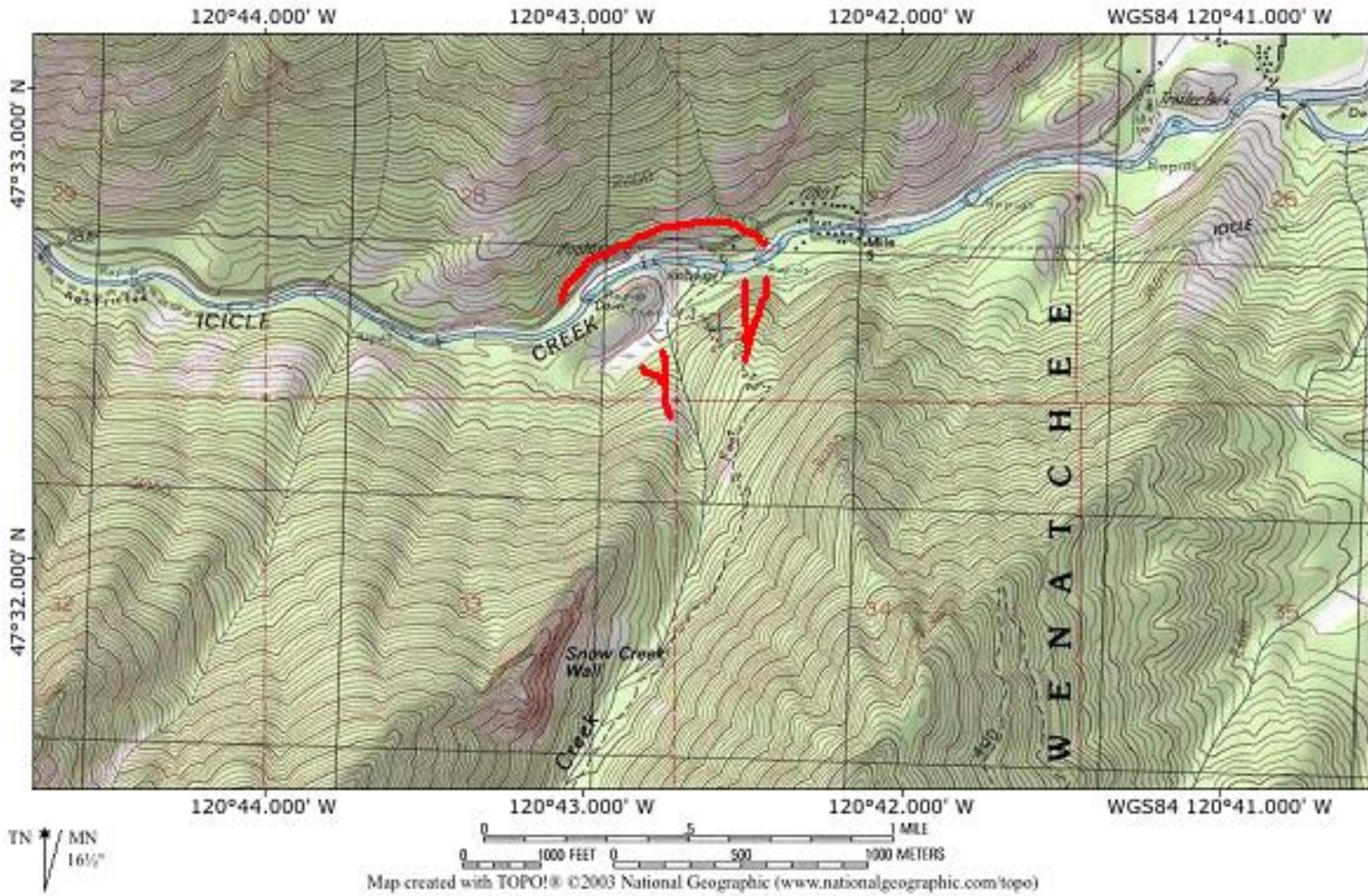


Figure 3. During Late Glacial time (12,000 – 14,000 years ago) the Snow Creek glacier deposited small loop moraines across Icicle Creek that have since been truncated by fluvial erosion following original deposition. Remnant morainal deposits are outlined in red. The boulder field within the study area is comprised of remnant morainal till boulders that were too large to be transported by post-glacial fluvial erosion processes.

Figure 4: The Snow Creek trailhead parking lot and colluvium observed on the lower, southerly valley sidewall is comprised of matrix-supported till deposited within the original Late Glacial moraines. The crest of the oldest Late Glacial moraine is shown by a solid white line and inferred (shown by white dashed line) where it was eroded by post-glacial fluvial processes or the topography is too steep to support unconsolidated till.

To better characterize the potential for encountering bedrock at the Boulder Field site, a cross-sectional slope profile was derived from 2007 bare-earth LiDAR digital elevation models (Puget Sound LiDAR Consortium 2007). The cross-section includes the steep bedrock face and wedge of colluvium and glacial sediments on the north side of Icicle Creek (Figure 5). The cross-section also goes through both roads and the Anchor Rock situated in the channel. A projection of the bedrock below the colluvial wedge and the U.S. Forest Service 7600 Road suggests that the depth to bedrock exceeds excavation depths for the proposed fishway. The construction of the proposed fishway will likely encounter large native boulders derived from the Snow Creek glacial moraine deposits. A matrix of finer sediments from glacial and colluvial sources may also be present between the boulders.

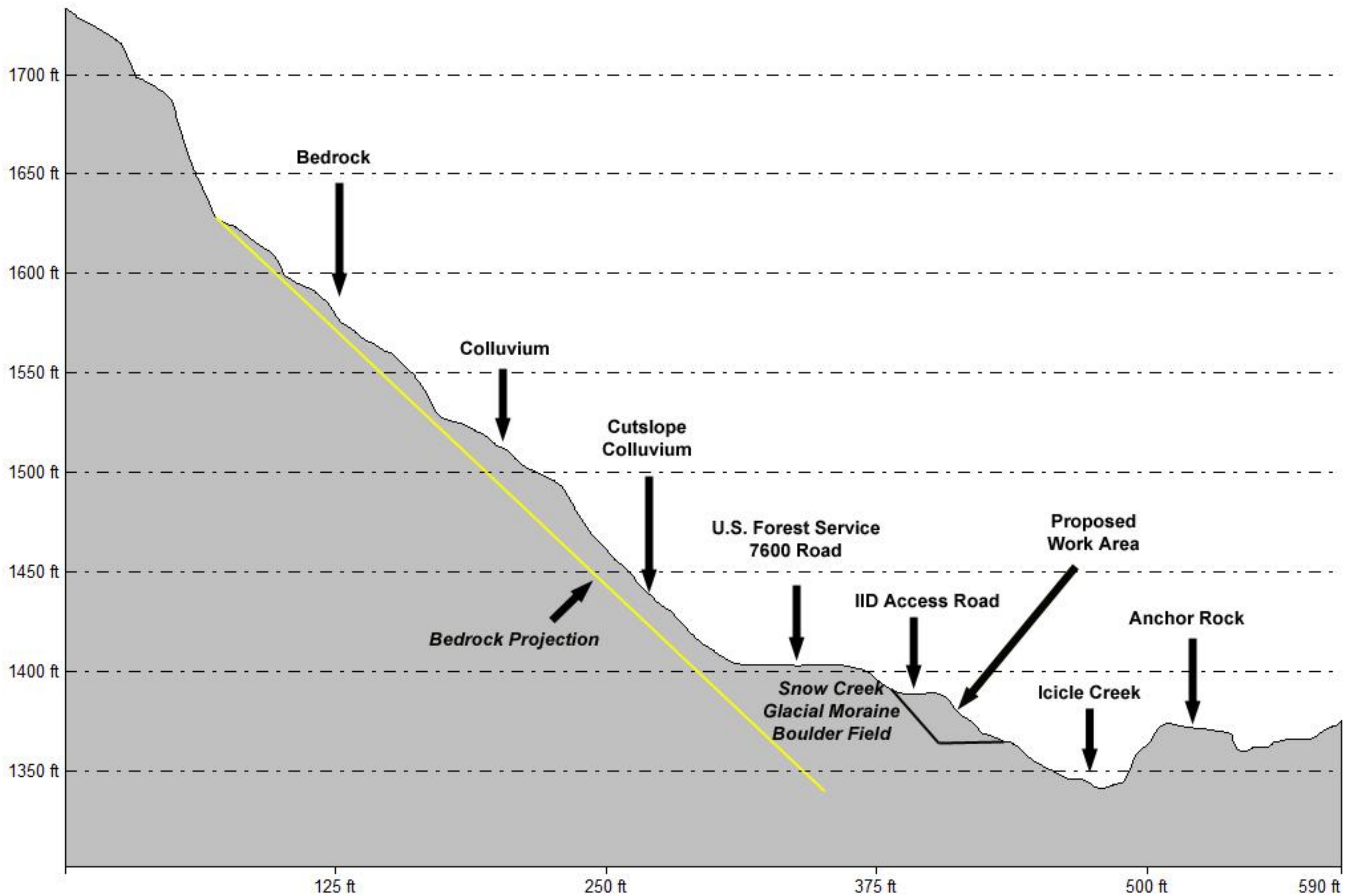


Figure 5. Bedrock projection for a typical cross-section of the project area from bare-earth LiDAR digital elevation models.

3.0 Boulder Characteristics

The proposed step-pool fishway will require the breaking of at least 20 to 30 large boulders greater than 500 cubic feet in volume. Based on the size, angularity, weathering, and coloration of the rock, almost all of the boulders being removed are of native origin. Several feet of overburden exists on the IID access road upslope from most of the large boulders. During construction, smaller rocks were manually stacked along the fillslope and finer, rocky material was likely dumped between and on top of existing large boulders to create a stable road prism at the proper grade. A few hundred feet of the road will likely need to be removed in order to accommodate the step-pool fishway.

Table 1 summarizes the size and placement of various boulders around the potential step-pool fishway. Figures 6 through 9 shows four different perspectives of the boulders located within the proposed fishway.

At the start of the fishway, Boulder 43/45 will need to be removed to allow more flow through the primary channel area (Figure 9). The fishway will then begin to gain elevation, requiring the removal of most of the boulders along the north side of the Icicle Creek channel (Figure 7). The IID access road will also need to be removed to access the boulders and allow for construction of the fishway. Excavation depths will vary from 15 to 24 feet. The fishway will reconnect with the primary channel at about the location of Boulder 18 (Figures 6 and 7). The reconstructed slope below the U.S. Forest Service 7600 Road will be at a 1.4:1 angle and is based on adjacent stable reference slopes constructed from similar rock. The reconstructed slope should be able to utilize existing native boulders in the road prism and strategic placement of large rock from the fishway construction activities.

One design feature worth noting in the proposed fishway is that a line of boulders will be maintained between the roughened channel and the primary channel area. The lineup of boulders can be best viewed in Figure 6, where Boulders 41, 42, and likely Boulder 25 will be retained in the channel to help direct flows and protect the fishway from hydraulic forces. In addition, Boulders 14 and 17 will be retained to preserve the large pool that has formed below them (Figures 6 and 7).

Boulder	Estimated Width (ft)	Estimated Length (ft)	Estimated Height (ft)	Estimated Volume (cu ft)	Remove	Notes
14	20	30	20	12,000	N	Blocks flow, creates small falls, try to keep in place or shave/step upper part of boulder
15-16					N	Keep in place
17	15	20	20	6,000	N	Perched on rounded large boulder and Boulder 22; forms cave pool under Boulder 14
18	8	30	15	3,600	Y	Comes out entirely for new side channel, helps keep up road fill
19-21					N	Keep in place
22	10	30	12	3,600	Y	Holding Boulder 17 and Boulder 38; comes out for new side channel
23	10	12	5	600	Y	Resting on Boulder 22, 34, and 40; comes out for new channel
24	15	15	10	2,250	Y	On top of Boulder 30; comes out for new channel
25	15	20	10	3,000	Y?	Propped up on in-channel boulder; not clear if planned for removal
26-29					N	Keep in place
30	10	15	4	600	Y	On top of Boulder 25 and 26; Boulder 24 rests on it; comes out for new channel
31	10	10	5	500	Y	Comes out for new channel
32	5	20	5	500	Y	Could be holding Boulder 33
33	15	25	20	7,500	Y	Appears to end at edge of road fill

Table 1. Summary of boulder characteristics in the proposed step-pool fishway.

Boulder	Estimated Width (ft)	Estimated Length (ft)	Estimated Height (ft)	Estimated Volume (cu ft)	Remove	Notes
34	20	20	20	8,000	Y	Large boulder that props up Boulder 23 and holds up Boulder 35 and road fill
35	15	20	20	6,000	Y	Propped up on 34; part of road fill; unclear how far extends into road prism
36	10	20	10	2,000	Y	Unclear how far rock extends into road prism
37	10	15	5	750	Y	Holding up road fill
38	10	20	8	1,600	Y	Located behind Boulder 22 and below Boulder 37, holding smaller boulders in place upslope
39	15	20	20	6,000	Y	Resting on Boulder 41 and located below Boulder 22; Boulder 40 rests on it, comes out for new channel
40	6	15	5	450	Y	Resting on Boulder 39 and 44; Boulder 23 rests on top; comes out for new channel
41	10	20	12	2,400	N	Might be propped up by Boulder 39; resting on smaller boulders and Boulder 20; try to keep in place
42	10	15	20	3,000	N	Propped up by Boulder 25; likely to stay
44	15	20	10	3,000	Y	Props up Boulder 40; comes out for new channel
43/45	15	25	15	5,625	Y	Double numbered rock in channel will be removed

Table 1 (continued). Summary of boulder characteristics in the proposed step-pool fishway.

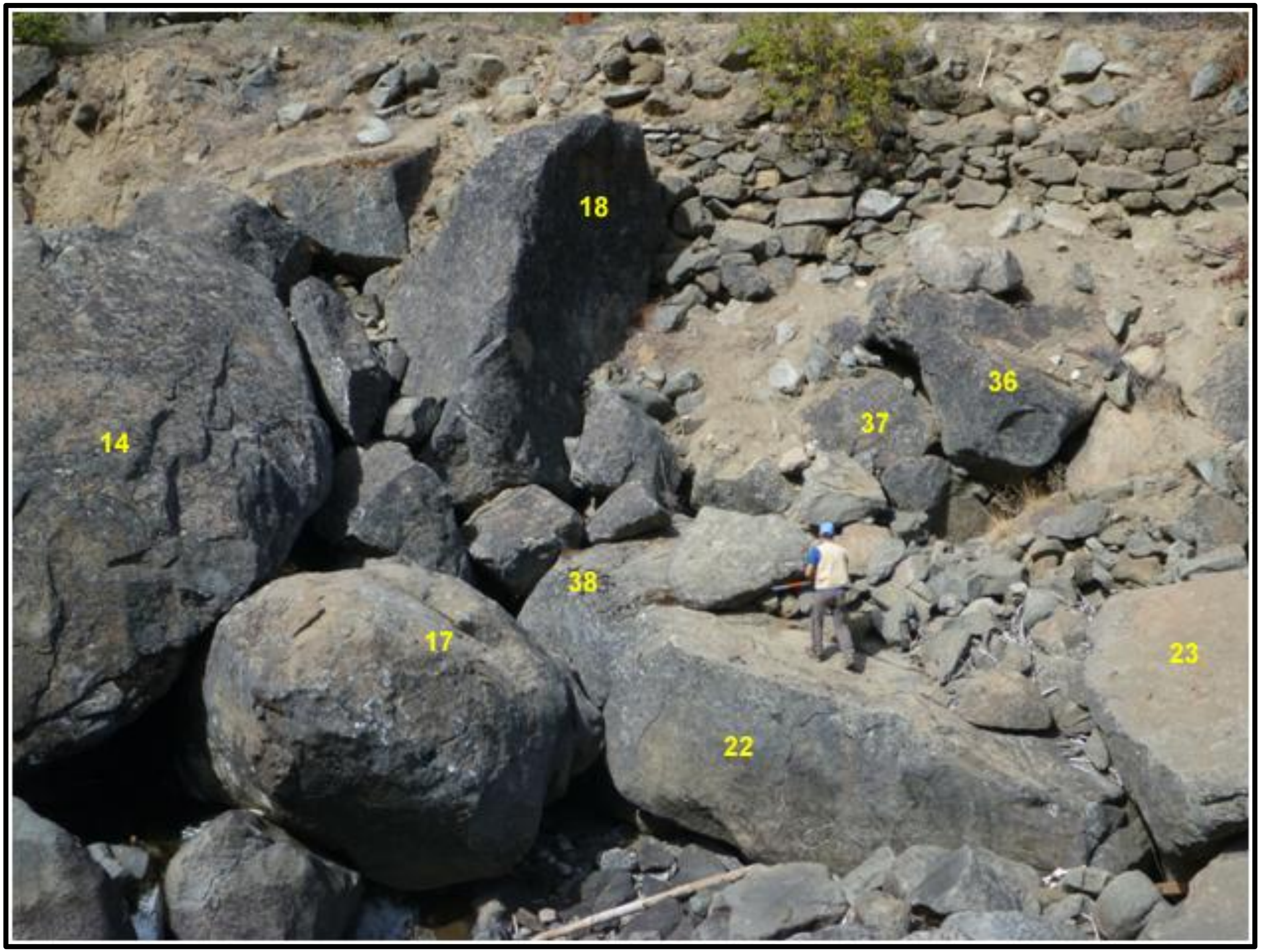


Figure 6. View from the Anchor Rock of the boulders located in the upper portion of the proposed step-pool fishway.

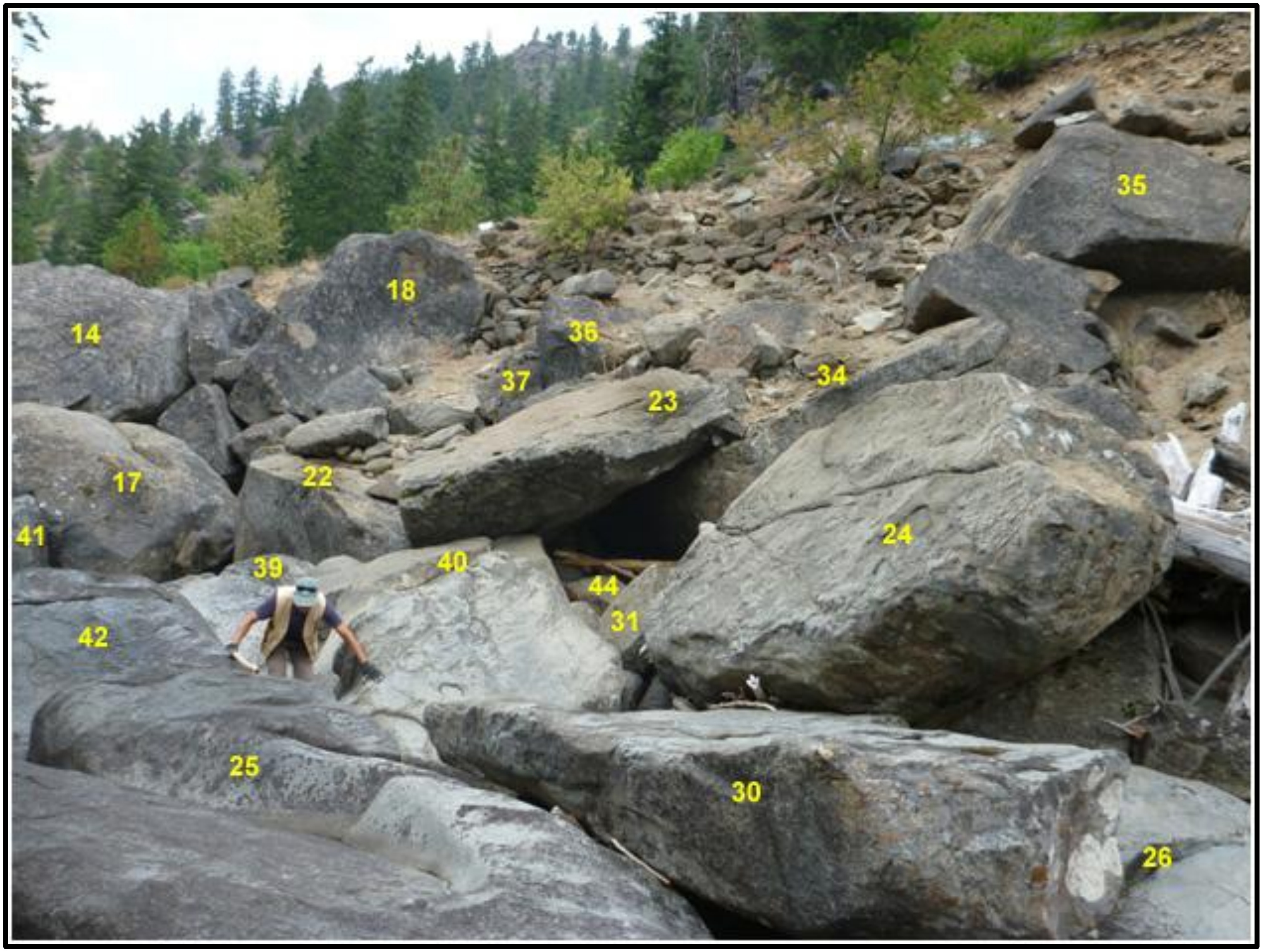


Figure 7. Upstream view of the boulders located in the proposed step-pool fishway area.

Figure 8. Downstream view of the boulders located in the proposed step-pool fishway area.

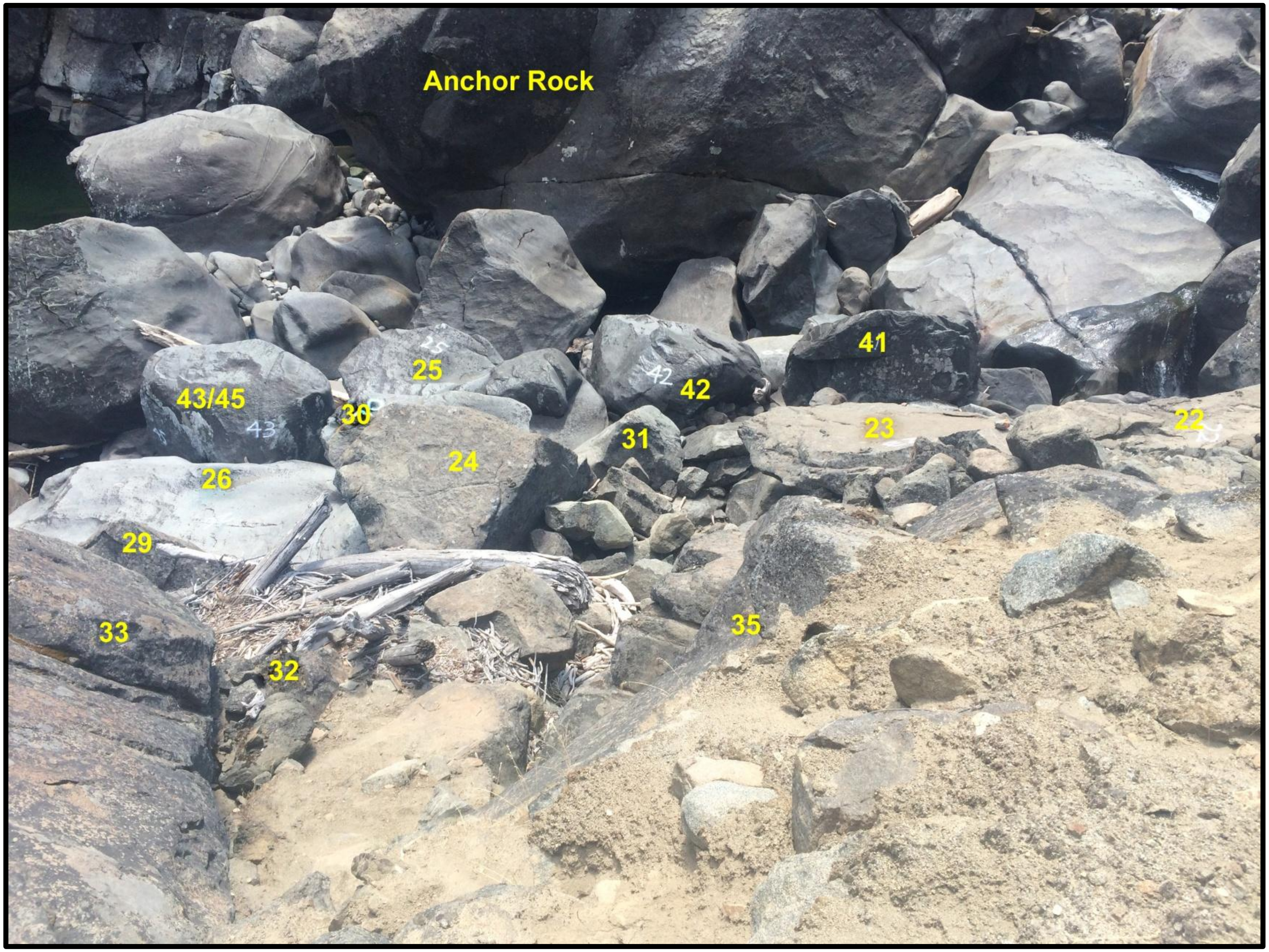


Figure 9. View from the Icicle Creek Irrigation District access road of the boulders located in the proposed step-pool fishway area.

4.0 Rock Engineering Properties

Several methods were used to assess the engineering properties of the boulders in the project area. Rock samples were collected and measured to determine hardness and density. A Schmidt hammer was used to assess the *in situ* unconfined compressive strength of several boulders. Finally, various rock-breaking methods were tested to evaluate their effectiveness in fracturing the granitic boulders.

4.1 Rock Density

Rock samples were collected during field work and brought back to the office for further testing. Tests were conducted to calculate the unit weight of the samples and density of the rock. Test samples averaged about 2 inches by 1-inches (6 cm by 3 cm) in size. The samples were weighed after drying for at least 48 hours and then submerged in water. The difference in weight is used to calculate the volume and density of the sample. Table 2 shows the unit weight data for all of the measured samples. The average density of the weathered tonalite samples was 2.76 g/cm^3 or 172.07 lbs/ft^3. The tonalite sample densities are similar to the 2.73 g/cm^3 value for granodiorite samples that were collected further upstream on Icicle Creek (Shannon and Wilson 2004).

Boulder No.	Rock Type	Weight in Air (g)	Weight in Water (g)	Density (g/cm^3)	Density (lb /ft^3)
14	Tonalite	32.38	20.54	2.73	170.73
20	Tonalite	115.27	74.42	2.82	176.16
22	Tonalite	22.40	13.96	2.65	165.69
26	Tonalite	226.59	146.09	2.81	175.72
Average Density				**2.76**	**172.07**

Table 2. Summary of unit weight and density data for measured samples.

4.2 Compressive Strength

During field work, a Schmidt hammer was used to estimate the compressive strength of various boulders in their natural state. The Schmidt hammer applies a calibrated impact to a rock surface and the rebound value is measured after each blow. The rebound value can be correlated to a compressive strength based on rock type and empirical laboratory measurements.

Slight weathering of the rock surface was observed across most of the boulders, unless the boulder surface has been regularly in contact with flowing water. Minor exfoliation of the rock surface layer was also noted on many of the rocks. Exfoliation involves thin sheeting joints that are generally flat, somewhat curved and parallel to the rock surface. The areas of the boulders with a noticeable weathered surface layer were prepped with carborundum abrasive. Carborundum treatment removes a thin, weaker surface layer allowing the device to record harder, less weathered rock below. Treatment with carborundum abrasives allows for more consistent measurements of rock hardness (Viles et al. 2011).

Table 3 shows the field rebound readings and the estimated unconfined compressive strength (UCS). Aydin and Basu (2005) provide a regression correlation between Schmidt hammer rebound values and unconfined compressive strength for granite rock. The average compressive strength of the boulders is estimated to be 152 MPa or 21,980 psi. The range of values, however, is significant and largely reflects differential weathering of the boulder surface. More detailed data from the Schmidt hammer tests are available in Appendix A.

Boulder	Average Rebound Value	Standard Deviation	Estimated Compressive Strength (MPa)	Estimated Compressive Strength (psi)
17	59	8.2	90	13,053
18	51	9.8	51	7,397
22	59	8.9	90	13,053
24	72	10.2	224	32,488
30	70	6.6	195	28,282
31	71	7.0	209	30,313
34	54.5	9.9	66	9,573
39	77	4.0	318	46,122
40	59	12.4	90	13,053
43	66.5	13.1	152	22,046
44	69	9.3	182	26,397

Table 3. Summary of Schmidt hammer data and estimated compressive strengths.

The unconfined compressive strength of the boulders ranges from medium strength to very high strength rock. Unconfined compressive strength values of less than 50 MPa or 8,000 psi would be considered medium strength rock, while values greater than 100 MPa or 16,000 psi are considered very high strength rock. Boulders with more exfoliated and weathered tonalite have relatively low strength values compared to unweathered intact granitic rock, but the specific gravity of 2.76 suggests a generally high interior strength. The weathering of these rocks over several thousand years, however, does reduce their overall compressive strength.

4.3 Rock Breaking Methods

Waterfall Engineering contracted with Maple Leaf Powder Company to evaluate the boulders at the site and to provide an assessment of potential rock-breaking methods for the proposed step-pool fishway. The assessment identified several potential methods for breaking rocks including the use of a hydraulic hammer, low-impact deflagrating explosives, and high explosives. The conclusions suggested that a hydraulic hammer or deflagrating explosives would likely be the most effective methods. Both methods would result in very little ground vibration. Rock drilling could be accomplished by an excavator-mounted hydraulic drill or hand drilled using a portable air compressor. The complete report can be found in Appendix B.

To increase our understanding of the best methods for breaking rock at the site, five boulders were removed from along the IID access road and taken to a construction yard for rock drilling and breaking tests. Rock sizes ranged from 5 to 6 feet in diameter. Three methods were tested for breaking up the boulders in the project area:

1) A hydraulic rock-breaking hammer mounted on an excavator,
2) Boulder Buster™ non-detonating rock-breaking propellant, and
3) Expansive demolition grout.

A Caterpillar 320E hydraulic excavator was mounted with a Caterpillar H115ES hammer. The tool was jack-hammered into the boulder to break the rock into smaller pieces. The hammer was used on two of the boulders and took 10 to 15 minutes to break each of the boulders into manageable pieces. Rocks with existing cracks or fractures typically can be broken into smaller pieces within just a few minutes.

The Boulder Buster™ is a non-detonating rock-breaking tool that utilizes propellant technology. A pressure impulse is generated in the tool by a cartridge filled with propellant. The pressure impulse is directed via a barrel into a pre-drilled hole in the rock filled with water. The rapidly developing pressure wave transmitted by the fluid column creates fractures in the rock. The static pressure causes further mechanical stress and tensile fracturing of the rock. The propellant is low concussion with little flying rock and scatter. Blasting mats can be used to prevent even small amounts of flying rock. Two boulders were used to test the effectiveness of the Boulder Buster™ tool. A pneumatic rock drill with an approximately 1½-inch diameter bit was used to drill to approximately 80 percent of the boulder's depth. Drilling of each boulder took about 10 minutes. Another 5 minutes was needed to insert the water and cartridge and to fire the tool. The two boulders broke into manageable pieces almost instantly with only minor amounts of flying rock.

The expansive demolition grout is available to the general public and does not require any special licenses. Using the expansive grout required the drilling of three 1½-inch diameter holes in the boulder, which took approximately 20 minutes. The hole spacing generally needs to be on one-foot centers. Dexpan™ non-explosive controlled demolition agent was mixed with water to the proper proportions and poured into the three holes. The Dexpan™ grout has 19,000 psi expansive strength when mixed with water, but generally takes at least 24 hours to be completely effective. The results of the tests suggest that cracking of the large granitic boulders may require from 36 to 48 hours to achieve best results.

Appendix C includes photographs of the boulder transport and the three methods used for breaking the rock.

5.0 Construction Considerations

Based on the valley wall bedrock slope angles and the size of the glacial moraine boulder field in the surrounding area, we do not believe that excavation depths of up to 25 feet will encounter bedrock. Excavations below the road prism will likely encounter large native boulders, as well as fill material from the original construction. These native boulders may need to be excavated to a degree before boulder cracking can commence. All of the rock-cracking methods require that boulders not be buried to allow for expansion of the rock. Following excavation activities, a few of the large boulders under the road fill may need to be partially cracked or shaped in order to reconstruct a stable slope.

We believe that a combination of the hydraulic rock hammer and the Boulder Buster™ non-detonating rock-breaking tool would be optimal for constructing the step-pool fishway. Both methods require a similar amount of time to break up boulders, but the Boulder Buster™ would likely be a more efficient and effective tool on larger, intact boulders. The hydraulic hammer could be used to break up larger pieces or fractured rocks to allow for easier excavation. The hydraulic rock hammer may also be a good tool for shaping boulders.

Removal of talus rock carries a risk of slope instability whenever slopes are oversteepened or key buttressing rocks are removed. The stability of talus slopes depends upon the interlocking of the larger rock fragments. Rock-supported talus is often inherently unstable because the weight of the deposit is transmitted as point loads among the fragments. Particular care must be taken in constructing access points and reconstructing the slope face. Rocks should be removed progressing in a downhill direction to reduce the potential for initiating upslope rock movement and threatening operator safety.

6.0 References

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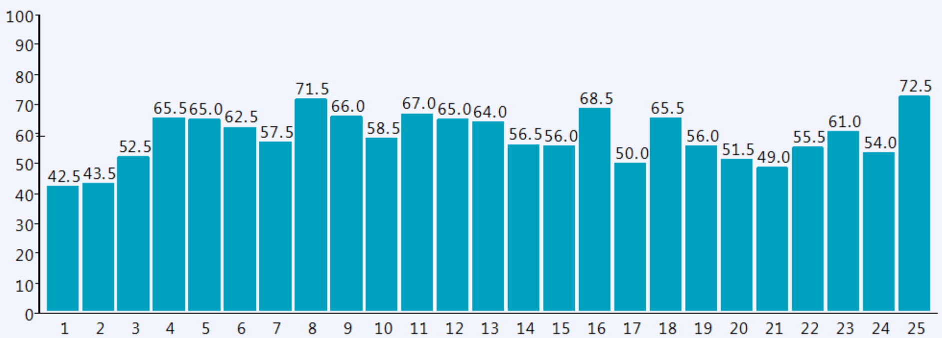
Appendix A

Schmidt Hammer Results

Boulder Number 17

Impact counter	Name	Date & Time	Mean value
Σ 341		08/04/2015 3:31 PM	59.0 R

R-Values diagram [measurement order]



R-Values

42.5	65.5
43.5	56.0
52.5	51.5
65.5	49.0
65.0	55.5
62.5	61.0
57.5	54.0
71.5	72.5
66.0	
58.5	
67.0	
65.0	
64.0	
56.5	
56.0	
68.5	
50.0	

Statistics

Measurements	N = 25
Invalid measurements	Ni = 0 (0%)
Mean value	f = 59.0 R
Range	R = 30.0 R
Standard deviation	s = 8.2 R

Settings

Averaging mode	Mean
Conversion curve	---
Correction factor	1.00
Unit	R
Serial number	SH01-007-0842
Spring type	RockSchmidt N

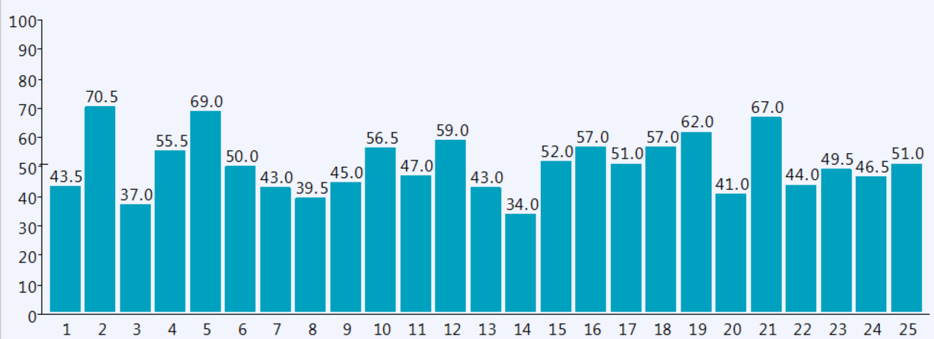
Comment

[Add]

Boulder Number 18

Impact counter	Name	Date & Time	Mean value
Σ 392		08/04/2015 3:48 PM	51.0 R

R-Values diagram [measurement order]



R-Values

43.5	57.0
70.5	62.0
37.0	41.0
55.5	67.0
69.0	44.0
50.0	49.5
43.0	46.5
39.5	51.0
45.0	
56.5	
47.0	
59.0	
43.0	
34.0	
52.0	
57.0	
51.0	

Statistics

Measurements	N = 25
Invalid measurements	Ni = 0 (0%)
Mean value	f = 51.0 R
Range	R = 36.5 R
Standard deviation	s = 9.8 R

Settings

Averaging mode	Mean
Conversion curve	---
Correction factor	1.00
Unit	R
Serial number	SH01-007-0842
Spring type	RockSchmidt N

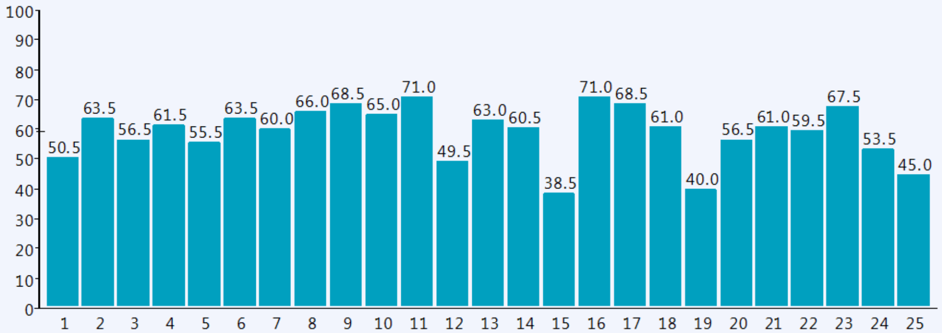
Comment

[Add]

Boulder Number 22

Impact counter	Name	Date & Time	Mean value
Σ 366		08/04/2015 3:36 PM	59.0 R

R-Values diagram [measurement order]



R-Values

50.5	61.0
63.5	40.0
56.5	56.5
61.5	61.0
55.5	59.5
63.5	67.5
60.0	53.5
66.0	45.0
68.5	
65.0	
71.0	
49.5	
63.0	
60.5	
38.5	
71.0	
68.5	

Statistics

Measurements	N = 25
Invalid measurements	Ni = 0 (0%)
Mean value	f = 59.0 R
Range	R = 32.5 R
Standard deviation	s = 8.9 R

Settings

Averaging mode	Mean
Conversion curve	---
Correction factor	1.00
Unit	R
Serial number	SH01-007-0842
Spring type	RockSchmidt N

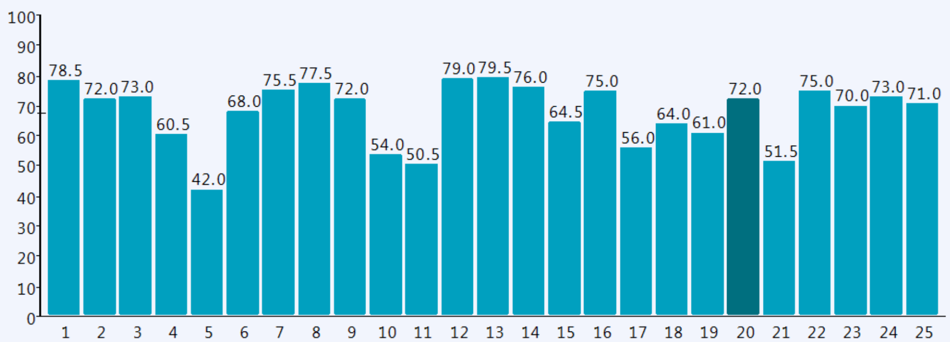
Comment

[Add]

Boulder Number 24

Impact counter	Name	Date & Time	Mean value
Σ 153		08/04/2015 2:47 PM	72.0 R

R-Values diagram [measurement order]



R-Values

78.5	64.0
72.0	61.0
73.0	72.0
60.5	51.5
42.0	75.0
68.0	70.0
75.5	73.0
77.5	71.0
72.0	
54.0	
50.5	
79.0	
79.5	
76.0	
64.5	
75.0	
56.0	

Statistics

Measurements	N = 25
Invalid measurements	Ni = 0 (0%)
Median	f = 72.0 R
Range	R = 37.5 R
Standard deviation	s = 10.2 R

Settings

Averaging mode	Median
Conversion curve	---
Correction factor	1.00
Unit	R
Serial number	SH01-007-0842
Spring type	RockSchmidt N

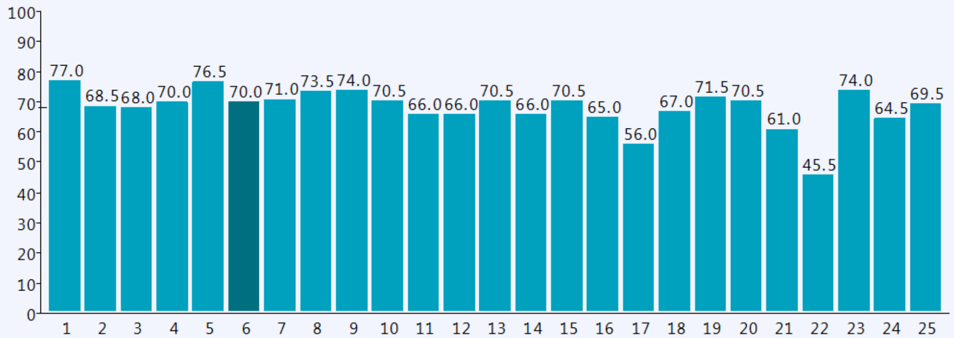
Comment

[Add]

Boulder Number 30

Impact counter	Name	Date & Time	Mean value
Σ 178		08/04/2015 2:57 PM	70.0 R

R-Values diagram [measurement order]



R-Values

77.0 67.0
68.5 71.5
68.0 70.5
70.0 61.0
76.5 45.5
70.0 74.0
71.0 64.5
73.5 69.5
74.0
70.5
66.0
66.0
70.5
66.0
70.5
65.0
56.0

Statistics

Measurements	N = 25
Invalid measurements	Ni = 0 (0%)
Median	f = 70.0 R
Range	R = 31.5 R
Standard deviation	s = 6.6 R

Settings

Averaging mode	Median
Conversion curve	---
Correction factor	1.00
Unit	R
Serial number	SH01-007-0842
Spring type	RockSchmidt N

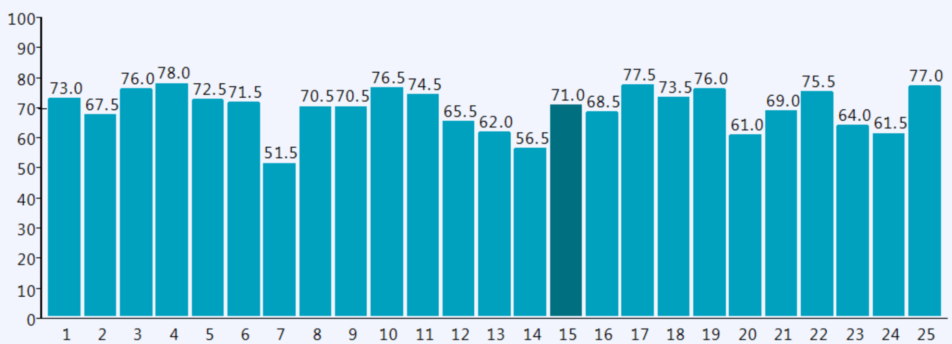
Comment

[Add]

Boulder Number 31

Impact counter	Name	Date & Time	Mean value
Σ 203		08/04/2015 2:59 PM	71.0 R

R-Values diagram [measurement order]



R-Values

73.0 73.5
67.5 76.0
76.0 61.0
78.0 69.0
72.5 75.5
71.5 64.0
51.5 61.5
70.5 77.0
70.5
76.5
74.5
65.5
62.0
56.5
71.0
68.5
77.5

Statistics

Measurements	N = 25
Invalid measurements	Ni = 0 (0%)
Median	f = 71.0 R
Range	R = 26.5 R
Standard deviation	s = 7.0 R

Settings

Averaging mode	Median
Conversion curve	---
Correction factor	1.00
Unit	R
Serial number	SH01-007-0842
Spring type	RockSchmidt N

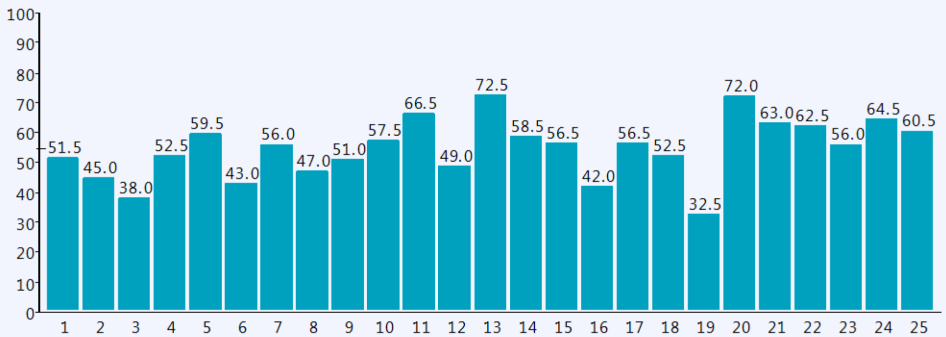
Comment

[Add]

Boulder Number 34

Impact counter	Name	Date & Time	Mean value
290		08/04/2015 3:15 PM	54.5 R

R-Values diagram [measurement order]



R-Values

51.5	52.5
45.0	32.5
38.0	72.0
52.5	63.0
59.5	62.5
43.0	56.0
56.0	64.5
47.0	60.5
51.0	
57.5	
66.5	
49.0	
72.5	
58.5	
56.5	
42.0	
56.5	

Statistics

Measurements	N = 25
Invalid measurements	Ni = 0 (0%)
Mean value	f = 54.5 R
Range	R = 40.0 R
Standard deviation	s = 9.9 R

Settings

Averaging mode	Mean
Conversion curve	---
Correction factor	1.00
Unit	R
Serial number	SH01-007-0842
Spring type	RockSchmidt N

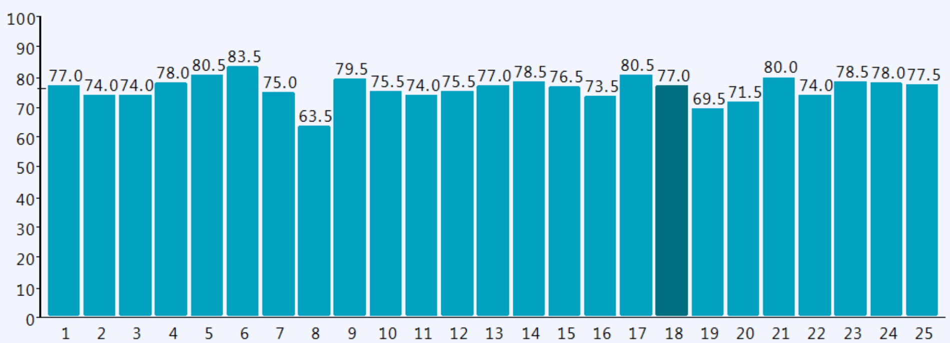
Comment

[Add]

Boulder Number 39

Impact counter	Name	Date & Time	Mean value
253		08/04/2015 3:06 PM	77.0 R

R-Values diagram [measurement order]



R-Values

77.0	77.0
74.0	69.5
74.0	71.5
78.0	80.0
80.5	74.0
83.5	78.5
75.0	78.0
63.5	77.5
79.5	
75.5	
74.0	
75.5	
77.0	
78.5	
76.5	
73.5	
80.5	

Statistics

Measurements	N = 25
Invalid measurements	Ni = 0 (0%)
Median	f = 77.0 R
Range	R = 20.0 R
Standard deviation	s = 4.0 R

Settings

Averaging mode	Median
Conversion curve	---
Correction factor	1.00
Unit	R
Serial number	SH01-007-0842
Spring type	RockSchmidt N

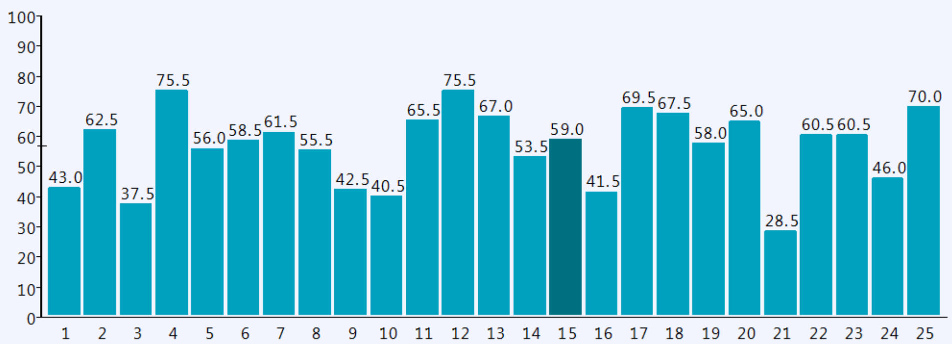
Comment

[Add]

Boulder Number 40

Impact counter	Name	Date & Time	Mean value
Σ 228		08/04/2015 3:03 PM	59.0 R

R-Values diagram [measurement order]



R-Values

43.0	67.5
62.5	58.0
37.5	65.0
75.5	28.5
56.0	60.5
58.5	60.5
61.5	46.0
55.5	70.0
42.5	
40.5	
65.5	
75.5	
67.0	
53.5	
59.0	
41.5	
69.5	

Statistics

Measurements	N = 25
Invalid measurements	Ni = 0 (0%)
Median	f = 59.0 R
Range	R = 47.0 R
Standard deviation	s = 12.4 R

Settings

Averaging mode	Median
Conversion curve	---
Correction factor	1.00
Unit	R
Serial number	SH01-007-0842
Spring type	RockSchmidt N

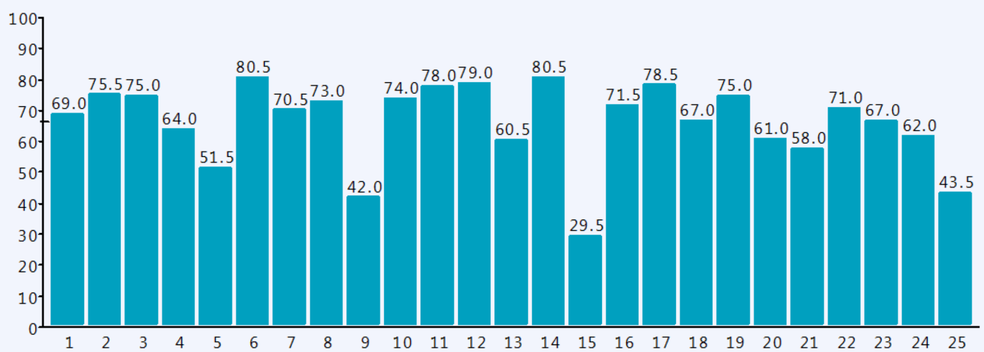
Comment

[Add]

Boulder Number 43

Impact counter	Name	Date & Time	Mean value
Σ 115		08/04/2015 2:39 PM	66.5 R

R-Values diagram [measurement order]



R-Values

69.0	67.0
75.5	75.0
75.0	61.0
64.0	58.0
51.5	71.0
80.5	67.0
70.5	62.0
73.0	43.5
42.0	
74.0	
78.0	
79.0	
60.5	
80.5	
29.5	
71.5	
78.5	

Statistics

Measurements	N = 25
Invalid measurements	Ni = 0 (0%)
Mean value	f = 66.5 R
Range	R = 51.0 R
Standard deviation	s = 13.1 R

Settings

Averaging mode	Mean
Conversion curve	---
Correction factor	1.00
Unit	R
Serial number	SH01-007-0842
Spring type	RockSchmidt N

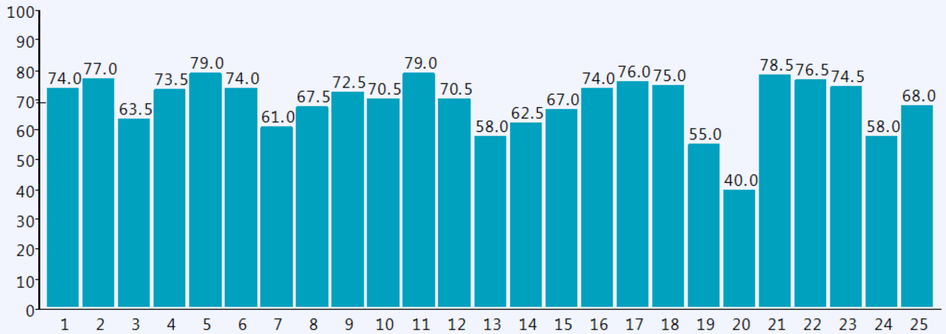
Comment

[Add]

Boulder Number 44

Impact counter	Name	Date & Time	Mean value
Σ 316		08/04/2015 3:20 PM	69.0 R

R-Values diagram [measurement order]



R-Values

74.0	75.0
77.0	55.0
63.5	40.0
73.5	78.5
79.0	76.5
74.0	74.5
61.0	58.0
67.5	68.0
72.5	
70.5	
79.0	
70.5	
58.0	
62.5	
67.0	
74.0	
76.0	

Statistics

Measurements	N = 25
Invalid measurements	Ni = 0 (0%)
Mean value	f = 69.0 R
Range	R = 39.0 R
Standard deviation	s = 9.3 R

Settings

Averaging mode	Mean
Conversion curve	---
Correction factor	1.00
Unit	R
Serial number	SH01-007-0842
Spring type	RockSchmidt N

Comment

[Add]

Appendix B

Maple Leaf Powder Company Report

Maple Leaf Powder Company

2025 Allenby St.
Victoria B.C. V8R 3B9
Canada
(250) 744-8765
www.mapleleafpowder.com

October 25 2014

Icicle Creek Boulder Field Passage
Leavenworth Washington USA
Project # 13-1342

To Waterfall Engineering LLC
9427 Delphi Road
Olympia WA
98512 USA
Patrick Powers, P.E. 360 352 5773 office, 360 701 8433 cell

A site visit to Icicle creek was conducted on October 22 2014. The purpose of the site visit was to view the project and establish effective, safe, legal and environmentally responsible methods of removing the fill and boulders and constructing a fish channel.

In attendance
Patrick Powers -Waterfall Engineering LLC
Aaron Penvose -Project Director, Trout Unlimited, Washington Water Project 509 881 7689
Dan Jaspers- Construction Manager, Trout Unlimited, Washington Water Project 509 881 669 0028
Rod Shearer -Contractor, RM Shearer Inc. 509 430 9144
Aaron Jones -Contractor POW Contracting 509 366 6050

General

Icicle Creek in the Cascade mountain range flows into the Wenatchie River on the west side of the town of Leavenworth WA. Many years ago a mining road was built along side the creek. A 16 inch steel waterline was installed along side the creek and buried in the road. A walking bridge was built over the creek and a number of recreational services were put in.

All this activity caused a stretch where the water in the creek falls at approximately a 20 percent incline, to get narrowed, confined and potentially clogged up with large boulders that where placed there during the road and waterline constructions. There was likely some of these boulders that fell into the creek from natural occurrences tumbling down from the top of the steep banks above the creek.

Generally speaking the rocks in the creek appear to be very hard granite.

This boulder field has caused a situation where the fish passage is partially

The purpose of this project is to design and build a passage around and /or through this boulder field to allow the various fish species to get up stream into the natural habitat.

The main fish species are Steelhead and Bull trout with the potential for Chinook and Spring Salmon

Patrick Powers identified three different construction options. All three options involve breaking up the boulders in the creek. Each option would involve different amounts of boulder breaking depending on how wide the channel is built and exactly where the channel is installed along the side of the creek.

This report focuses on different methods of breaking the boulders and moving them safely effectively and economically. Bearing in mind trying to minimize the impact on the surrounding environment and fish and wildlife in the creek.

Hydraulic Rock Breaking Hammers

This method of breaking rock can be very effective. It eliminates the need for a certified blaster on the project. It eliminates the need for legal ATF storage of either high explosives or deflagrating explosives.

Rock hammers come in a variety of sizes. This report feels that a large size would be required here to break these large, tough, dense, granite boulders.

These rock hammers operate on the end of the exactor arm. So it eliminates the need for a rock drill.

If the boulders can be successfully broken down in this fashion, in a reasonable time frame, it would certainly reduce costs and speed up the entire project.

This would be the lowest impact on the surrounding environment and the safest method.

This report recommends a trial of breaking some of these boulders with a rock hammer to establish the effectiveness of this method.

Deflagrating Low Impact Explosives

Technology today has developed a new generation of deflagrating explosives. These types of explosives are designed to minimize the impact on the surrounding environment while still carrying out the job of breaking rocks.

The product formulation inside the waterproof cartridges is a mixture of ammonium nitrates blended with black powders.

These blends when primed and confined properly, create a very low velocity deflagration rather than a detonation. The speed at which the gases created move is very low velocity in the range of 600 meters per second. This would compare to a detonation of high explosives, which move at velocities of 18000 feet per second.

These blends also create a lot of this slow moving gas. Therefore when confined properly, the gases expand slowly and enable the rocks to break without throwing rock particles through the air.

It is the recommendation of this report that this generation of low impact explosives should certainly be tried for effectiveness on these boulders.

If they can successfully break the boulders it would be a far safer method than using conventional high explosives.

This method would eliminate the need for covering each boulder with expensive and very heavy blasting mats.

These explosives would only crack the boulders into smaller sizes that can be handled by an excavator bucket. No flyrock would be created.

There are a number of different brand names of these type of explosives and they are all equally effective. These products are readily available throughout the USA.

The brand name that this report is familiar with is Nxburst explosives. Just google this name for product information

High Explosives

If the above two methods are proven to be too cumbersome, slow or ineffective, high explosives can certainly be used to break these boulders. There is no question this method will work.

But when using high explosives, a number of new issues arise.

Good quality, heavy rubber tired blasting mats would need to be used.
This hard granite rock will certainly fly a long ways when broken with high velocity explosives.
Therefore flyrock created from this method is a very real and definite concern for public and wildlife safety.

Each boulder would have to be completely covered with these blasting mats.

The area would have to be completely evacuated of all people and wild life when blasting.

Blasting would cause higher ground vibrations than the above two methods.
Any wildlife living in the immediate area of the creek where the boulders are blasted would certainly be concussed to various degrees.

A proper rock drill would have to be employed to drill holes deep enough and large enough diameter.
A licensed blaster would need to carry out the blasting.

Legal ATF storage of the explosives would have to be confirmed. Legal transportation of the explosives to and from the project would have to be confirmed

High explosives are readily available throughout the USA. There are a number of legal explosive suppliers in Washington State who would have all the products required to carry out this method of blasting

This report recommends not to use high explosives on this project until the rock hammer and/or deflagrating explosives methods are proven to be ineffective, too cumbersome or too expensive.

If high explosives are to be used, this report recommends priming the explosives with high strength, shock tube detonators. **Do not prime the explosives with detonating cord.**

Detonating cord will cause very high decibel noise levels and could effect the overhanging rocks on the cliffs above the creek. As well these high noise levels will alarm the public and area wildlife.

Shock tube detonators are very effective primers and are almost noiseless if the explosives in the boreholes are confined properly and the blasting mats are applied properly.

If the project gets to the point of using high explosives please contact the writer for more detailed procedural information.

Drilling

If drilling is needed to be done there would be a few options here.
This report would first recommend finding a company that would have a hydraulic excavator mounted rock drill available.

This method of drilling would have some clear advantages on this project. These drills mount on the arm of the excavator. They therefore have a very wide-ranging area they can drill at. As long as the arm of the excavator can reach the boulder the drill can drill it. Some of these boulders are going to be difficult to reach and this method would assist greatly to reach the target boulder.

The drill connects to the excavator arm with a quick connect set up. This set up doesn't take very long to complete. It therefore enables one machine to do the excavating work and the drilling work. When not needed, the drill can be laid on its side near where the excavator is working. When a boulder is encountered the drill can easily and quickly be attached to the excavator arm to commence drilling.

A number of brand names of these drills are made. They are readily available throughout the USA. The brand name this report is familiar with is Traxxon excavator mounted hydraulic drills.

Tamrock small hole hydraulic commando drills.

These drills are very good at drilling small diameter holes quickly in all rock conditions. They are very agile and easily picked up with an exactor and placed in an appropriate position to drill. The drill is self-contained and no other equipment is needed at the boulder location.

If the excavator mount drill was not available this style drill may be a good fit.

Hand Drilling

Hand drilling for loading of either deflagrating explosives or high explosives with a jack hammer is certainly an option on this project.

This method would give good access to each boulder. It would only require a driller to stand on each boulder to carry out the drilling.

A compressor could be located above the creek with an air hose attached to the drill down on the boulder location.

The problem with this method is these granite boulders are very dense, very large and hard. It would require a very long difficult drilling schedule.

Care would have to be taken to ensure the driller is safe while out in the creek drilling. This would have to be done during low water flow levels.

Vibration Analysis

Questions arose during the site meeting about ground vibration from blasting. There are precarious looking boulders perched high on the cliffs above the creek. Concern was raised about ground vibration jarring these boulders free causing them to tumble down the banks into the creek.

All methods of breaking the boulders will create some ground vibrations.
The most severe ground vibrations will be caused when using the high explosives methods described above.
But because the blasting or boulder breaking will be carried out in boulders and not in any bedrock. Ground vibrations of all methods will be very low.

The only concern this report would have with ground vibration is for the fish and any other wildlife in the immediate area of the creek when using high explosives.

This report would not be concerned about ground vibrations disturbing ground above the creek from any of the boulder breaking methods.

To confirm this fact, below is a spread sheet of a typical explosion that would result from a high explosives blast.

The bottom of the sheet has a PPV (Peak Particle velocity) prediction of how intense the ground vibrations would be at 50 feet from a blast that would occur in bed rock. Above ground boulders would create even less ground vibrations.

The spreadsheet uses the high explosives method of blasting for all values inputted into the blast program. Therefore this would be the worst-case scenario.

A PPV vibration level of 7mm per second as predicted, is very low and is close to being an undetectable amount of ground vibration. The further away you get from the blast the lower the ground vibration becomes.
Hydraulic hammers and low impact explosives would cause even less ground vibratuons.

Heavy equipment working on the road above the creek would cause equally or even high ground vibrations than 7 mm per second.

This report therefore is not concerned about ground vibrations from any method of boulder breaking.

Conclusions

Initially try breaking the boulders with a large excavator mounted hydraulic hammer.

If this proves in-effective for various reasons try breaking the boulders with low impact deflagrating explosives.

Only use high explosives if the above two methods prove in-effective

Try to have your rock breaking and or drilling equipment capable of working from the end of an excavator arm. This will reduce the congestion of multiple pieces of equipment working in these tight ground conditions.

Try to find a contractor with a large size excavator and a large size hydraulic hammer. A 245 caterpillar size excavator or larger would be appropriate.

If it is decided that high explosives need to be used, please use extreme caution and make sure all ATF and State regulations are followed.

It is the opinion of this report that if the correct size equipment is used, this project will not take more than two months to complete.

Maple Leaf Powder Company

Initial Blast Design Guide

Icicle Creek Vibration Prediction

Enter units 1=BCM, 2=Tonnes	1	
1 for kg/bcm, 2 for bcm/kg, 3 kj/t	1	
Explosive Name	Dynamite	
Explosive Diameter	25	millimetres
Explosive Density	1.43	grams per cubic centimetre
Explosive Energy	1105	calories per gram
Rock Density	2.4	grams per cubic centimetre
Bench Height	1.5	metres
Hole Angle (0 = vertical)	0	degrees
Desired Powder Factor	0.75	kilograms of explosive per bcm
Suggested Burden	***0.6***	***metres***
Actual Burden	0.6	metres
Stiffness Ratio	2.5	*favorably flexible*
Suggested Spacing	***0.7***	***metres***
Actual Spacing	0.6	metres
Suggested Stemming	***1.1***	***metres***
Actual Stemming	1.0	***Use With Caution!***
Vertical Energy Distribution	33%	
Confinement Factor	1.35	*fair energy confinement*
Suggested Subdrill	***0.2***	***metres***
Actual Subdrill	0.0	metres
Blasthole Length	1.5	metres
Explosive Length	0.5	metres
Loading Density	0.7	kilograms per metre of blasthole
Explosive Weight	0	kilograms per blasthole

6

Explosive Energy	0	megajoules per blasthole
Volume Shot	1	bank cubic metres per blasthole
Mass Shot	1	tonnes per blasthole
Powder Factor	0.65	kilograms per bank cubic metre
Powder Factor	1.54	bank cubic metres per kilogram
Energy Factor	298	kilocalories per tonne
Distance Away	15	metres
Blastholes Per 8ms Delay	1	
Est. Peak Part. Velocity	***7***	***millimetres per second***

Sincerely

Maple Leaf Powder Company
David Sly
President

7

Disclaimer

Maple Leaf Powder Company shall not be responsible for the use of any product, service or information referred to herein. Any users of information contained in this report assume the risk of relying on such information. Maple Leaf Powder Company makes no representations or warranties as to the information provided herein or with respect to products or services referred to in this report. The information contained herein may contain inaccuracies and is subject to change without notice. Maple Leaf Powder Company shall not be responsible for any damages caused by blasting or as a result of blasting on this project. Maple Leaf Powder Company will not be responsible for any injuries caused by or as a result of blasting on this project.

Appendix C

Rock Breaking Photographs

Figure C-1. Boulder collection along the Icicle Irrigation District access road.

Figure C-2. Boulder transport on trailer to construction yard.

Figure C-3. Rock drilling of boulders.

Figure C-4. Boulder Blaster™ rock-breaking propellant tool.

Figure C-5. Results from the use of Boulder Blaster™ rock-breaking propellant tool.

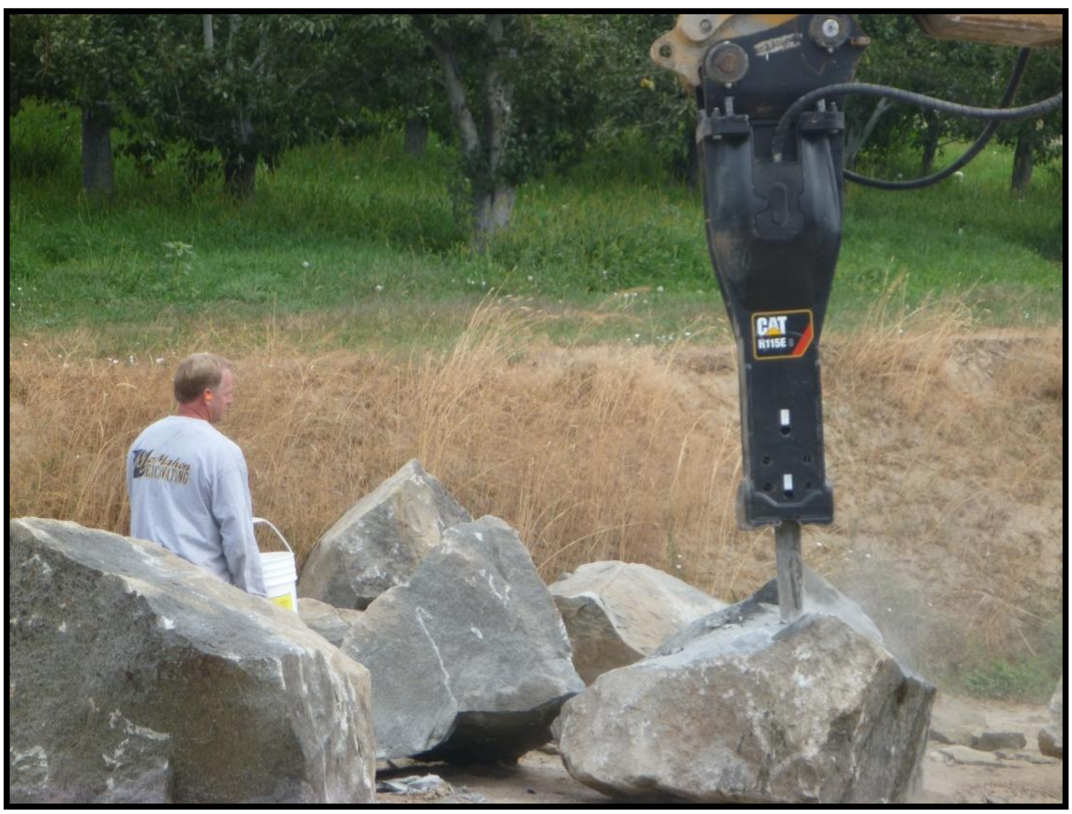


Figure C-6. Hydraulic rock-breaking hammer mounted on excavator.

Figure C-7. Preparation for expansive demolition grout.

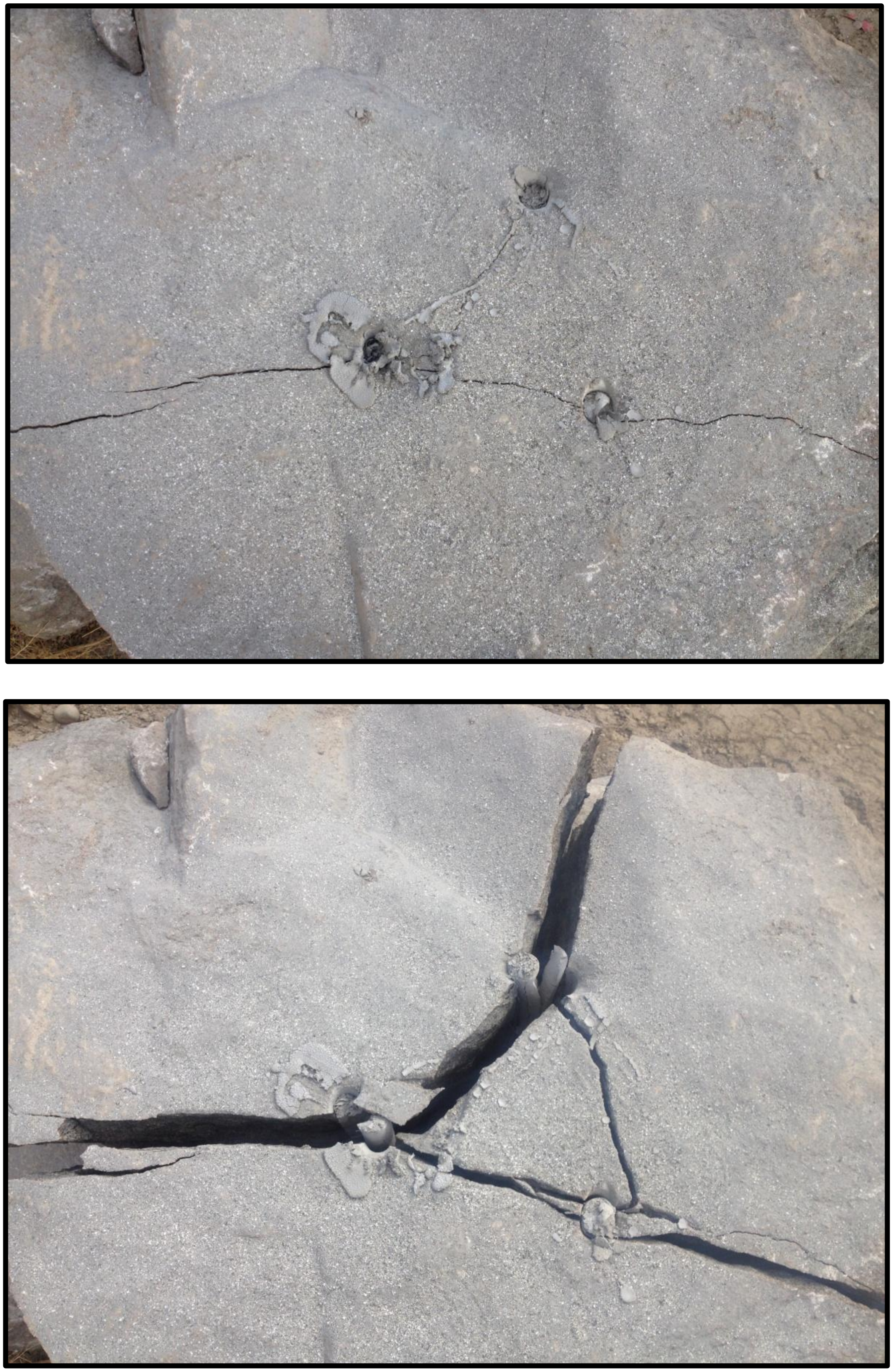


Figure C-8. Results of expansive demolition grout 18 hours and 36 hours after application.

APPENDIX D: CITY OF LEAVENWORTH WATERLINE ASSESSMENT

INTEGRITECH

Mechanical and Civil Engineering, Machine Design, and Troubleshooting

ICICLE BOULDER FIELD PASSAGE DESIGN 13-1342

TASK 4 – WATERLINE ASSESSMENT

CITY OF LEAVENWORTH'S

GRAVITY-FEED INTAKE PIPING

TO THE

WATER TREATMENT PLANT

SEPTEMBER 2015

AARON DOUGLAS SCHMIDT
STATE OF WASHINGTON
49530
REGISTERED
PROFESSIONAL ENGINEER

Aaron Schmidt
10 SEP 15

PREPARED FOR: WATERFALL ENGINEERING/TROUT UNLIMITED

4350 Icicle Road ▪ Leavenworth, Washington ▪ 98826 (509) 548-5765

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I. Introduction

Trout Unlimited is studying barriers which prevent fish from reaching the upper portions of the Icicle River. To better understand the partial barriers which often prevent fish passage, and the feasibility of removing them, Trout Unlimited has consulted with several experts, including Mr. Patrick Powers, P.E., of Waterfall Engineering. Mr. Powers has defined the barriers and proposed several possible solutions for a section of river labeled the "Icicle Boulder Field". One of these solutions (known as Option 4) has been chosen for further study.

Unfortunately, the chosen solution will likely impact the City of Leavenworth's water system. The City operates a Water Treatment Plant which utilizes surface water from Icicle River. Intake piping to the plant operates under gravity flow. A portion of this pipeline could be affected by the project.

This report provides an analysis of the City's water system and quantifies the impact of the proposed fish passage solution. Two new full-length pipeline alignments are presented, along with a partial-length replacement (representing the minimum impact) along one of the alignments. Conceptual cost estimates were prepared for all three options, but are not presented in this report.

II. History of the Entire Water System

The City of Leavenworth began using surface water from Icicle River in the early 1900s. The original intake structure was located near the current intake. Wood-stave pipelines provided gravity flow to town without any treatment.

In 1938, a 700,000 gallon reservoir was built near the junction of Highway 2 and Icicle Road.

In 1940, the Screen House was added downstream of the Intake. The Screen House provides large debris screening and sediment settling and functions to this day.

In 1949, the City installed a 30' deep central vertical well with horizontal infiltration pipes at the current wellfield location, and began using Wenatchee River ground water.

Beginning in 1950, the City started to replace wood-stave pipe with steel, cast iron, or ductile iron pipe. It is believed that no more wood-stave pipe remains in the system.

At an unknown time, most likely in the early 1950s, the Intake was revised. The Icicle Irrigation District and the City installed a full-width weir-style dam across Icicle River. Icicle Irrigation District draws water from the eastern side of the dam, and the City draws water from the western (road) side. Several improvements to the City's intake structure have been made since then, including a concrete roof, expanded intake structure, and security improvements (fencing and locks).

In 1954, the original water reservoir was reinforced with a concrete liner.

In 1960, an Infiltration Gallery was constructed beneath Icicle River, just downstream of the surface intake. However, due to clogging of the infiltration beds the Gallery was abandoned.

In 1971, the Water Treatment Plant was built. This plant is an Infilco-Degremont-Westinghouse design, and contains a pretreatment reaction chamber, sand filter beds, and chemical and chlorine injection systems. A chlorine contact basin was later added to improve the chlorine contact time prior to the first water customer.

In 1989, two water wells and a pump house were installed at the well field. The horizontal infiltration system that was installed in 1949 was then abandoned.

In 2004, a new, 700,000 gallon steel reservoir was constructed near the Leavenworth Ski Hill. This reservoir serves a higher pressure zone on Ski Hill Drive (Pressure Zone 2).

In 2006, a booster pump station was constructed near Pine Street which provides water to the Ski Hill reservoir and Pressure Zone 2.

In 2008, the existing reservoir was replaced with a new, 800,000 gallon concrete reservoir.

In 2014, a third well was brought on-line at the well field.

III. Description of the Surface Water System

Please see the photographs of Appendix C.

Intake

Besides drawing water from the Icicle River, the Intake provides three stages of screening for coarse debris. It primarily consists of a concrete structure extending into the river connected to a short tunnel through the adjacent bedrock. The concrete portion has an opening on the downstream side, forcing captured water to turn 180 degrees to enter the structure. This turn prevents large debris and logs from blocking the intake. Next, the flow passes over submerged baffles. This provides a settling basin to capture the more dense sediments. A flushing gate allows sediment to be removed when the baffles are withdrawn. Next, flow must pass through one of two 4′ square metal screens. The screens' openings are ¼″ by ½″. The second screen is lowered into place when the first screen is raised for cleaning.

A final screen has been placed over the entrance to the pipeline. This screen is not intended to filter debris, it is intended to prevent a trespassing human, or animal, from being unintentionally drawn into the pipeline. Please see Appendices A1-1, D2, D3-1, D3-3, D4, D6-2, D6-3, and D8.

Dam

The shared concrete weir-style dam creates a pool, which allows water to reach the intakes located on both sides of the river. In low flow periods, when the pool level would otherwise drop, 2 x 12 planks are placed on edge on top of the dam using steel pins that are inserted into holes in the top of the weir. By managing these planks, the pool level is kept at an acceptable elevation for the intakes. Please see Appendices A1-1, D2, D3-1, and D4.

Upper Pipeline

The upper pipeline carries water from the Intake to the Screen House. The pipeline is steel and 18″ in diameter. It is approximately 741′ long and drops approximately 5.4′ (Flowline elevations are 1,406.0′ to 1,400.6′). In operation, both ends of the pipe are fully submerged.

About 307′ downstream of the Intake, a tee and shutoff valve can provide water to the center pipe (three parallel pipes in total) of the abandoned Infiltration Gallery. All three pipes are labeled

"Collection Channels", while the center pipe is also labeled the "Charging Line". The purpose of the Charging Line is unclear. Please see Appendices A1-1, A1-2, D2, D3-1, D3-2, and D4.

Screen House

The Screen House provides another layer of debris screening. It consists of an intake chamber, with an overflow and shut-off valve, and two influent shut-off valves which lead to two identical settling chambers. At the far side of the settling chambers are wire screens (2 per side, for cleaning one while the other is in operation) with 1/8" openings. Each settling chamber also has a flushing line with a shut-off valve. Beyond the screens are two effluent shut-off valves, a common chamber, and the connection to the Lower Pipeline. None of the chambers are sealed; all are open to atmosphere. Please see Appendices A1-2, D1, D2, D3-2, and D3-5.

The overflow shut-off valve is left open. In this way, the Upper Pipeline is allowed to remain flowing at its natural rate; no throttling is required. Any excess flow above that demanded by the Water Treatment Plant is simply returned to the river.

Lower Pipeline

The Lower Pipeline carries water from the Screen House to the Water Treatment Plant. The pipeline is steel and 16" in diameter. It is approximately 1,532 feet long and drops a maximum of 36.9' (1,400.2' to 1,363.3'). However, once inside the plant, continuous piping raises the elevation to 1,374.9', making the piping's net elevation change 25.3'. This pipeline, like the Upper Pipeline, normally operates with both ends fully submerged. Please see Appendices A1-3, A1-4, D2, D3-2, D3-5, D5-4, D5-5, D7-2, and D7-4.

Water Treatment Plant

The Water Treatment Plant primarily consists of a pre-treatment clear-well, four filter chambers, and a chlorine contact chamber. The plant has automatically controlled butterfly valves on both influent and effluent pipelines and can operate at variable flows. However, for consistency the plant is currently attempted to be operated at a continuous flow. The rate is chosen to provide a steady, base supply for the City. As demands occur above the plant's output, the wellfield is activated to keep both reservoirs full. The plant's numerous chambers are all open to atmosphere. Please see Appendices A1-4, D5-1 to D5-5, and D7-1 to D7-4.

Abandoned Infiltration Gallery

The Infiltration Gallery consists of a Filter Bed (with imported rock), Collection Channels (three 18" perforated, corrugated steel pipelines), Manhole #1 at the upper end of the center Collection Channel, Manhole #2 at the lower end of the center Collection Channel, and a Collection Chamber which merged flows from the Collection Channels. A chlorination room, for equipment and operator, was installed on top of the chamber.

As previously mentioned, Manhole #1 has a connection to the Upper Pipeline with a shut-off valve. The purpose of this connection is unclear. One possibility is that it could provide an external water source for reverse flushing of the Collection Channels. Unfortunately, an operations manual for the system was not located during the course of this investigation.

Manhole #2 has a cover plate which could be installed to close off the center Collection Channel pipe. The purpose of this manhole is also unclear.

The Collection Chamber has three influent pipelines. Each entrance to the chamber is fitted with studs, allowing for the installation of cover plates. A single 16" gate valve controls flow to the 16" effluent pipeline. Please see Appendices A1-1, A1-2, D3-1 to D3-4, and D4.

The effluent pipeline from the Collection Chamber is actually a straight line extension of the Lower Pipeline. The pipeline coming from the Screen House tees into the Lower Pipeline and has a shut-off valve and drain valve installed in it. It was clearly the designer's intention that the Screen House, Upper Pipeline, and Intake would become a secondary, backup system, and the Infiltration Gallery would become the primary source. However, the infiltration beds apparently became clogged, and the entire system is now abandoned. Despite this, the visible portions of the system have remained in excellent condition. Please see Appendix D3-5.

IV. Pipeline's Capacities

Theory

Both Upper and Lower Pipelines normally operate in fully submerged conditions. Unless the overflow is in use, the Screen House functions as a flow equalizer between the pipelines. If the Screen House water level is high, the tailwater of the Upper Pipeline is high, and its flow will be reduced. Similarly, the headwater of the Lower Pipeline will be high, maximizing its flow. The reverse is also true. Therefore, for a range of flows, the water level in the Screen House will self-adjust, and the influent's flow rate will match the effluent's. Outside this range, if the demand at the plant is less than the minimum for the Upper Pipeline, water will spill into the overflow at the Screenhouse. If the demand at the plant is higher than the maximum the Upper Pipeline can supply, the stabilized water level will drop, eventually extending beyond the Screen House and into the Lower Pipeline.

For a normal range of flows, the condition is best analyzed using submerged culvert methods. Please see Appendix B2-1, B2-2, and B3 for hand and spreadsheet calculations.

Upper Pipeline

It was calculated that the minimum free flow (tailwater high) for this 18" pipeline is 1,565 GPM (headwater = 1,407.39', tailwater = 1,406.32'). The maximum free flow (tailwater low) is theoretically 3,747 GPM (headwater = 1,407.39', tailwater = 1,401.94).

Of course, headwater levels vary with river flow levels. The level used in this analysis is near the minimum, as the 2 x 12 planks mentioned above are used to maintain the river's water level (at the intake) during lower river-flow periods.

Lower Pipeline

It was calculated that the minimum free flow (headwater low) for this 16" pipeline is 4,041 GPM (headwater = 1,401.94', tailwater = 1,379.94'). The maximum free flow (headwater high) is theoretically 4,456 GPM (headwater = 1,406.32', tailwater = 1,379.94').

The tailwater level is controlled by either manual or automatic valves at the plant, and remains relatively constant during the present method of normal operation.

Flow Testing

To verify the accuracy of the calculations, a flow test was accomplished using the plant's flow meter on the incoming Lower Pipeline. By recording Lower Pipeline flows without any overflow at the Screen House, the Upper Pipeline actual flows are determined as well. Measurements of the water level elevation at the time of the flow meter reading were also recorded.

A test was recorded at 1,588 GPM, which was achieved with the clear-well emptied and the plant's influent valve wide open. Calculations using the resulting water level (1,406.02') predicted that the Upper Pipeline's flow should have been 1,786 GPM. By lowering the Hazen-Williams roughness coefficient from 100 to 88, the calculations matched the test. Possible explanations for the difference include sediment or biological growth on the inside of the pipeline, or a leak (~200 GPM) somewhere along the pipeline. It is suspected that the connection valve at Manhole #1 is leaking.

While the test verified the adjusted, calculated flow for the Upper Pipeline, the Lower Pipeline did not match predictions. Using a roughness coefficient of 100, the flow should have been 4,868 GPM. Using a roughness coefficient of 88, the flow should have been 4,308 GPM. Possible explanations for this difference include debris blockage (large woody debris), crushed sections of pipe, significant leaks, or a combination of the above. It is also possible, but unlikely, that the continual flow rates used at the plant have resulted in a stabilized mixture of sediment and debris at various low points, which restricts the flow. The plant Operator, Mr. Stan Adams, noted that during the test the influent was notably more turbid. Mr. Adams is planning on investigating further using extended flushing and/or a camera review.

V. Water Treatment Plant Capacity

In 1996, a study was commissioned by the City to investigate the possibility of increasing the plant's production. Infilco's off-the-shelf design capacity was 2,780 GPM. However, it is believed that the City has never been able to achieve this level of output, due to several limiting, and sometimes inter-related factors. The investigator, Mr. Bob Heggs, P.E. of Process Applications, determined the following restrictions:

Reaction Chamber (Cold Water)	1,390 GPM
Reaction Chamber (Warm Water)	1,600 GPM
Filtering system	1,910 GPM
Disinfection chambers	1,700 GPM

It is also noted, however, that three external factors also influence the plant's production. First, EPA and Washington State DOH regulations (standards) that the plant must meet have varied. Second, raw water coagulation products continue to evolve and improve. Third, the staffing levels of the plant could change. Higher outputs could be reached with the addition of a night crew, for example. Therefore, it is reasonable to assume that at some point in the future, 1,700 GPM could be achieved with the present plant. With modifications, even higher flows may be possible.

VI. Wellfield Production Capacity

Presently, the wellfield has the following maximum physical pumping rates:

Well #1	1,250 GPM
Well #2	750 GPM
Well #3	1,350 GPM
Total	3,350 GPM

VII. Instantaneous Water Rights

The City's water rights are complicated, and have been reviewed and revised in court. For historical information, please see the "City of Leavenworth Water System Plan", August 2011, by Varela and Associates. Below is a summary of the City's current understanding of instantaneous rights. Please see Appendix B4.

Ground Water Rights

The City has two instantaneous ground-water rights for the Wenatchee River wellfield.

Cert. No.	Type	Max. Allowable Inst. Flow
437-A	Uninterruptible	1,000 GPM
G4-29958	Interruptible	2,000 GPM
	Total	3,000 GPM

Surface Water Rights

The City has three instantaneous surface-water rights for the Icicle River intake.

Cert. No.	Type	Max. Allowable Inst. Flow
#4	Uninterruptible	682 GPM
8105	Uninterruptible	673 GPM
S4-28122	Interruptible	1,427 GPM
	Total	2,782 GPM

VIII. Intake Piping Requirements

The preceding information was presented to describe the operation of the water system, the importance of the intake piping, and the relevant performance characteristics. The following flow rates are repeated here for comparison:

Upper Pipeline (theory)	1,565 to 3,750 GPM
Upper Pipeline max (actual today)	1,590 GPM
Lower Pipeline (theory)	4,041 to 4,456 GPM
Lower Pipeline max (actual today)	1,590 GPM
Water Treatment Plant (theoretical design)	2,780 GPM
Water Treatment Plant (actual today)	~800 GPM
Water Rights	2,782 GPM

There are no current plans to expand the plant, but improvements are foreseeable. Also, because the existing plant appears to be incapable of utilizing the existing water right, the City may decide to replace the plant with a new, higher capacity plant at some point in the future. With this in mind, the intake piping should be designed to pass at least 2,780 GPM. After adding a factor of safety of 1.5, and considering the long term degradation in pipeline performance that is likely to occur (C = 88), it is reasonable to conclude that the 16" diameter pipeline was sized correctly, and that a replacement pipeline should also be 16" in diameter. Further, any new pipeline should be installed with continuous fall (not necessarily the same slope, but without any sags in the profile), and a full-diameter, gently curved HDPE pipeline extension with shutoff valve near the entrance to the plant should be provided for flushing debris to the plant's waste pond (the plant's existing incoming waterline has a 90° bend coincident with a sag in the profile, which invites blockage).

Before design work is undertaken, it is recommended that the causes of the lower-than-predicted flows found in the Lower Pipeline be determined. These findings may affect the conclusions found in the preceding paragraph.

Any new pipeline design should also accommodate long-term maintenance needs and protection from flood damage. As such, future designs should include backhoe access (limiting both the bury depth and the cross slope above the pipeline). The cut slope design must ensure that river bank erosion will not occur which could undermine or expose the pipeline.

IX. Fish Passage Design Impacts

The chosen fish passage design, labeled "Option 4", involves widening the river bed to provide room for the fish passage improvements. The widening requires that a new cut slope be excavated, which would expose the Lower Pipeline for approximately 70'. The old road, which is used today as an access road, will also be removed in this location. This will also necessitate a new approach (off of Icicle Road) on the upstream side of the cut.

By considering the requirements presented in Section VIII (continual fall, 16" pipe, backhoe access), two options are available. The first would involve lowering the pipeline in the affected area, while moving its horizontal alignment away from the river as much as possible. The second would involve moving the horizontal alignment from the access road to Icicle road. This alignment would be aided by raising the profile as high as possible. Each option is discussed in more detail below.

X. Option A

As mentioned, this option makes the maximum horizontal adjustment away from the cut as can easily be achieved (without destabilizing Icicle Road), while lowering the profile at the same time. To provide backhoe access, a bench should be installed in the cut slope of at least 8' in width. Downstream of the cut location, the existing pipeline was installed off of the access road, presumably to maintain a consistent pipeline slope. This section of pipeline was likely buried in the fill slope when the new Icicle Road was constructed. To keep the pipeline from having intermediate sags, and to avoid Icicle road, fill would need to be placed to raise a portion of the profile of the access road so that the pipeline would have adequate cover. Please see Appendices A1-3, A1-4, A2, A3, and E1-1 to E1-6.

XI. Option B

As mentioned, this option avoids the new cut slope entirely by leaving the access road upstream of the abandoned chlorine house and relocating the pipeline beneath Icicle Road. This will involve significant rock excavation and blasting, which could be minimized by raising the profile as much as possible. The concept would require permits and new easements, and repair and replacement of the roadway pavement. Due to the significant bury depths and the difficulty working with traffic, this alignment is undesirable from both construction and maintenance perspectives. It does, however, offer better flood damage resistance than Option A. Please see Appendices A1-3, A1-4, A2, A4, and E1-1 to E1-6.

XII. Option C

For comparison purposes, a concept was also prepared for the minimum amount of pipeline replacement. This would involve the design concept of Option A, but be restricted to the closest points where connections could be made to the existing pipeline. Please see Appendices A1-3, A1-4, A2, A5, and E1-1 to E1-6.

XIII. Other Alternatives

At the start of this investigation, it was requested that broader, more extreme solutions be considered as well. The following represent some of the concepts considered, but none of them rose to a level of feasibility which would have justified further investigation.

Alternate Water Supply to the Water Treatment Plant

This concept involves using a different intake location and piping alignment to supply Icicle River surface water to the plant. Two options are available: gravity-fed and pumped.

A new gravity-fed intake site would have to be at the same elevation, or above, the present site. The present intake site is at a relatively wide spot in the canyon. Upstream, the canyon narrows and the roadway rises relatively higher above the river. This topography means that moving the intake upstream would require significantly more pipe and more excavation, blasting, and/or drilling. There is no shortcut available for the water supply. As no advantages were found in this concept, no further investigation was made.

Another gravity-fed option that was discussed was to tie into the Icicle Irrigation District canal, possibly crossing the river with a pipeline attached to the existing footbridge. However, this concept was not developed due to the vulnerability of the pipeline on the bridge during flooding and freezing conditions, the possible need to strengthen (or replace) the bridge to handle the additional load, and because Icicle Irrigation does not keep the canal charged during winter months. Also, the footbridge is located upstream of the pipeline impact area, meaning that the pipeline relocation would still be required.

Pumping water to the plant provides more options. An intake could be positioned closer to the plant, and downstream of the Boulder Field. A new intake would have to be designed, along with pumping equipment that could withstand variable river flows, from drought to flood conditions. The system would also require electrical power, and a backup generator or a mechanical, direct drive connection to an internal combustion engine for continued operation during PUD power outages. Water rights would need to be amended, and new property acquired. While this may be more feasible than a new gravity-fed intake location, it is believed to be much less feasible and much more costly than realigning and replacing the current pipeline.

Abandon the Water Treatment Plant

Another concept is to abandon the plant, and make up for the lost production in another way, such as a second well field. This would require revised water rights, property acquisition, new wells, pumphouse(s), and connecting water mains. A new reservoir would need to be built at the plant location to service the high-elevation customers, along with an additional booster pump station. This concept is clearly beyond that which could be justified when compared to a new Lower Pipeline. It would also remove a valuable, diverse source of water for the City; one that has served them reliably for many decades.

XIV. Conclusion

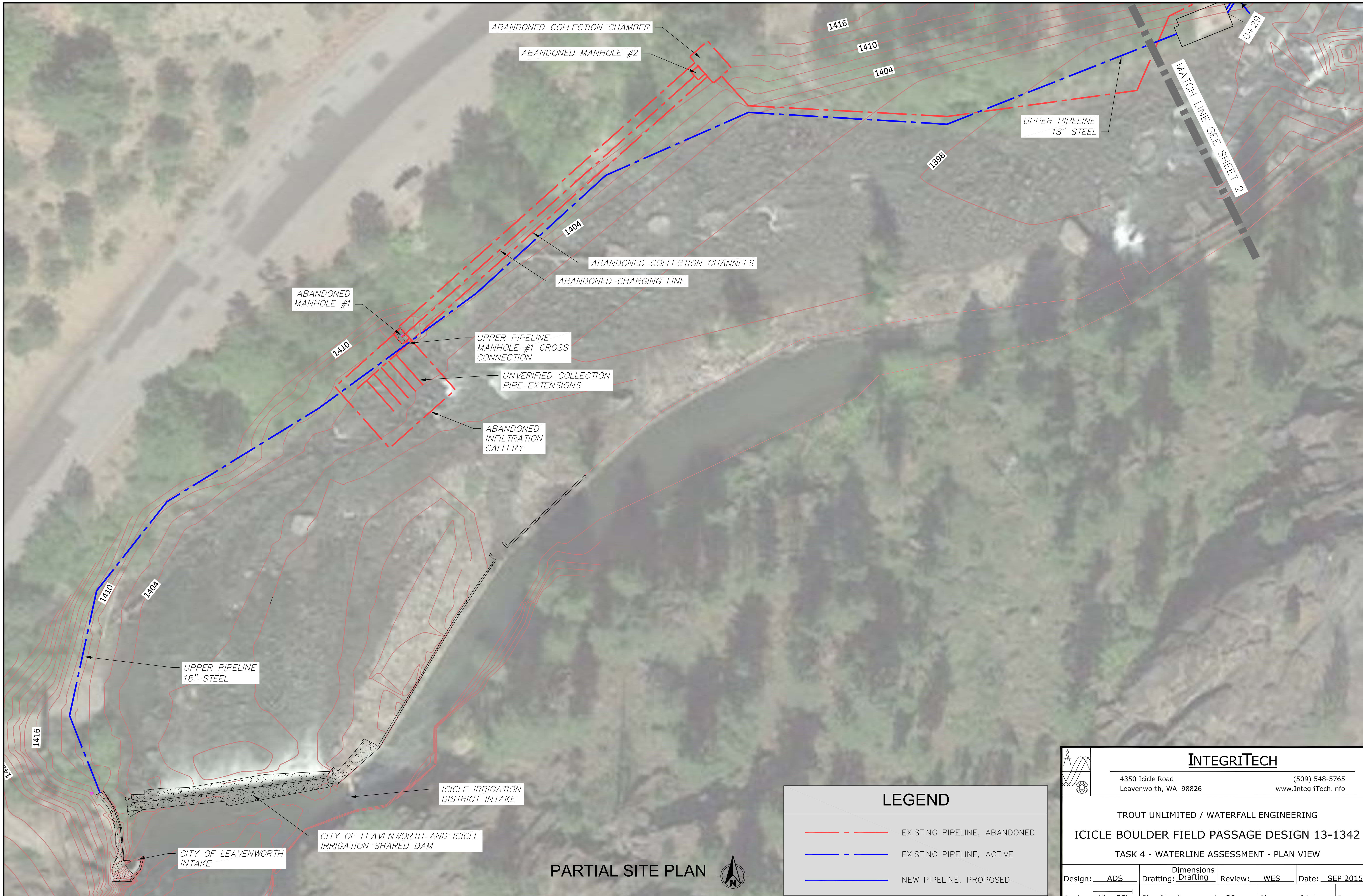
It is clear that any attempt to improve fish passage must not restrict the City's ability to meet its present and future water supply needs and responsibilities. Fortunately, these two very different goals are not fundamentally opposed. It appears possible to accommodate both, and Option A represents a possible solution. However, further pipeline research, review, and design will be required once the fish passage design is finalized and the actual impacts to the pipeline are known.

This report represents a summary of the information gathered during the course of my investigation. If there are any further details which are desired, please enquire. It may be that the desired information has already been collected.

Sincerely,

Aaron Schmidt

Aaron Schmidt, P.E.
Consulting Engineer



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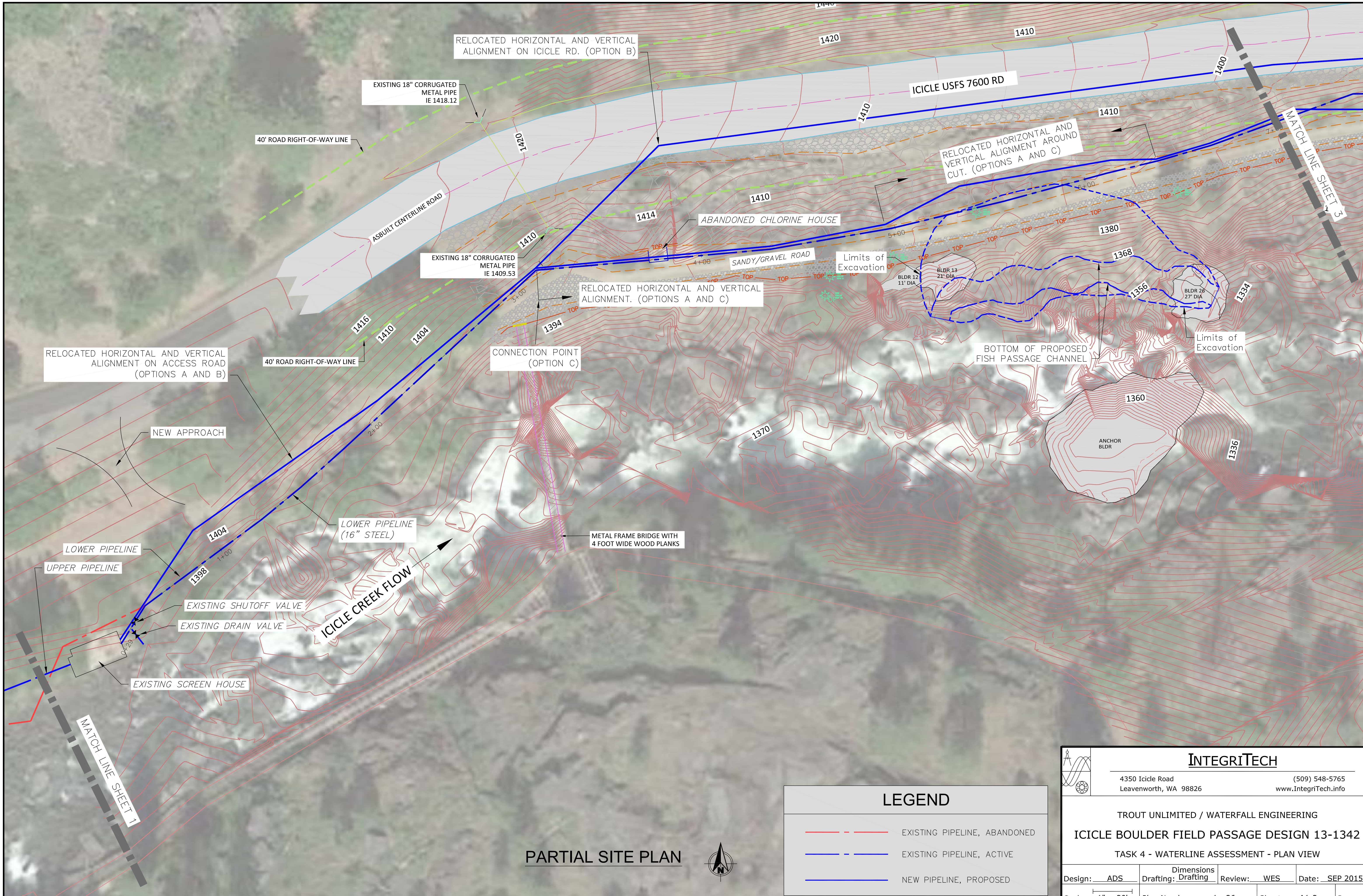
ICICLE BOULDER FIELD PASSAGE DESIGN 13-1342

TASK 4 - WATERLINE ASSESSMENT - PLAN VIEW

Design: ADS	Drafting: Dimensions Drafting	Review: WES	Date: SEP 2015
Scale: 1" = 20'	Plan Number: 1 - 26	Sheet: A1-1	Rev:



PARTIAL SITE PLAN

LEGEND

- EXISTING PIPELINE, ABANDONED
- EXISTING PIPELINE, ACTIVE
- NEW PIPELINE, PROPOSED

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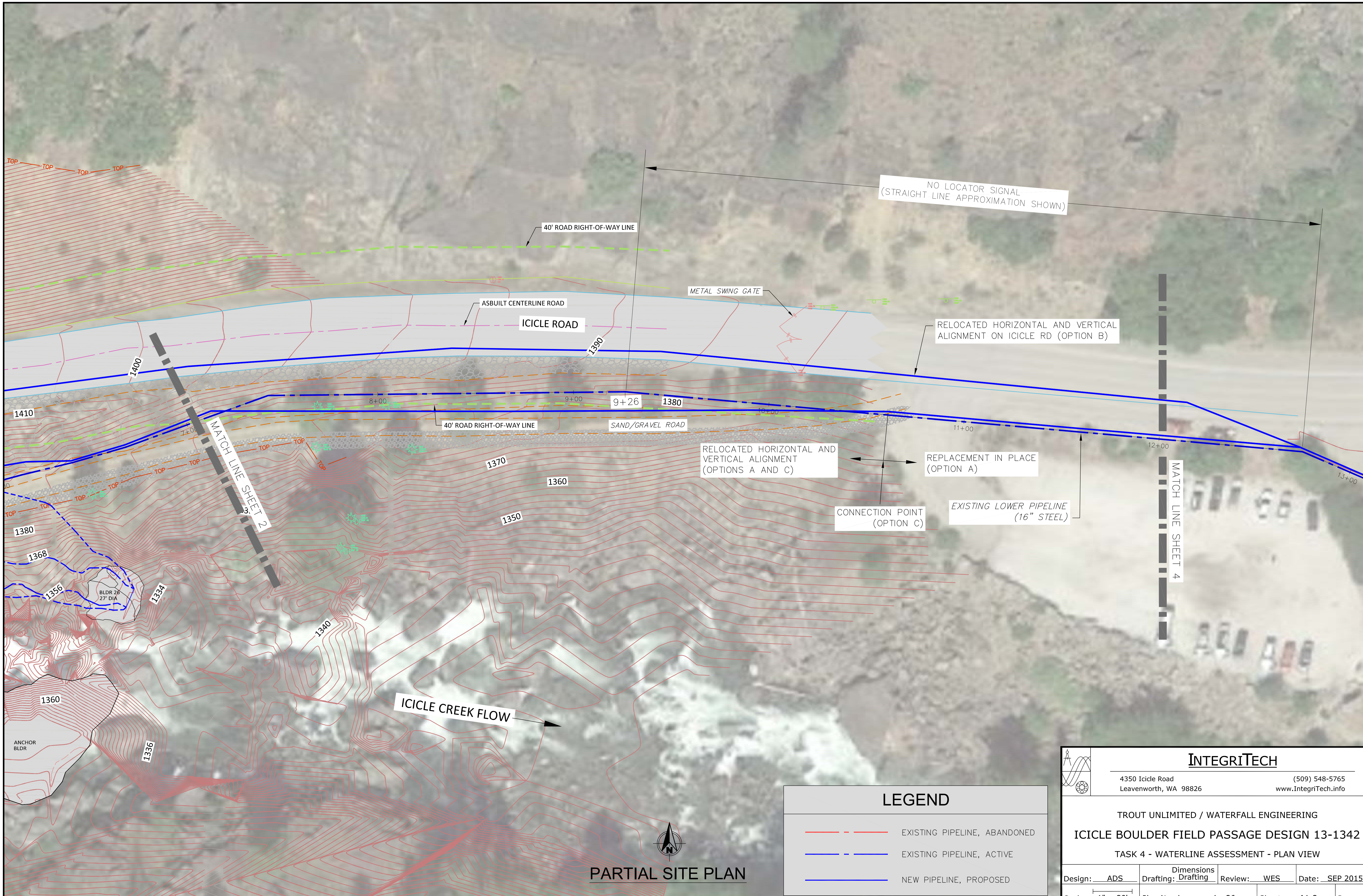

LEGEND

- EXISTING PIPELINE, ABANDONED
- EXISTING PIPELINE, ACTIVE
- NEW PIPELINE, PROPOSED

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TASK 4 - WATERLINE ASSESSMENT - PLAN VIEW

Design: ADS	Drafting: Dimensions Drafting	Review: WES	Date: SEP 2015
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TASK 4 - WATERLINE ASSESSMENT - PLAN VIEW

Design: ADS | Drafting: Dimensions Drafting | Review: WES | Date: SEP 2015

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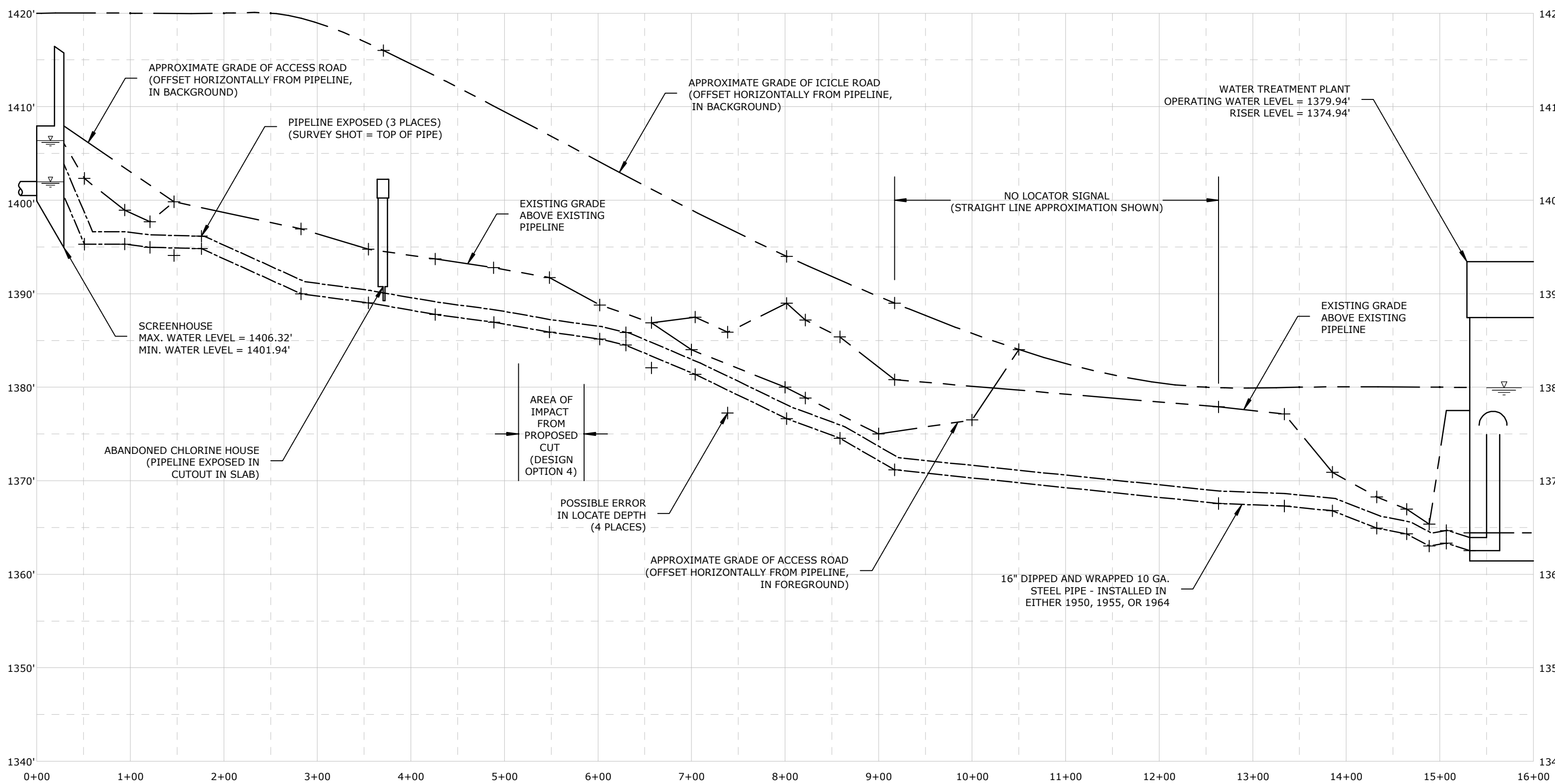

EXISTING PROFILE

AS VIEWED FROM RIVER

NOTES

- DATUM SET BY MTN 2 COAST, LLC SEE SHEET SV-1. NAVD 88
- LOCATED POSITIONS AND DEPTHS PROVIDED BY CITY OF LEAVENWORTH AND INTEGRITECH USING A MCLAUGHLIN "VERIFIER" LOCATOR.
- PIPELINE SURVEY DATA PROVIDED BY WATERFALL ENGINEERING USING CST-BERGER TOTAL STATION SURVEY EQUIPMENT.

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ICICLE BOULDER FIELD PASSAGE DESIGN 13-1342

TASK 4 - WATERLINE ASSESSMENT - EXISTING PROFILE

Design: ADS	Drafting: ADS	Review: WES	Date: JULY 2015
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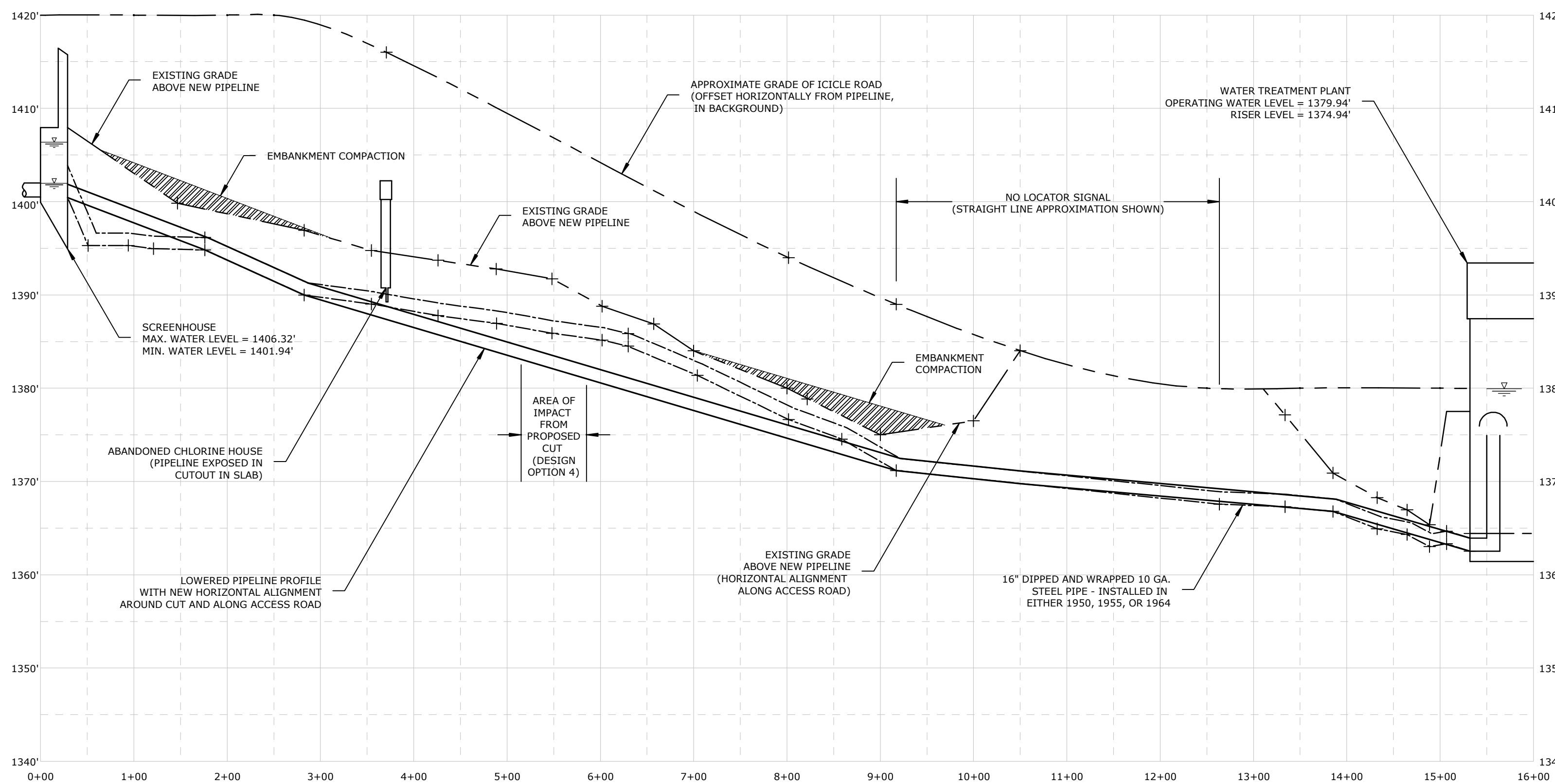

OPTION A

AS VIEWED FROM RIVER

NOTES

- DATUM SET BY MTN 2 COAST, LLC
  SEE SHEET SV-1. NAVD 88

- LOCATED POSITIONS AND DEPTHS PROVIDED BY CITY OF LEAVENWORTH AND INTEGRITECH
  USING A MCLAUGHLIN "VERIFIER" LOCATOR.

- PIPELINE SURVEY DATA PROVIDED BY WATERFALL ENGINEERING
  USING CST-BERGER TOTAL STATION SURVEY EQUIPMENT.

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TROUT UNLIMITED / WATERFALL ENGINEERING

ICICLE BOULDER FIELD PASSAGE DESIGN 13-1342

TASK 4 - WATERLINE ASSESSMENT - PROFILE, OPTION A

Design: ADS	Drafting: ADS	Review: WES	Date: JULY 2015
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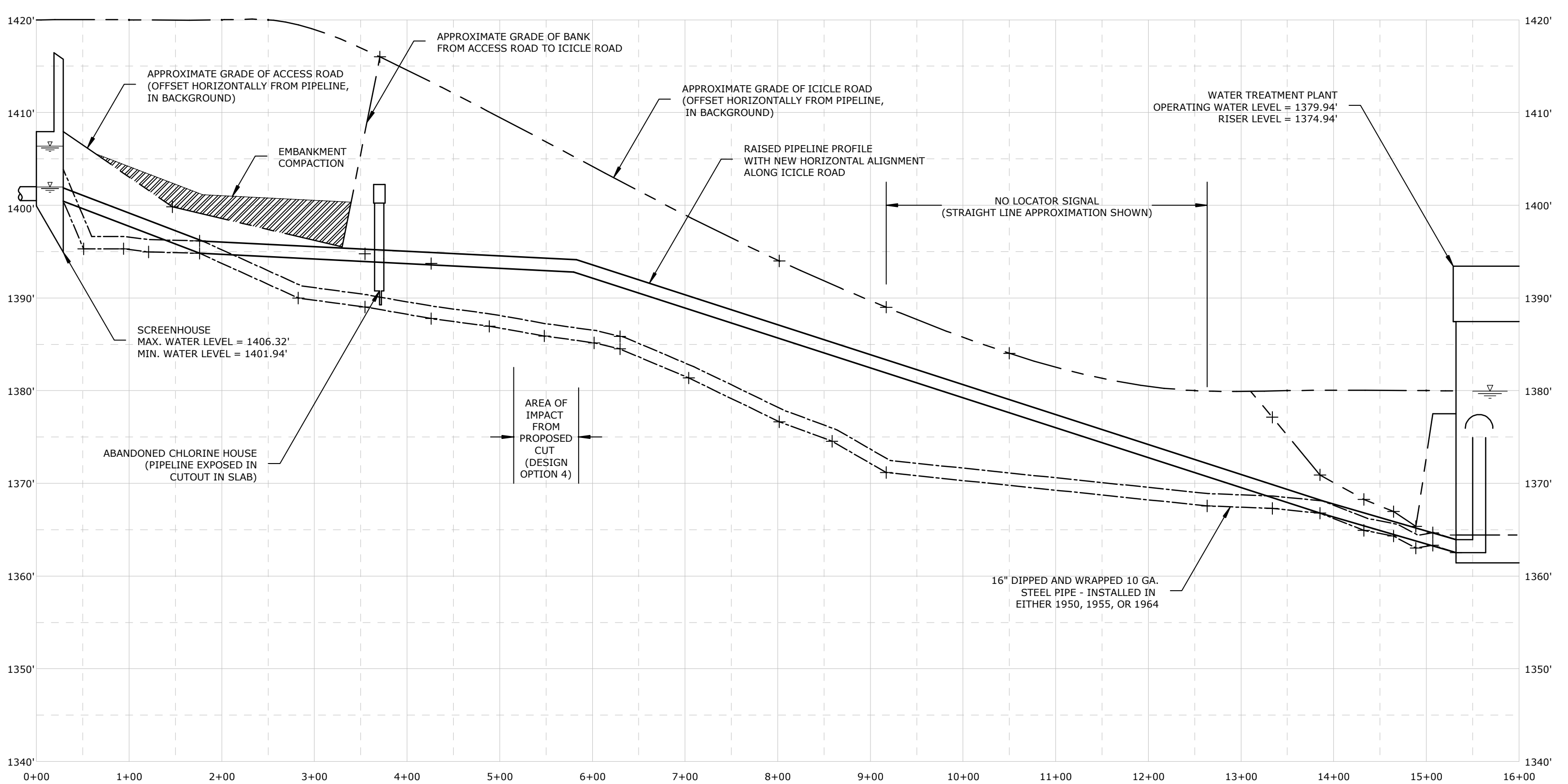

OPTION B

AS VIEWED FROM RIVER

NOTES

- DATUM SET BY MTN 2 COAST, LLC
  SEE SHEET SV-1. NAVD 88

- LOCATED POSITIONS AND DEPTHS PROVIDED BY CITY OF LEAVENWORTH AND INTEGRITECH
  USING A MCLAUGHLIN "VERIFIER" LOCATOR.

- PIPELINE SURVEY DATA PROVIDED BY WATERFALL ENGINEERING
  USING CST-BERGER TOTAL STATION SURVEY EQUIPMENT.

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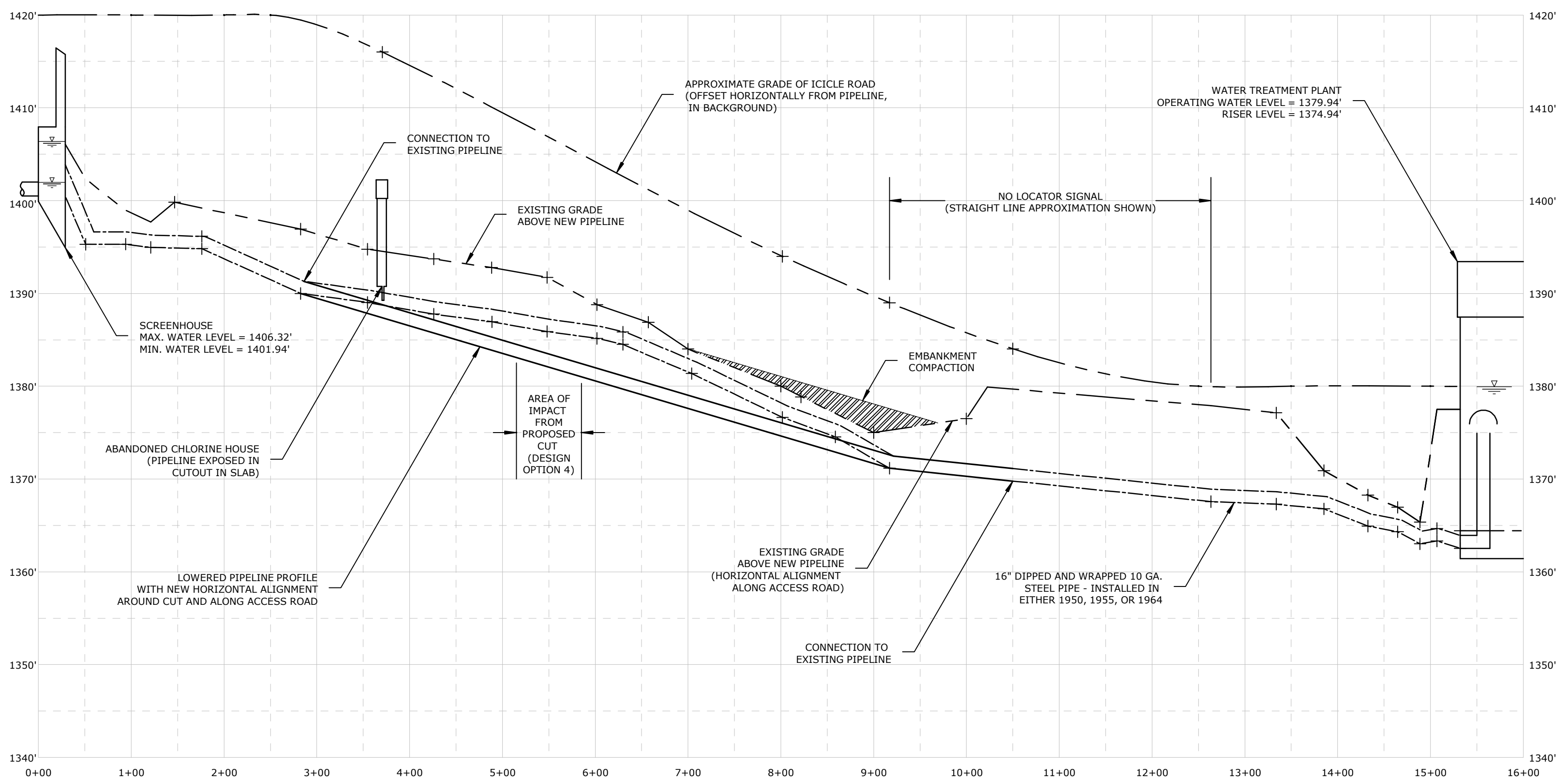
ICICLE BOULDER FIELD PASSAGE DESIGN 13-1342

TASK 4 - WATERLINE ASSESSMENT - PROFILE, OPTION B

Design: ADS	Drafting: ADS	Review: WES	Date: JULY 2015
Scale: HOR: 1" = 50' VER: 1" = 5'	Plan Number: 1 - 26	Sheet: A4	Rev:



OPTION C

AS VIEWED FROM RIVER

NOTES

- DATUM SET BY MTN 2 COAST, LLC SEE SHEET SV-1. NAVD 88
- LOCATED POSITIONS AND DEPTHS PROVIDED BY CITY OF LEAVENWORTH AND INTEGRITECH USING A MCLAUGHLIN "VERIFIER" LOCATOR.
- PIPELINE SURVEY DATA PROVIDED BY WATERFALL ENGINEERING USING CST-BERGER TOTAL STATION SURVEY EQUIPMENT.

INTEGRITECH
4350 Icicle Road
Leavenworth, WA 98826
(509) 548-5765
www.IntegriTech.info

TROUT UNLIMITED / WATERFALL ENGINEERING

ICICLE BOULDER FIELD PASSAGE DESIGN 13-1342

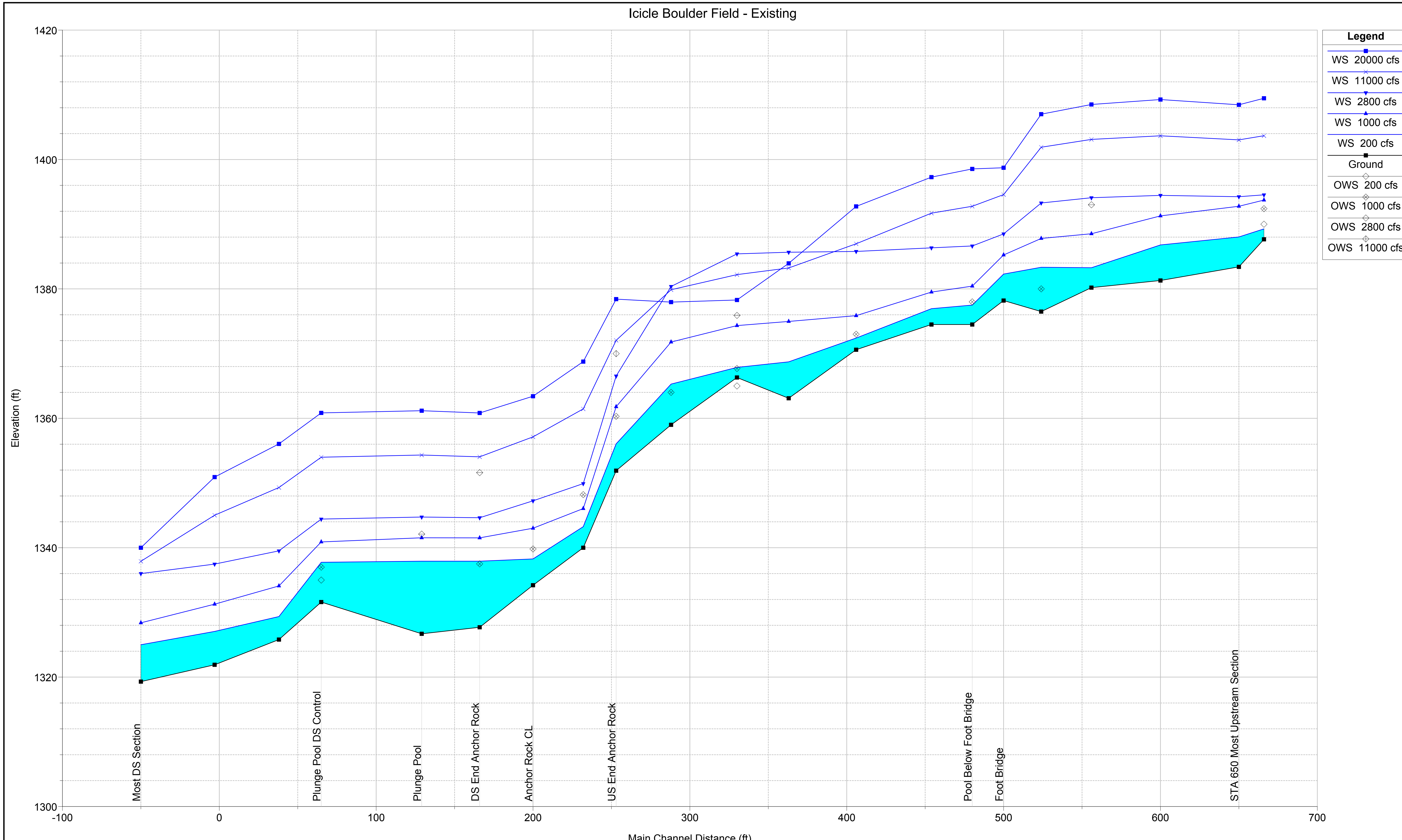
TASK 4 - WATERLINE ASSESSMENT - PROFILE, OPTION C

Design: ADS	Drafting: ADS	Review: WES	Date: JULY 2015	
Scale: HOR: 1" = 50' VER: 1" = 5'	Plan Number: 1 - 26		Sheet: A5	Rev:

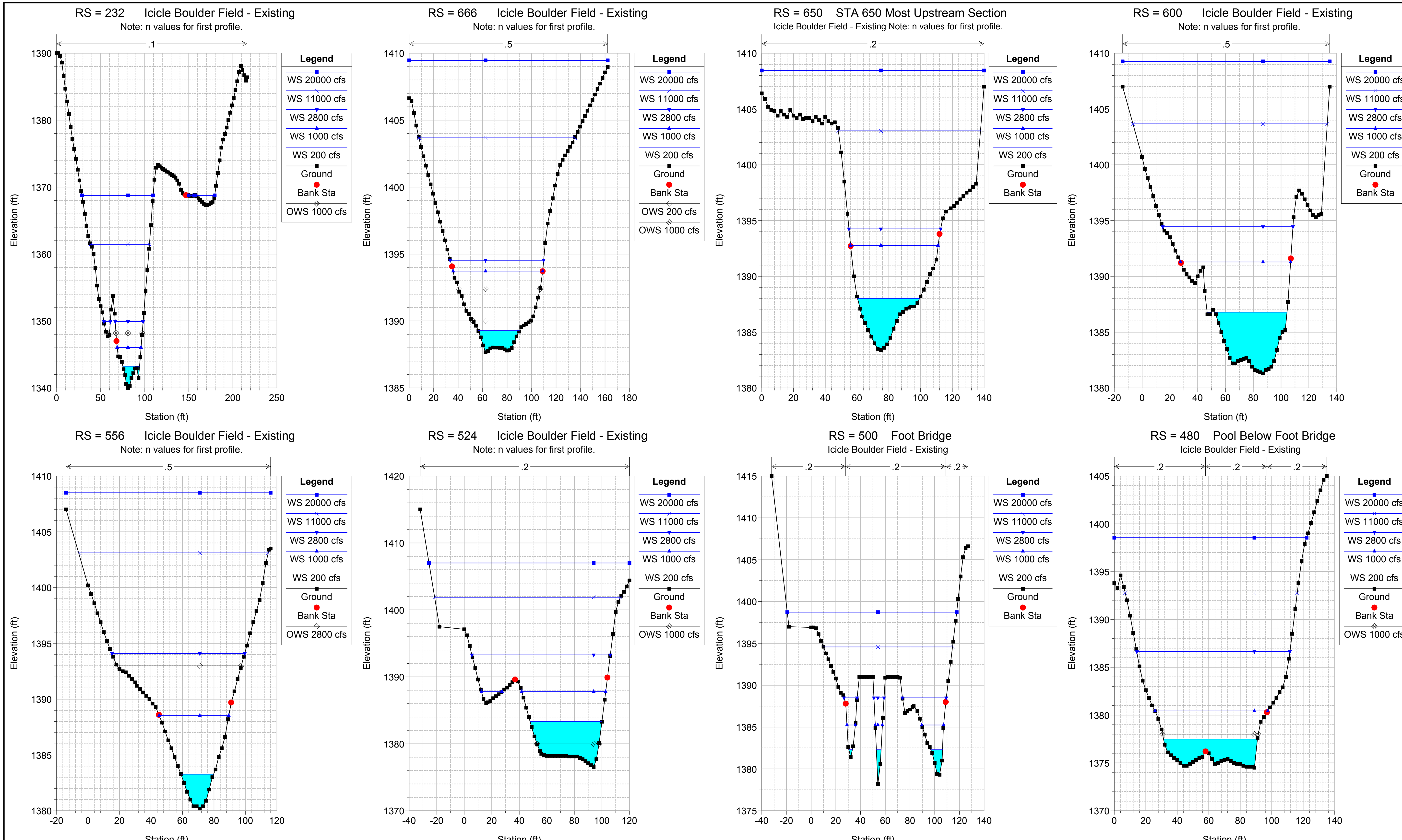
APPENDIX E: HEC RAS MODEL OUTPUT

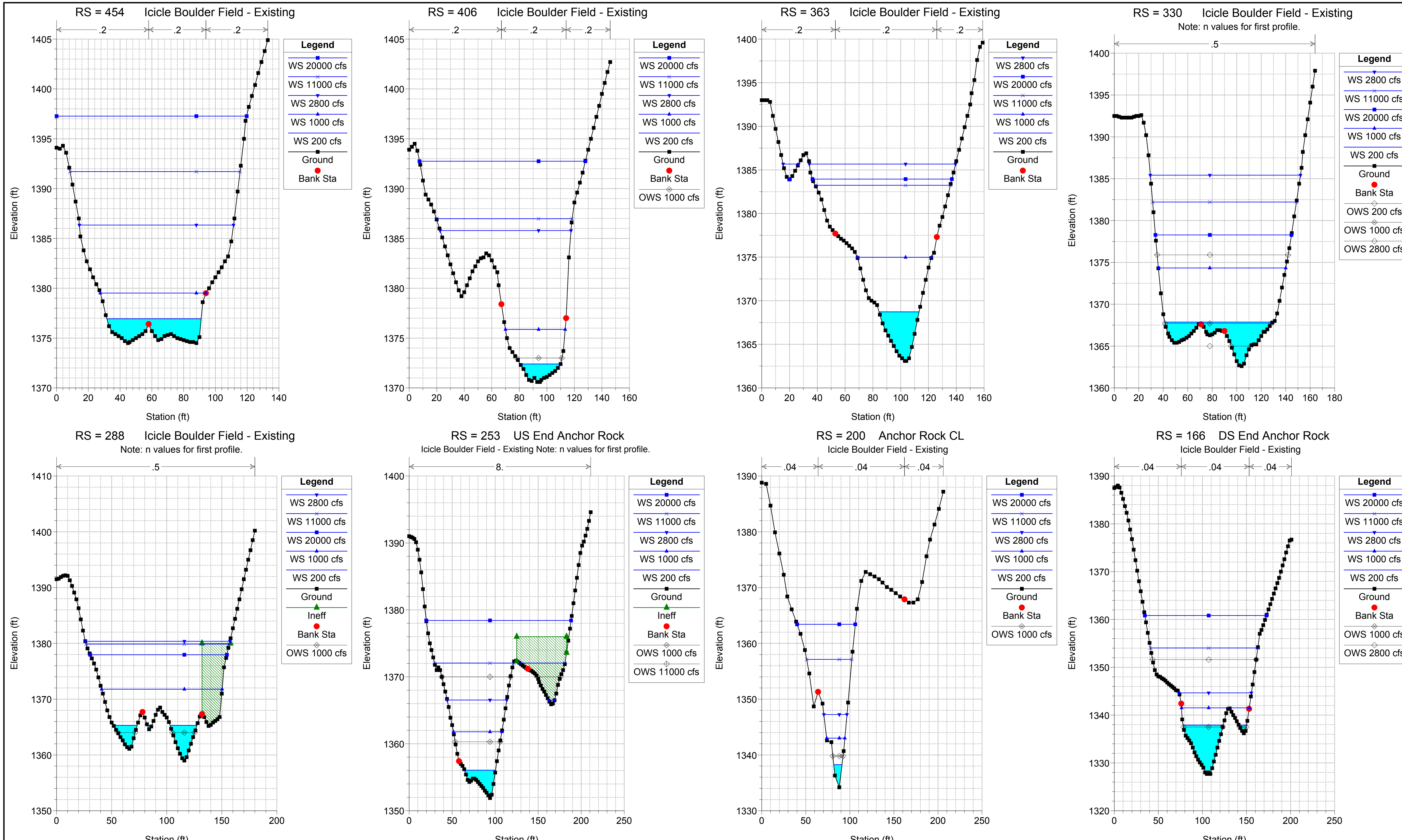
<u>Existing</u>
Water Surface Profiles
Cross Sections
Output Data

<u>Proposed Option 4</u>
Water Surface Profiles
Cross Sections
Output Data

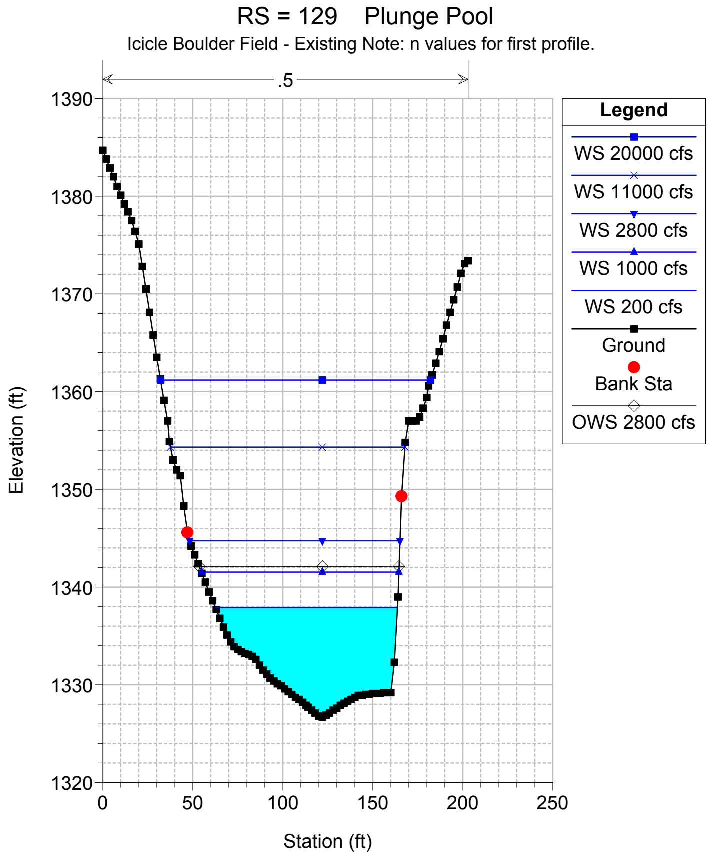


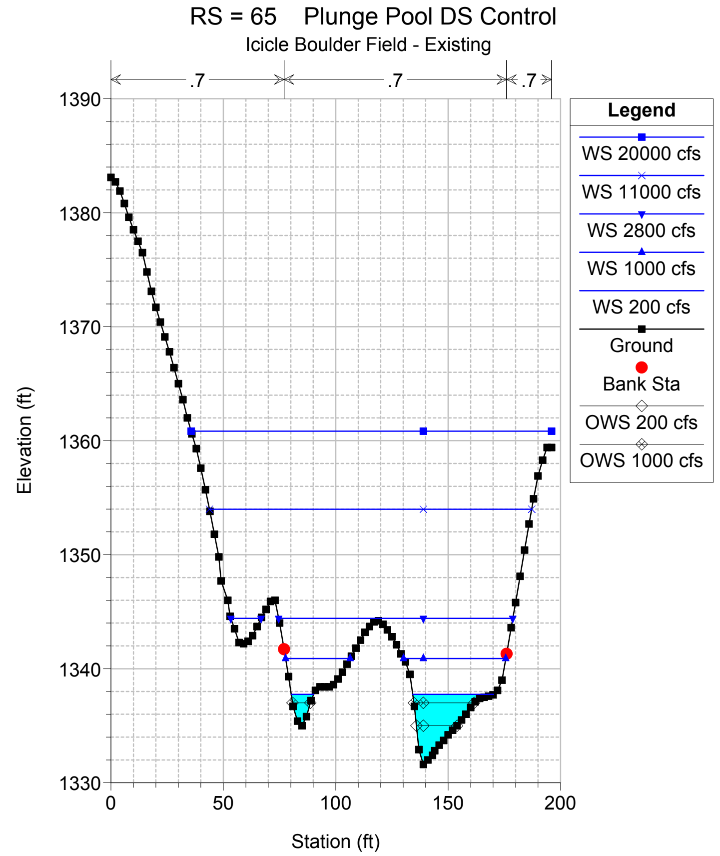
Icicle Boulder Field - Existing
Legend
WS 20000 cfs
WS 11000 cfs
WS 2800 cfs
WS 1000 cfs
WS 200 cfs
Ground
OWS 200 cfs
OWS 1000 cfs
OWS 2800 cfs
OWS 11000 cfs
Elevation (ft)
Main Channel Distance (ft)
1420
1400
1380
1360
1340
1320
1300
-100
0
100
200
300
400
500
600
700
Most DS Section
Plunge Pool DS Control
Plunge Pool
DS End Anchor Rock
Anchor Rock CL
US End Anchor Rock
Pool Below Foot Bridge
Foot Bridge
STA 650 Most Upstream Section

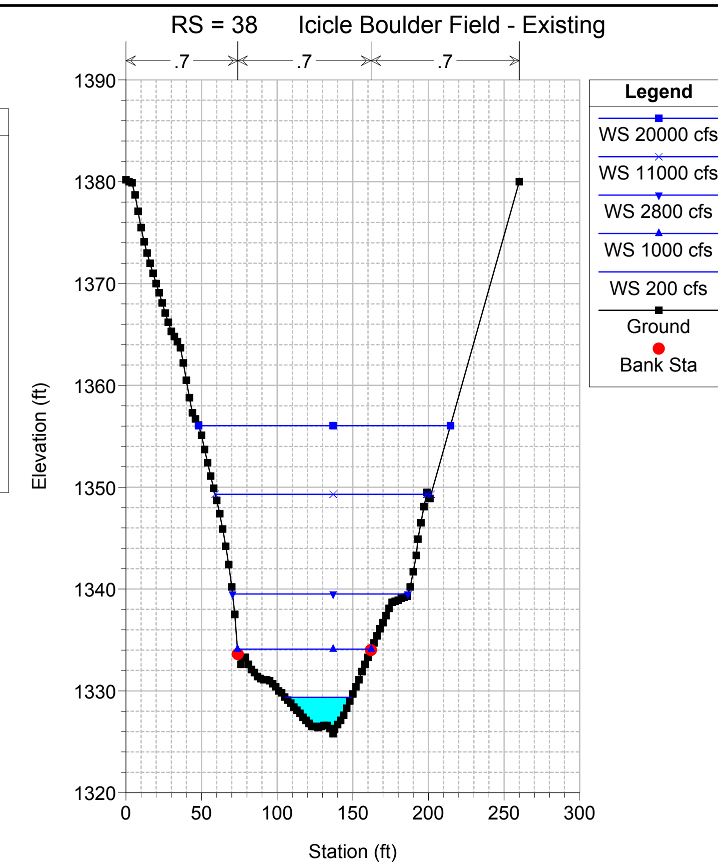

RS = 232 Icicle Boulder Field - Existing
Note: n values for first profile.
.1
Legend
WS 20000 cfs
WS 11000 cfs
WS 2800 cfs
WS 1000 cfs
WS 200 cfs
Ground
Bank Sta
OWS 1000 cfs
Elevation (ft)
Station (ft)
RS = 666 Icicle Boulder Field - Existing
Note: n values for first profile.
.5
Legend
WS 20000 cfs
WS 11000 cfs
WS 2800 cfs
WS 1000 cfs
WS 200 cfs
Ground
Bank Sta
OWS 200 cfs
OWS 1000 cfs
Elevation (ft)
Station (ft)
RS = 650 STA 650 Most Upstream Section
Icicle Boulder Field - Existing Note: n values for first profile.
.2
Legend
WS 20000 cfs
WS 11000 cfs
WS 2800 cfs
WS 1000 cfs
WS 200 cfs
Ground
Bank Sta
Elevation (ft)
Station (ft)
RS = 600 Icicle Boulder Field - Existing
Note: n values for first profile.
.5
Legend
WS 20000 cfs
WS 11000 cfs
WS 2800 cfs
WS 1000 cfs
WS 200 cfs
Ground
Bank Sta
Elevation (ft)
Station (ft)
RS = 556 Icicle Boulder Field - Existing
Note: n values for first profile.
.5
Legend
WS 20000 cfs
WS 11000 cfs
WS 2800 cfs
WS 1000 cfs
WS 200 cfs
Ground
Bank Sta
OWS 2800 cfs
Elevation (ft)
Station (ft)
RS = 524 Icicle Boulder Field - Existing
Note: n values for first profile.
.2
Legend
WS 20000 cfs
WS 11000 cfs
WS 2800 cfs
WS 1000 cfs
WS 200 cfs
Ground
Bank Sta
OWS 1000 cfs
Elevation (ft)
Station (ft)
RS = 500 Foot Bridge
Icicle Boulder Field - Existing
.2 .2 .2
Legend
WS 20000 cfs
WS 11000 cfs
WS 2800 cfs
WS 1000 cfs
WS 200 cfs
Ground
Bank Sta
Elevation (ft)
Station (ft)
RS = 480 Pool Below Foot Bridge
Icicle Boulder Field - Existing
.2 .2 .2
Legend
WS 20000 cfs
WS 11000 cfs
WS 2800 cfs
WS 1000 cfs
WS 200 cfs
Ground
Bank Sta
OWS 1000 cfs
Elevation (ft)
Station (ft)

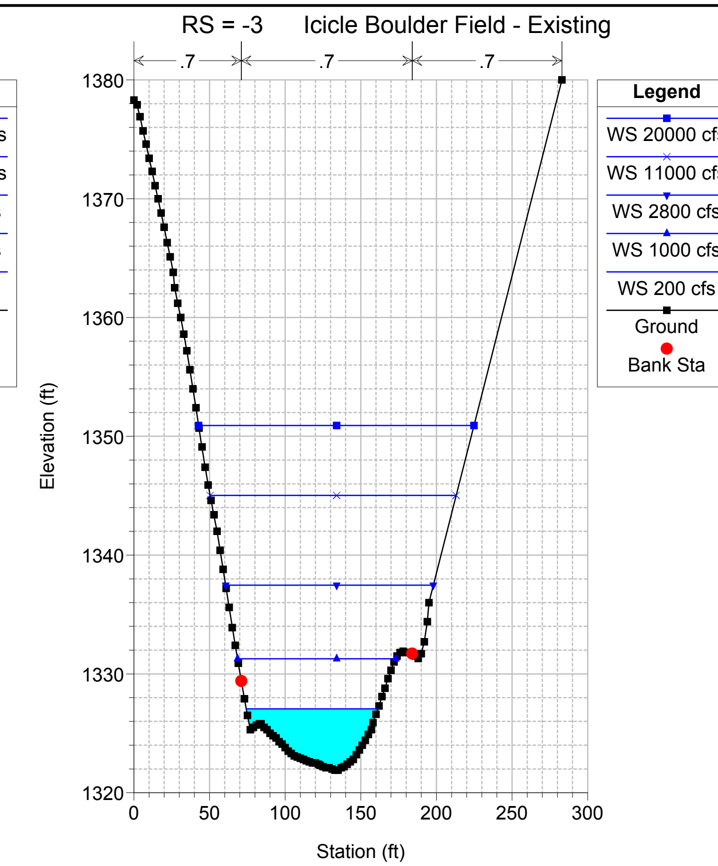


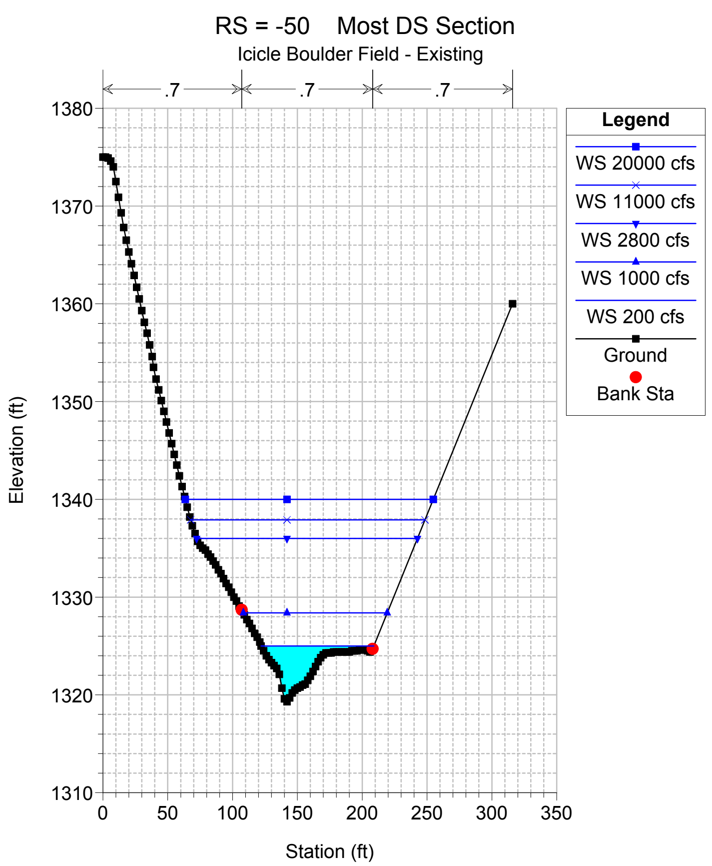
RS = 454 Icicle Boulder Field - Existing
RS = 406 Icicle Boulder Field - Existing
RS = 363 Icicle Boulder Field - Existing
RS = 330 Icicle Boulder Field - Existing
Note: n values for first profile.
RS = 288 Icicle Boulder Field - Existing
Note: n values for first profile.
RS = 253 US End Anchor Rock
Icicle Boulder Field - Existing Note: n values for first profile.
RS = 200 Anchor Rock CL
Icicle Boulder Field - Existing
RS = 166 DS End Anchor Rock
Icicle Boulder Field - Existing
Legend
WS 20000 cfs
WS 11000 cfs
WS 2800 cfs
WS 1000 cfs
WS 200 cfs
Ground
Ineff
Bank Sta
OWS 200 cfs
OWS 1000 cfs
OWS 2800 cfs
OWS 11000 cfs
Elevation (ft)
Station (ft)


RS = 129 Plunge Pool
Icicle Boulder Field - Existing Note: n values for first profile.
.5
Elevation (ft)
Station (ft)
Legend
WS 20000 cfs
WS 11000 cfs
WS 2800 cfs
WS 1000 cfs
WS 200 cfs
Ground
Bank Sta
OWS 2800 cfs


RS = 65 Plunge Pool DS Control
Icicle Boulder Field - Existing
.7
.7
.7
Elevation (ft)
Station (ft)
Legend
WS 20000 cfs
WS 11000 cfs
WS 2800 cfs
WS 1000 cfs
WS 200 cfs
Ground
Bank Sta
OWS 200 cfs
OWS 1000 cfs

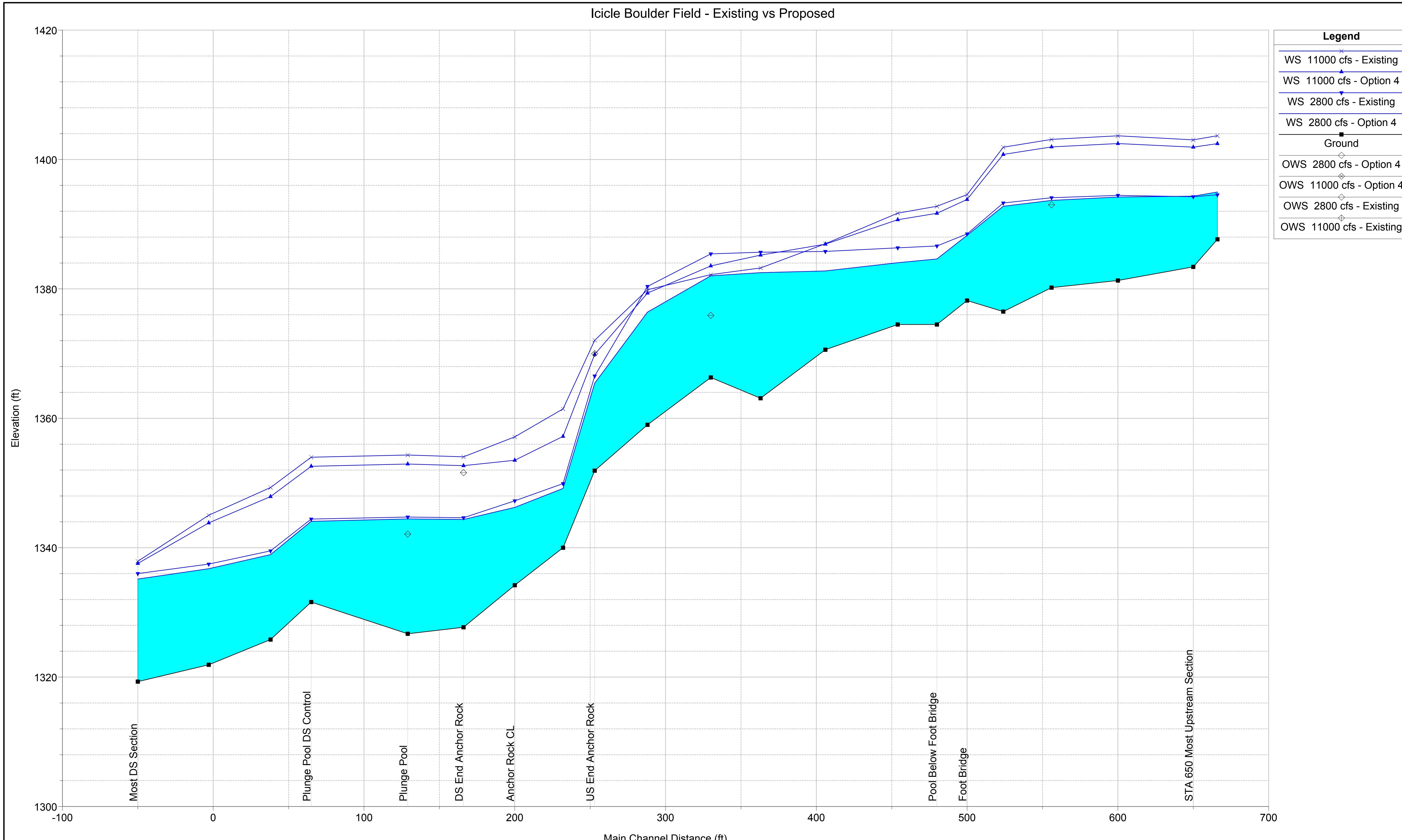

RS = 38 Icicle Boulder Field - Existing
.7
.7
.7
Elevation (ft)
Station (ft)
Legend
WS 20000 cfs
WS 11000 cfs
WS 2800 cfs
WS 1000 cfs
WS 200 cfs
Ground
Bank Sta


RS = -3 Icicle Boulder Field - Existing
.7
.7
.7
Elevation (ft)
Station (ft)
Legend
WS 20000 cfs
WS 11000 cfs
WS 2800 cfs
WS 1000 cfs
WS 200 cfs
Ground
Bank Sta

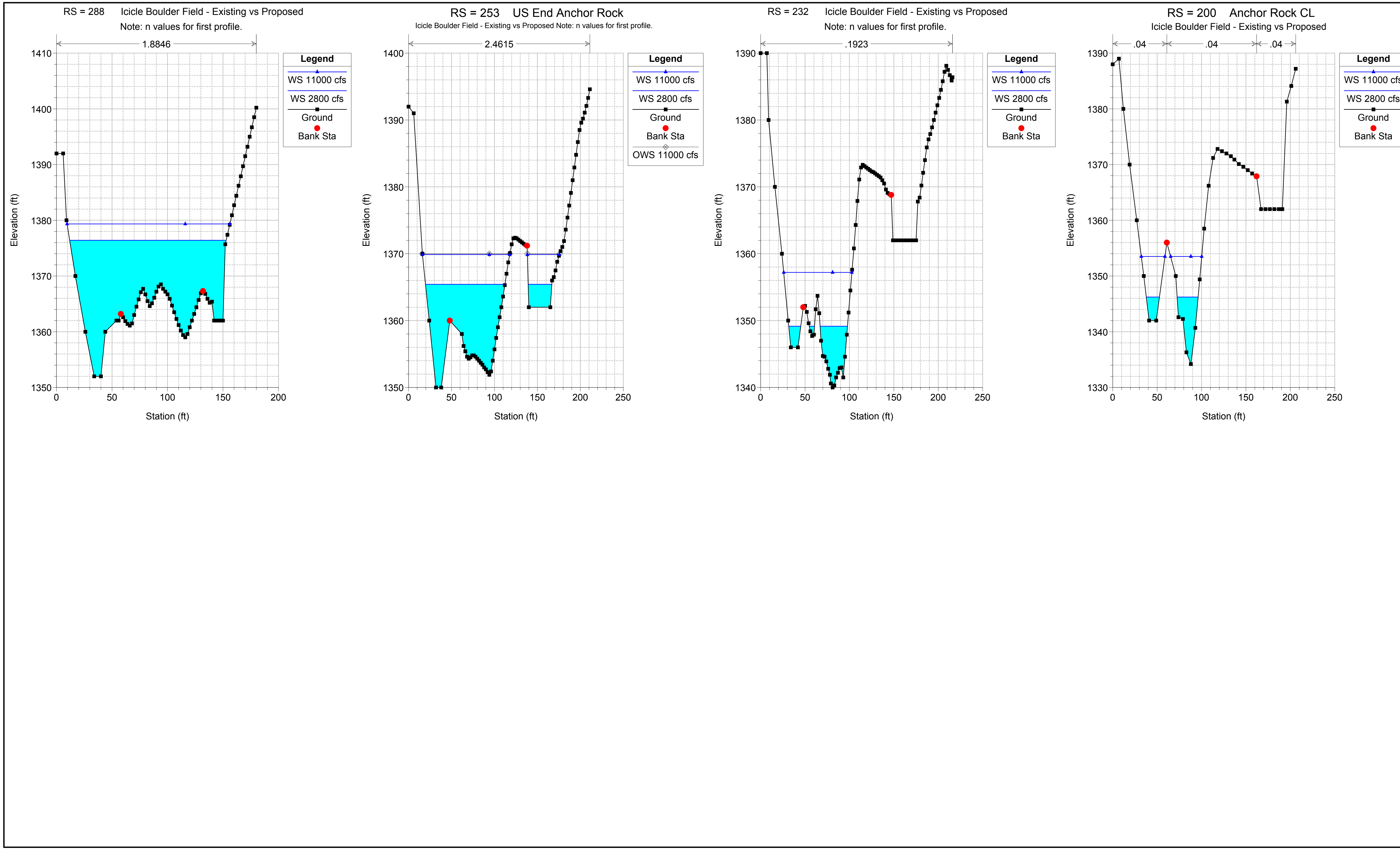

RS = -50 Most DS Section
Icicle Boulder Field - Existing
.7
.7
.7
Elevation (ft)
Station (ft)
Legend
WS 20000 cfs
WS 11000 cfs
WS 2800 cfs
WS 1000 cfs
WS 200 cfs
Ground
Bank Sta

HEC-RAS Plan: Existing River: Icicle Creek Reach: Boulder Falls

Reach	River Sta	Profile	Q Total	W.S. Elev	Max Chl Dpth	Vel Chnl	Top Width	Shear Total	Power Total	Froude # Chl
			(cfs)	(ft)	(ft)	(ft/s)	(ft)	(lb/sq ft)	(lb/ft s)	
Boulder Falls	-50	2800 cfs	2800.00	1336.00	16.70	1.98	170.32	17.44	31.19	0.10
Boulder Falls	-50	11000 cfs	11000.00	1337.91	18.61	6.50	180.76	177.52	1027.49	0.30
Boulder Falls	-3	2800 cfs	2800.00	1337.46	15.56	1.96	137.26	19.88	37.41	0.10
Boulder Falls	-3	11000 cfs	11000.00	1345.02	23.12	4.54	162.68	82.56	346.82	0.18
Boulder Falls	38	2800 cfs	2800.00	1339.51	13.71	3.09	115.96	48.54	143.72	0.17
Boulder Falls	38	11000 cfs	11000.00	1349.30	23.50	5.54	141.78	115.34	578.67	0.22
Boulder Falls	65	2800 cfs	2800.00	1344.42	12.82	4.49	117.64	136.75	597.61	0.32
Boulder Falls	65	11000 cfs	11000.00	1353.98	22.38	6.20	143.36	178.11	1020.41	0.28
Boulder Falls	129	2800 cfs	2800.00	1344.74	18.04	1.84	116.88	0.11	0.19	0.09
Boulder Falls	129	11000 cfs	11000.00	1354.32	27.62	4.12	130.22	0.09	0.35	0.15
Boulder Falls	166	2800 cfs	2800.00	1344.64	16.94	3.71	82.43	0.28	1.04	0.21
Boulder Falls	166	11000 cfs	11000.00	1354.05	26.35	6.77	121.88	0.61	3.76	0.27
Boulder Falls	200	2800 cfs	2800.00	1347.24	13.04	15.12	26.28	6.17	93.30	1.00
Boulder Falls	200	11000 cfs	11000.00	1357.13	22.93	19.70	51.27	7.37	138.21	0.94
Boulder Falls	232	2800 cfs	2800.00	1349.90	9.90	13.32	39.04	92.06	1179.13	0.90
Boulder Falls	232	11000 cfs	11000.00	1361.45	21.45	14.43	66.78	82.90	1074.74	0.64
Boulder Falls	253	2800 cfs	2800.00	1366.54	14.64	4.52	76.19	948.66	4093.31	0.24
Boulder Falls	253	11000 cfs	11000.00	1372.05	20.15	10.95	144.62	4706.85	47856.92	0.51
Boulder Falls	288	2800 cfs	2800.00	1380.38	21.38	1.78	131.35	118.96	187.96	0.08
Boulder Falls	288	11000 cfs	11000.00	1379.87	20.87	8.24	129.96	44.88	342.87	0.37
Boulder Falls	330	2800 cfs	2800.00	1385.42	22.82	1.57	122.67	83.74	113.52	0.06
Boulder Falls	330	11000 cfs	11000.00	1382.21	19.61	7.38	117.51	32.95	215.76	0.33
Boulder Falls	363	2800 cfs	2800.00	1385.67	22.57	2.37	116.42	1.88	4.14	0.11
Boulder Falls	363	11000 cfs	11000.00	1383.24	20.14	11.37	97.22	51.98	564.47	0.56
Boulder Falls	406	2800 cfs	2800.00	1385.79	15.19	3.97	95.07	4.71	16.25	0.19
Boulder Falls	406	11000 cfs	11000.00	1386.98	16.38	13.83	98.57	55.97	664.48	0.64
Boulder Falls	454	2800 cfs	2800.00	1386.35	11.84	3.68	97.07	5.60	18.41	0.20
Boulder Falls	454	11000 cfs	11000.00	1391.71	17.21	9.05	107.08	28.69	225.73	0.39
Boulder Falls	480	2800 cfs	2800.00	1386.63	12.13	3.57	97.27	5.41	17.49	0.19
Boulder Falls	480	11000 cfs	11000.00	1392.77	18.27	8.39	109.34	24.44	179.25	0.36
Boulder Falls	500	2800 cfs	2800.00	1388.49	10.29	12.08	54.24	114.14	1376.05	1.01
Boulder Falls	500	11000 cfs	11000.00	1394.58	16.38	15.46	104.43	137.23	2041.10	0.95
Boulder Falls	524	2800 cfs	2800.00	1393.28	16.78	2.93	100.55	21.68	59.09	0.14
Boulder Falls	524	11000 cfs	11000.00	1401.89	25.39	6.15	135.05	70.22	377.85	0.23
Boulder Falls	556	2800 cfs	2800.00	1394.10	13.90	5.47	84.44	10.81	53.09	0.30
Boulder Falls	556	11000 cfs	11000.00	1403.11	22.91	8.85	120.50	22.10	161.61	0.36
Boulder Falls	600	2800 cfs	2800.00	1394.45	13.15	3.77	93.71	0.42	1.57	0.22
Boulder Falls	600	11000 cfs	11000.00	1403.67	22.37	6.54	139.84	0.84	4.86	0.27
Boulder Falls	650	2800 cfs	2800.00	1394.25	10.85	6.91	57.72	172.60	1190.11	0.45
Boulder Falls	650	11000 cfs	11000.00	1403.04	19.64	11.14	89.48	257.58	2602.85	0.49
Boulder Falls	666	2800 cfs	2800.00	1394.54	6.88	7.81	76.43	2.48	19.33	0.63
Boulder Falls	666	11000 cfs	11000.00	1403.68	16.02	9.73	127.32	1.93	16.92	0.46



Icicle Boulder Field - Existing vs Proposed
Legend
WS 11000 cfs - Existing
WS 11000 cfs - Option 4
WS 2800 cfs - Existing
WS 2800 cfs - Option 4
Ground
OWS 2800 cfs - Option 4
OWS 11000 cfs - Option 4
OWS 2800 cfs - Existing
OWS 11000 cfs - Existing
Elevation (ft)
Main Channel Distance (ft)
1420
1400
1380
1360
1340
1320
1300
-100
0
100
200
300
400
500
600
700
Most DS Section
Plunge Pool DS Control
Plunge Pool
DS End Anchor Rock
Anchor Rock CL
US End Anchor Rock
Pool Below Foot Bridge
Foot Bridge
STA 650 Most Upstream Section



RS = 288 Icicle Boulder Field - Existing vs Proposed
Note: n values for first profile.
1.8846
Legend
WS 11000 cfs
WS 2800 cfs
Ground
Bank Sta
Elevation (ft)
Station (ft)
RS = 253 US End Anchor Rock
Icicle Boulder Field - Existing vs Proposed Note: n values for first profile.
2.4615
Legend
WS 11000 cfs
WS 2800 cfs
Ground
Bank Sta
OWS 11000 cfs
Elevation (ft)
Station (ft)
RS = 232 Icicle Boulder Field - Existing vs Proposed
Note: n values for first profile.
.1923
Legend
WS 11000 cfs
WS 2800 cfs
Ground
Bank Sta
Elevation (ft)
Station (ft)
RS = 200 Anchor Rock CL
Icicle Boulder Field - Existing vs Proposed
.04
.04
.04
Legend
WS 11000 cfs
WS 2800 cfs
Ground
Bank Sta
Elevation (ft)
Station (ft)

HEC-RAS Plan: Option 4 River: Icicle Creek Reach: Boulder Falls

Reach	River Sta	Profile	Q Total	W.S. Elev	Max Chl Dpth	Vel Chnl	Top Width	Shear Total	Power Total	Froude # Chl
			(cfs)	(ft)	(ft)	(ft/s)	(ft)	(lb/sq ft)	(lb/ft s)	
Boulder Falls	-50	2800 cfs	2600.00	1335.15	15.85	2.00	164.01	18.54	33.86	0.10
Boulder Falls	-50	11000 cfs	9500.00	1337.56	18.26	5.79	178.91	142.33	735.74	0.27
Boulder Falls	-3	2800 cfs	2600.00	1336.75	14.85	1.94	134.95	20.07	37.52	0.10
Boulder Falls	-3	11000 cfs	9500.00	1343.83	21.93	4.20	158.37	73.31	286.87	0.17
Boulder Falls	38	2800 cfs	2600.00	1338.93	13.13	3.06	109.33	50.76	150.03	0.17
Boulder Falls	38	11000 cfs	9500.00	1347.90	22.10	5.21	135.51	107.59	511.26	0.21
Boulder Falls	65	2800 cfs	2600.00	1344.07	12.47	4.43	112.50	135.58	587.08	0.32
Boulder Falls	65	11000 cfs	9500.00	1352.59	20.99	5.94	140.69	170.18	938.99	0.28
Boulder Falls	129	2800 cfs	2600.00	1344.45	17.75	1.74	116.41	0.27	0.48	0.09
Boulder Falls	129	11000 cfs	9500.00	1352.93	26.23	3.80	128.18	0.11	0.42	0.15
Boulder Falls	166	2800 cfs	2600.00	1344.36	16.66	3.54	81.52	0.26	0.93	0.20
Boulder Falls	166	11000 cfs	9500.00	1352.67	24.97	6.40	119.50	0.56	3.29	0.27
Boulder Falls	200	2800 cfs	2600.00	1346.23	12.03	13.64	38.44	4.43	56.22	0.93
Boulder Falls	200	11000 cfs	9500.00	1353.51	19.31	17.76	61.78	7.03	119.01	0.97
Boulder Falls	232	2800 cfs	2600.00	1349.16	9.16	12.26	50.27	86.02	996.81	0.95
Boulder Falls	232	11000 cfs	9500.00	1357.20	17.20	12.87	76.78	89.14	1107.23	0.70
Boulder Falls	253	2800 cfs	2600.00	1365.43	15.43	2.91	119.95	587.95	1589.64	0.17
Boulder Falls	253	11000 cfs	9500.00	1369.88	19.88	6.85	138.79	1886.53	11666.80	0.34
Boulder Falls	288	2800 cfs	2600.00	1376.41	24.41	1.43	140.97	86.31	120.21	0.07
Boulder Falls	288	11000 cfs	9500.00	1379.35	27.35	4.39	146.66	66.54	276.12	0.20
Boulder Falls	330	2800 cfs	2600.00	1382.02	19.42	1.76	117.20	105.19	164.95	0.08
Boulder Falls	330	11000 cfs	9500.00	1383.55	20.95	5.89	119.65	102.59	529.89	0.25
Boulder Falls	363	2800 cfs	2600.00	1382.51	19.41	2.87	93.92	3.44	9.50	0.15
Boulder Falls	363	11000 cfs	9500.00	1385.23	22.13	8.33	113.33	23.85	185.58	0.38
Boulder Falls	406	2800 cfs	2600.00	1382.77	12.17	5.17	77.14	9.25	44.43	0.28
Boulder Falls	406	11000 cfs	9500.00	1386.92	16.32	12.01	98.37	42.27	436.06	0.56
Boulder Falls	454	2800 cfs	2600.00	1384.04	9.54	4.54	92.47	9.26	38.05	0.27
Boulder Falls	454	11000 cfs	9500.00	1390.69	16.19	8.43	105.09	25.62	188.69	0.38
Boulder Falls	480	2800 cfs	2600.00	1384.63	10.13	4.19	93.03	8.11	31.22	0.25
Boulder Falls	480	11000 cfs	9500.00	1391.68	17.18	7.81	107.03	21.90	150.54	0.35
Boulder Falls	500	2800 cfs	2600.00	1388.28	10.08	11.79	53.12	110.84	1305.20	1.01
Boulder Falls	500	11000 cfs	9500.00	1393.82	15.62	14.87	101.91	132.07	1896.23	0.96
Boulder Falls	524	2800 cfs	2600.00	1392.77	16.27	2.86	99.64	19.01	50.58	0.14
Boulder Falls	524	11000 cfs	9500.00	1400.79	24.28	5.71	132.07	61.73	309.19	0.22
Boulder Falls	556	2800 cfs	2600.00	1393.68	13.48	5.37	82.43	13.16	63.87	0.30
Boulder Falls	556	11000 cfs	9500.00	1401.95	21.75	8.36	116.31	20.22	140.52	0.35
Boulder Falls	600	2800 cfs	2600.00	1394.20	12.90	3.60	92.74	1.13	3.99	0.21
Boulder Falls	600	11000 cfs	9500.00	1402.47	21.17	6.15	136.54	0.76	4.17	0.26
Boulder Falls	650	2800 cfs	2600.00	1394.33	10.93	6.35	57.88	131.78	834.88	0.41
Boulder Falls	650	11000 cfs	9500.00	1401.91	18.51	10.52	87.81	236.31	2270.61	0.48
Boulder Falls	666	2800 cfs	2600.00	1394.98	7.32	6.64	78.14	4.89	32.31	0.51
Boulder Falls	666	11000 cfs	9500.00	1402.45	14.79	9.38	116.69	1.94	16.72	0.46

APPENDIX F: FALLS UPSTREAM – PHOTOS AND NOTES

Potential Barrier Name	Gage Falls
River Mile	6.0
Hydraulic Drop	Ranges from 6 to 7 feet
Description	Located approximately 0.5 miles upstream of Boulder Falls. Road repair from about 10 years ago due to left bank erosion. Large split boulder on right bank has the potential to topple into the channel and alter passage characteristics. Falls is confined and tailwater becomes very turbulent at high flow. Passage is best at low flow.

Potential Barrier Name	Pothole Falls
River Mile	6.5
Hydraulic Drop	Not Measured, Less Than 6 feet Based on Observation
Description	A series of smaller bedrock and boulder falls that do not appear to be a significant barrier to fish passage.

Potential Barrier Name	Bridge Falls
River Mile	9.5
Hydraulic Drop	7 to 8 feet
Description	Significant boulder falls but has potential alternate passage routes along left bank of Icicle Creek. Higher flows spread out (channel not confined) to reduce turbulence.

Potential Barrier Name	July 4 Falls
River Mile	11
Hydraulic Drop	Not Measured, Less Than 5' Based on Observation
Description	A series of small falls that would be better characterized as cascades. These cascades are unlikely to be a significant barrier to fish passage.

Potential Barrier Name	Icicle Gorge Falls
River Mile	16.5
Hydraulic Drop	6’ at low flow
Description	A series of smaller falls incised into bedrock that do not appear to be a significant barrier to fish. Witnessed a small trout jumping the largest of the falls. The crest is 30 feet wide with a 10’ deep plunge pool. The tailwater control downstream is very narrow (10’) so falls will likely backwater at higher flows.

Potential Barrier Name	Rock Falls
River Mile	18.2
Hydraulic Drop	Not measured, Less than 5' from observation.
Description	A short series of small falls slotted into bedrock that does not appear to be a significant barrier to fish passage.

APPENDIX G: STAKEHOLDER MEETING NOTES

February 9, 2015.

The first meeting was with the City of Leavenworth to discuss the evaluation of the waterline, and the second was a more technical group to discuss the overall project and designs.

<u>City of Leavenworth Meeting:</u>
Attendees: Aaron Penvose (TU), Steve Toth, Pat Powers, Joel Walinski (City Administrator), Herb Amick (Public Works Director), Stan Adams (Treatment Plant Manager).

Aaron provided a summary of the project and the proposed geological test details. The City misunderstood the testing plan and thought blasting would be part of it and had originally wanted TU to sign some form of waiver. Pat and Steve provided additional detail on the process for the testing plan. Aaron and Pat also requested any information about the history, present and future plans for the waterline. Herb agreed to check the City files and see what information was available.

The City explained this was 50 percent of the Cities water and that there were wells, but they were mainly for redundancy. The existing 16 inch steel line carries about 2200 gpm. The City's main concern is working near the existing waterline. The line in this area is 80 plus years old but has not experienced problems with leaks.

Aaron, Pat and Steve explained the possible design options and what portion of the road access road may be removed. The City noted there were not any plans for updating the line or intake.

Aaron asked again about the liability issue during testing, and Joel agreed to reconsider and get back to Aaron. Approval will likely rest on two items 1) a utility locate with Pat and Steve field locating the actual test dig areas, and 2) a construction contract for the City to review.

Pat than asked if the waterline was relocated how or who would design that work for the City. Joel provided two contacts for local consultants who were familiar with the line. Pat will follow up to better inform the potential design options.

<u>Technical Advisory Committee</u>
Attendees: Aaron Penvose (TU), Bruce Heiner, Jeremy Cram, Amanda Barg (WDFW), Mark Nelson (FWS), Robes Parrish (FWS)
Tony Jantzer (IPID), Pat Powers, Steve Toth
Stan Adams (City of Leavenworth)
USFS…………kmcmillan@fs.fed.us'; 'ksmith@fs.fed.us'

TU provided a review of the project, the Assessment from 2012, current timelines and deliverables. Drawings were handed out for the existing conditions, Option 1, 2 and 3.

Passage for coho and Spring Chinook was brought up by several different groups. The Assessment focused on Steelhead and Bull Trout and the flows during their migration seasons. There was not a resolution to this point, but the designs being considered would not preclude passage of Coho and/or Spring Chinook it they were present.

WDFW presented their case for passage above 600 cfs being a possibility because of the chinook redd and juvenile found upstream.

WDFW emphasized their policy on not providing passage at natural barriers and suggested the design options should focus on passage improvements which were more directly improving routes where there may have been some passage. They noted it would be difficult to permit removing major boulder elements which were historical features. They also suggested the design team coordinate permit review with NOAA and FWS to see what potential issues they might have.

There was general consensus that Option 3 should not be considered further. The main concern is the overall impact of filling the plunge pool and eliminating all the pool habitat. Even though long term passage may be better the loss of the pool could be significant.

The IPID noted that for Option 1 (or a modification to it), the existing access road should be removed in lieu of building another road down to the site.

There was preference for an option which combined features of Option 1 and 2. Pat reemphasized the difference between the two in terms of channel slope/drop and flow limitations. WDFW commented that since we have some level of passage now, that enhancing that with a potential to expand it later might be a good approach.

Pat presented another idea of lowering a 30 foot wide slot to the right of the Anchor Rock which would reduce the flow along the left bank and therefore the turbulence. This could improve the passage conditions near the entrance to the passage route for Option 1 and 2 at higher flows. There were no objections to making this potential modification.

The FWS asked a question about the certainty of success of the options. Pat answered that likely Option 2 had the highest certainty of meeting the fish passage criteria established.

There was discussion about the 12 inch sub-adult bull trout as the minimum fish size which needed passage. The point was discussed that smaller fish likely never passed the boulder field reach and only the larger fish would typically pass. WDFW felt the design should not be driven by the sub-adult fish and it would be reasonable to use a larger fish size. The USFS felt the 12 inch sub-adult should remain as smallest fish to provide upstream passage for.

March 19, 2015

Location: Leavenworth City Hall

Attendance:

Steve Toth, Toth Consulting
Kate Terrell, USFWS
Dan Davies, Trout Unlimited
Dick Rieman, Icicle Creek Watershed Council
Stan Adams, City of Leavenworth
Amanda Barg, WDFW
Chris Fisher, Colville Tribes
Justin Yeager, NMFS
Aaron Penvose, TU
Bruce Heiner, WDFW
Jeremy Cram, WDFW
Pat Powers, Waterfall Engineering
George Lange, TU Chapter
Dennis Snyder, Contractor, Clackamas Oregon

Aaron opened the meeting with the goals for the day and wants to keep discussion focus on design options pros and cons.

Pat presented new design information and new Option 4

Chris Fisher: Should consider a high flow and low flow channel.

Bruce: Options with flow control are not preferred, it would be better to just let the fishway function at a lower flow.

Jeremy: Option 4 preferred

Chris: Showed examples of Omak Creek where they blasted and removed 4000 cubic yards of material.

Amanda: Asked is designs like this have been used before? Pat responded with examples from the Chehalis and Willapa River where WDFW blasted bedrock to form rock fishways. Pat noted the big difference on Icicle is the excavation would go through a boulder field with loose rock.

Jeremy: With regards to high flow passage in May, not really a concern.

Dick: There are other passage problems upstream and downstream. These were discussed at the previous meeting.
Justin: Noted that Steelhead passage upstream is important

Dan: Suggest the preferred design be the one which meets the project objective.

Bruce: More discussion of inlet control

Pat: Noted a preference for phased construction, but Kate noted that would be a permitting problem. Kate suggested a different approach with adaptive management looking 3 to 5 years out for modifications.

Bruce: Question about TU commitment to maintenance. Concerns were brought up by several people about pools filling in.

Amanda: Suggested some monitoring. WDFW has a no net loss policy. Has concerns about making things worse. Likes the idea of flood flow relief on the right bank as Pat presented. Bruce not convinced this will have a benefit. Pat agreed this needs to be modeled to verify benefit.

Jeremy: WDFW committed long term to pit tag trapping.

Bruce: Need to address in design report maintenance needs and how passage will be monitored.

Bruce: Prefers Option 4

Chris: Need to maximize the opportunity for fish passage by making lower velocity boundary layer.