APPENDIX A

Index of Existing Reach Assessment Data

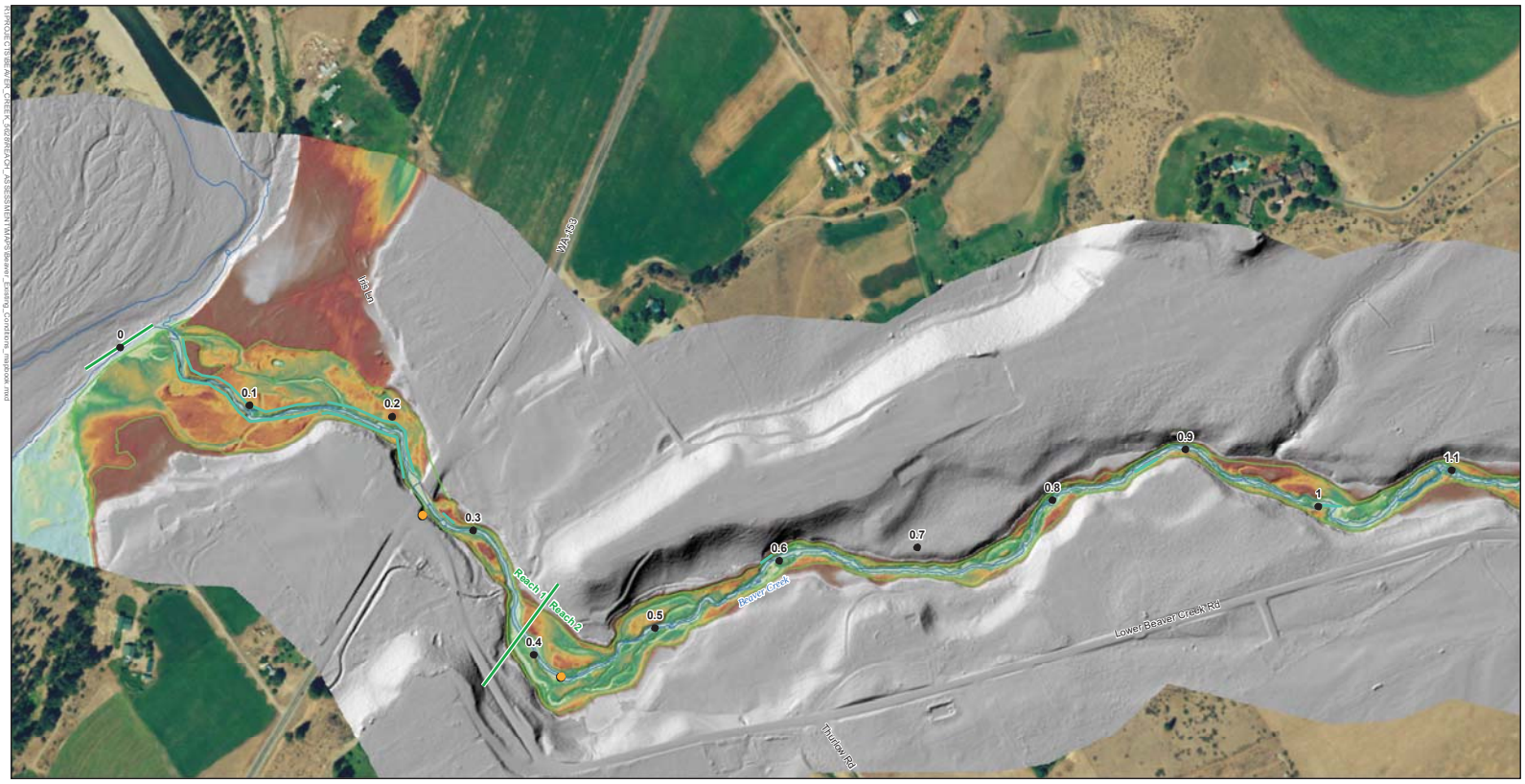
(provided on DVD)

This appendix is provided separately.

APPENDIX B

Reach Assessment Map Series

List of Figures



River Mile
Stream Gage
Irrigation Diversion
Armored Banks
Eroding Banks
Reach Breaks
Low Surface Boundary

Bathymetric LiDAR Flow Extent

Relative Elevation
- High : 115
- Low : 91.349

Source: 2016 Topobathymetric LiDAR (Appendix C)

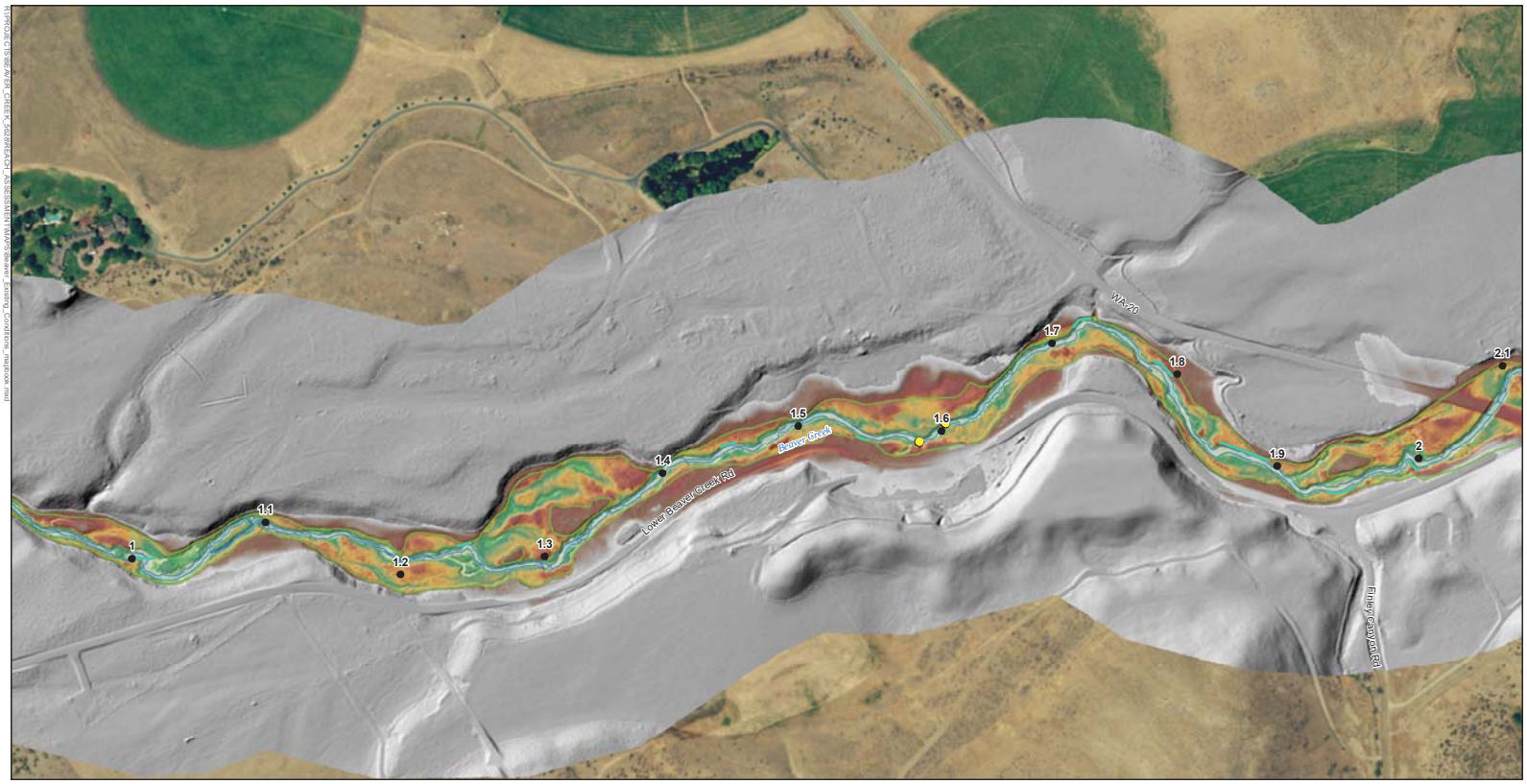
Beaver Creek Reach Assessment

Survey Area Topography and Existing Features

Figure B-1a

1 of 33

0 500 1,000
Feet



River Mile
Stream Gage
Irrigation Diversion
Armored Banks
Eroding Banks
Reach Breaks
Low Surface Boundary

Bathymetric LiDAR Flow Extent

Relative Elevation
High : 115
Low : 91.349

Source: 2016 Topobathymetric LiDAR (Appendix C)

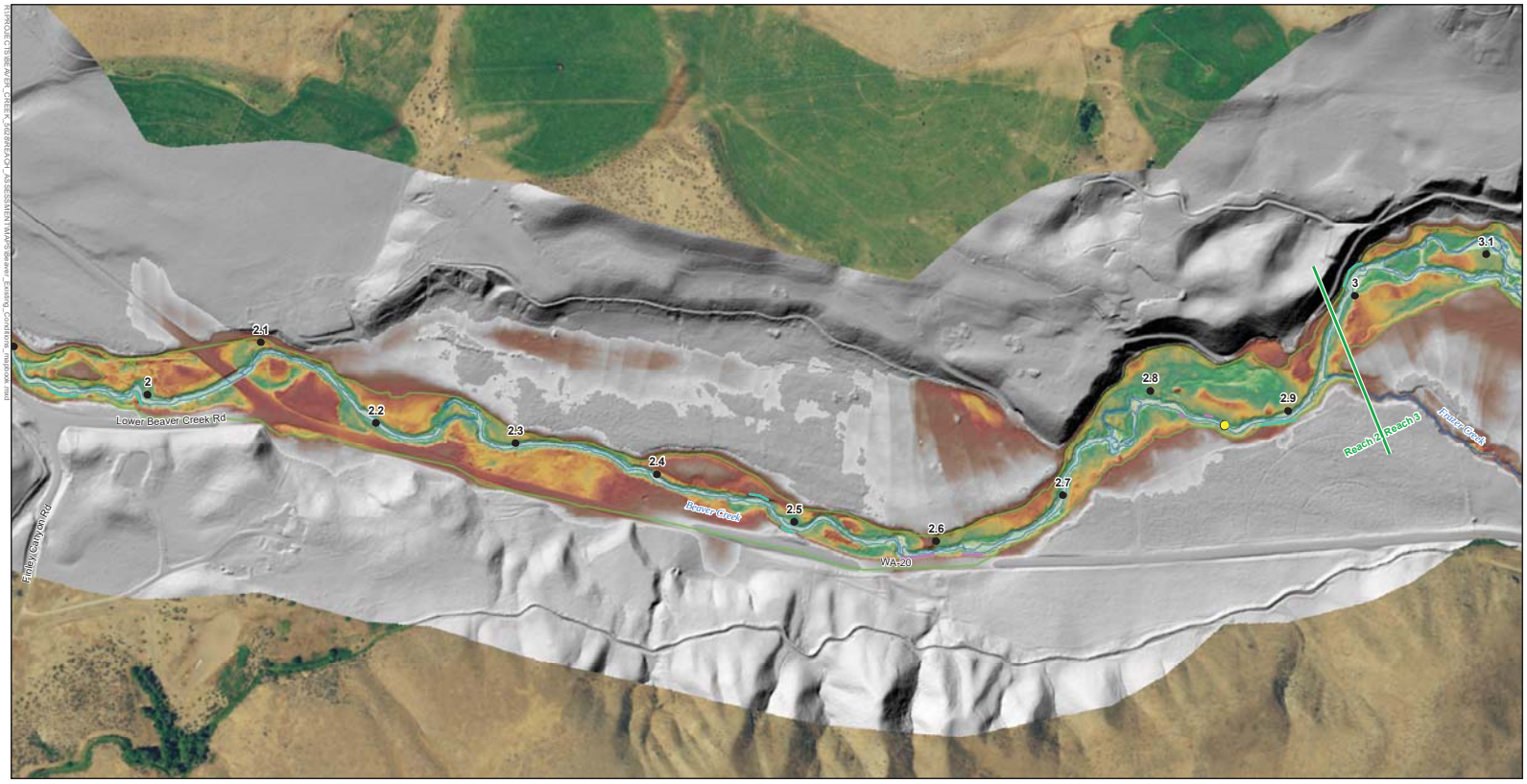
Beaver Creek Reach Assessment

Survey Area Topography and Existing Features

Figure B-1b

2 of 33

0 500 1,000
Feet



River Mile
Stream Gage
Irrigation Diversion
Armored Banks
Eroding Banks
Reach Breaks
Low Surface Boundary

Bathymetric LiDAR Flow Extent

Relative Elevation
- High : 115
- Low : 91.349

Source: 2016 Topobathymetric LiDAR (Appendix C)

Beaver Creek Reach Assessment

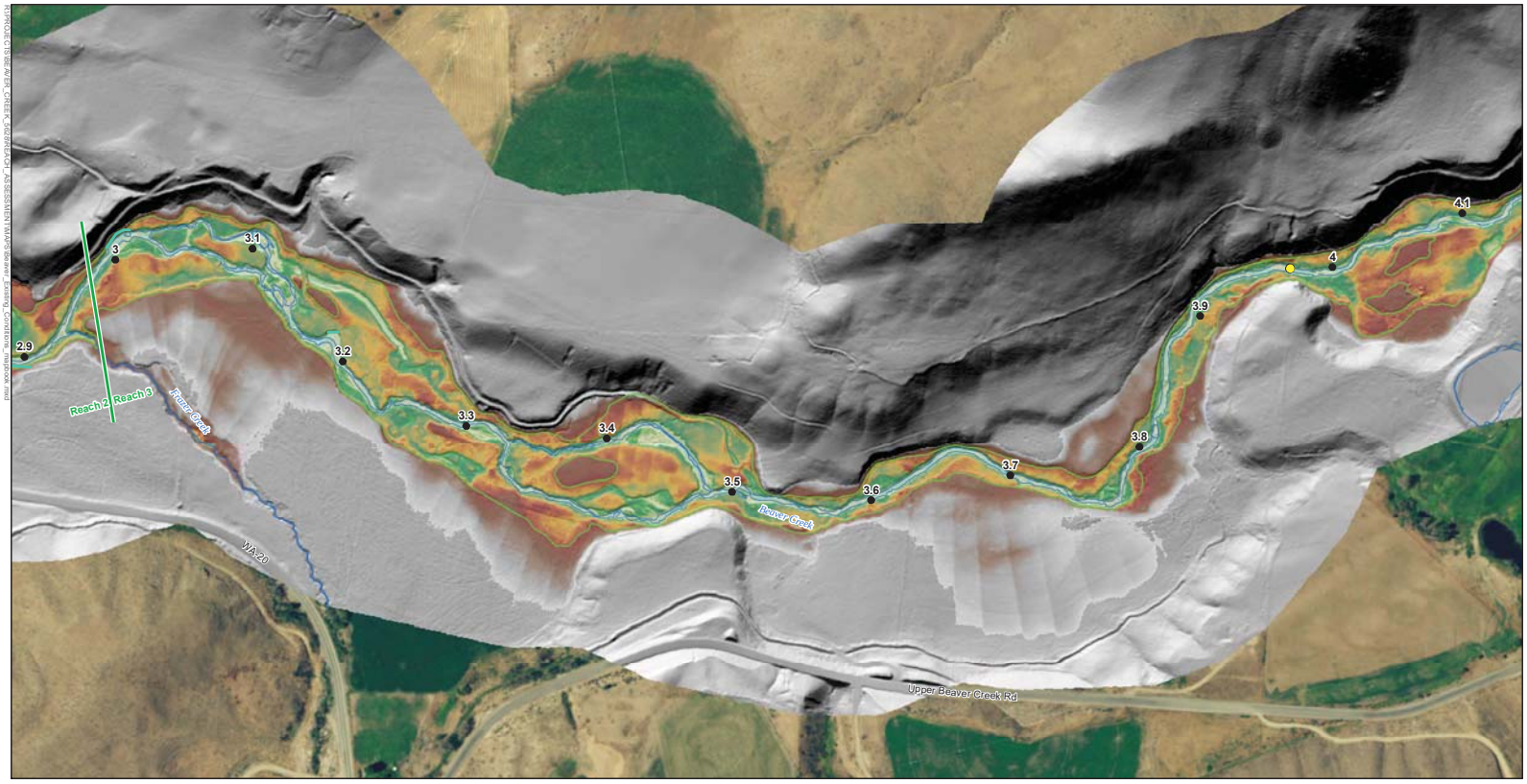
Survey Area Topography and Existing Features

Figure B-1c

3 of 33

0 500 1,000
Feet

R:\PROJECTS\BEAVER_CREEK_5628\REACH_ASSESSMENT\MAPS\Beaver_Existing_Conditions_mapbook.mxd



River Mile
Stream Gage
Irrigation Diversion
Armored Banks
Eroding Banks
Reach Breaks
Low Surface Boundary

Bathymetric LiDAR Flow Extent

Relative Elevation
High : 115
Low : 91.349

Source: 2016 Topobathymetric LiDAR (Appendix C)

Beaver Creek Reach Assessment

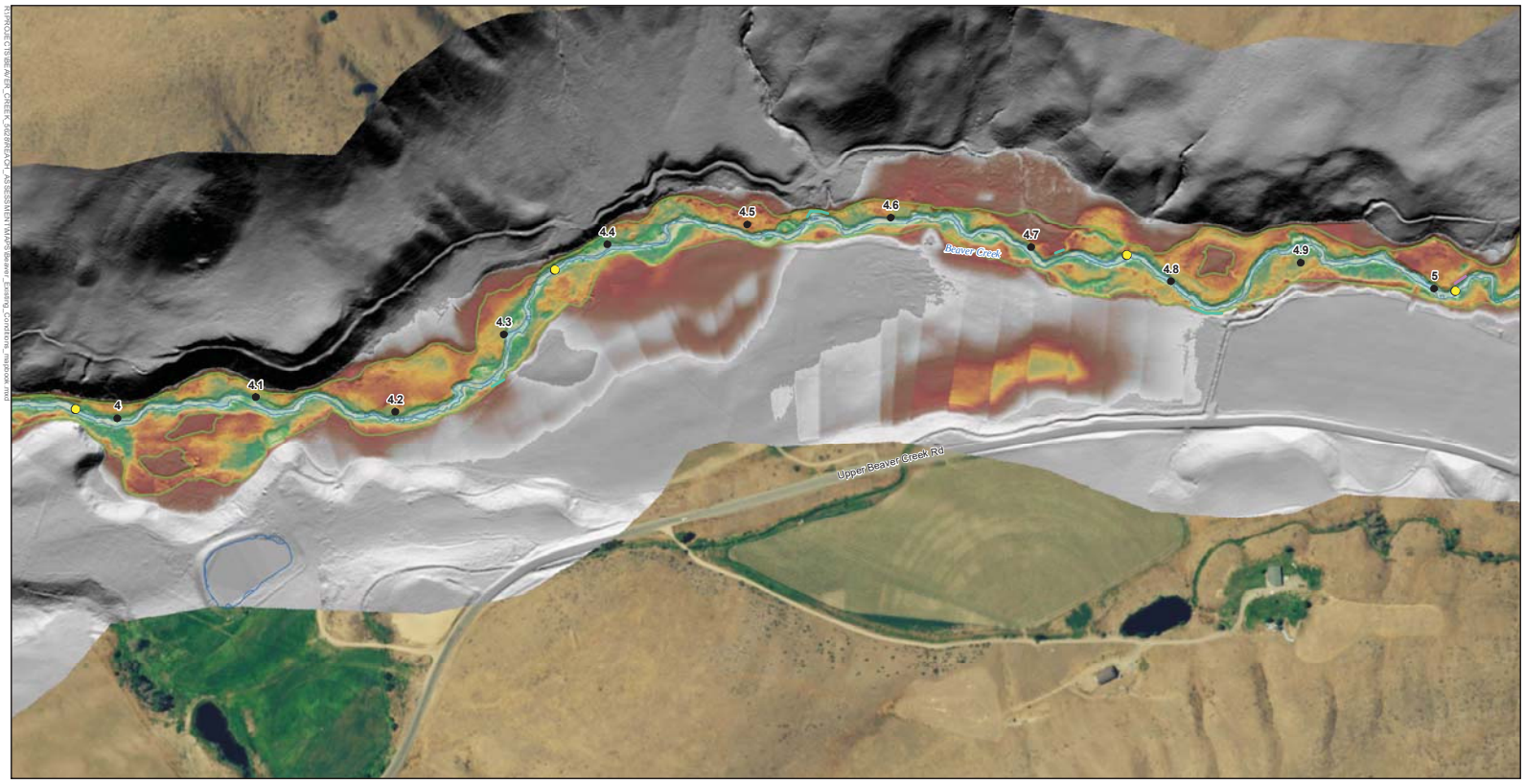
Survey Area Topography and Existing Features

Figure B-1d

4 of 33

W
S
N
E

0 500 1,000
Feet



River Mile
Stream Gage
Irrigation Diversion
Armored Banks
Eroding Banks
Reach Breaks
Low Surface Boundary

Bathymetric LiDAR Flow Extent

Relative Elevation
High : 115
Low : 91.349

Source: 2016 Topobathymetric LiDAR (Appendix C)

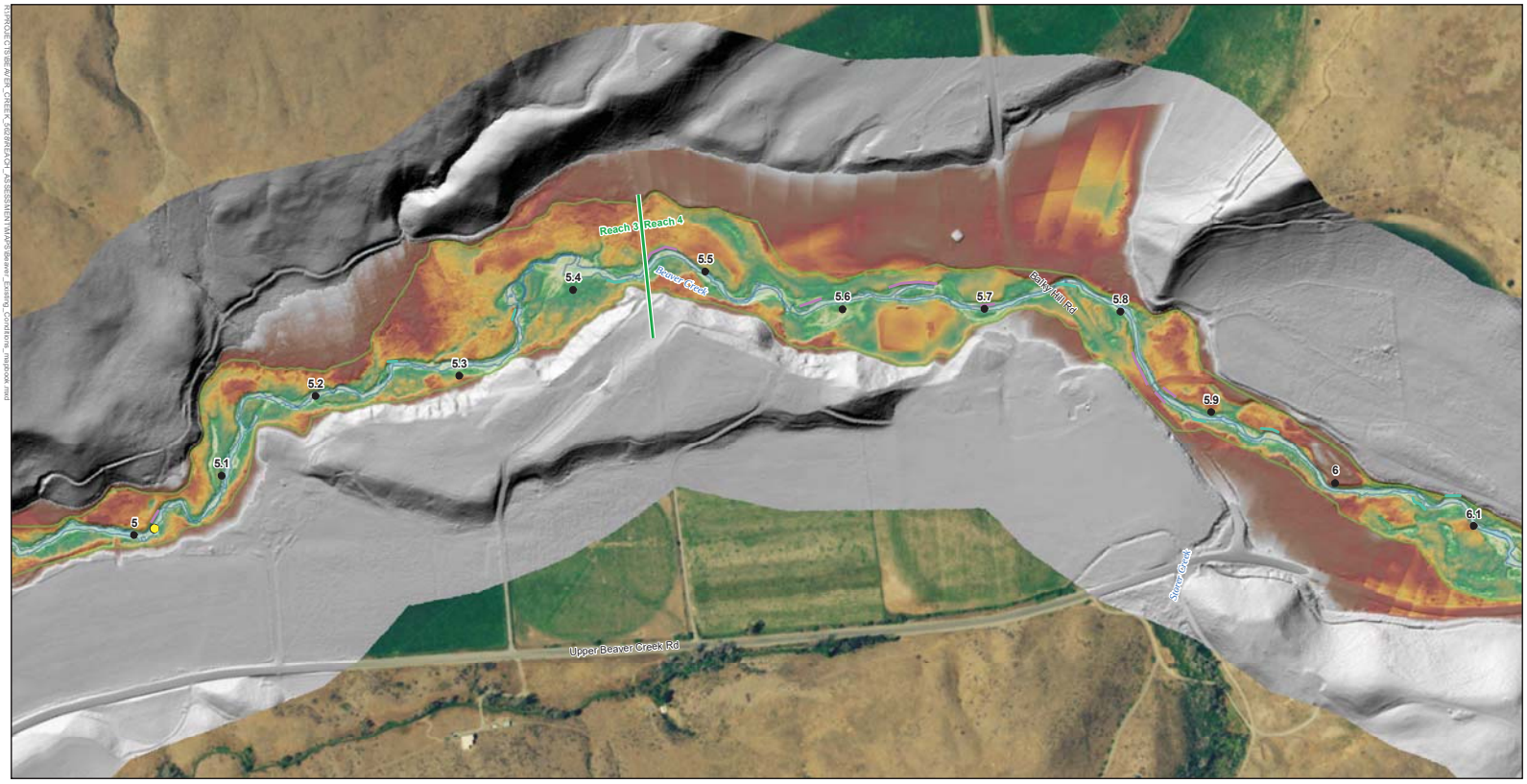
Beaver Creek Reach Assessment

Survey Area Topography and Existing Features

Figure B-1e

5 of 33

0 500 1,000
Feet



River Mile
Stream Gage
Irrigation Diversion
Armored Banks
Eroding Banks
Reach Breaks
Low Surface Boundary

Bathymetric LiDAR Flow Extent

Relative Elevation
- High : 115
- Low : 91.349

Source: 2016 Topobathymetric LiDAR (Appendix C)

Beaver Creek Reach Assessment

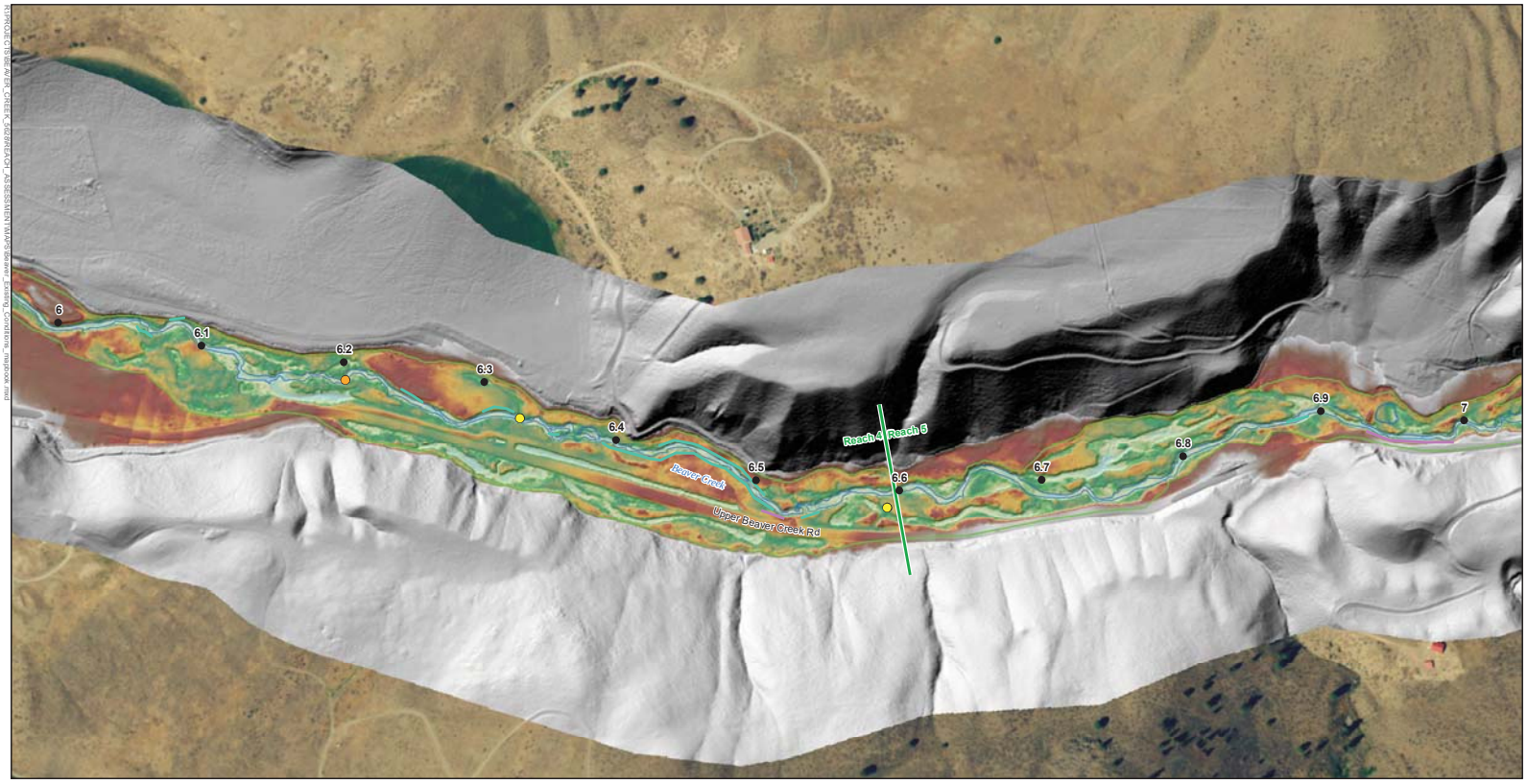
Survey Area Topography and Existing Features

Figure B-1f

6 of 33

W S N E

0 500 1,000
Feet



River Mile
Stream Gage
Irrigation Diversion
Armored Banks
Eroding Banks
Reach Breaks
Low Surface Boundary

Bathymetric LiDAR Flow Extent

Relative Elevation
High : 115
Low : 91.349

Source: 2016 Topobathymetric LiDAR (Appendix C)

Beaver Creek Reach Assessment

Survey Area Topography and Existing Features

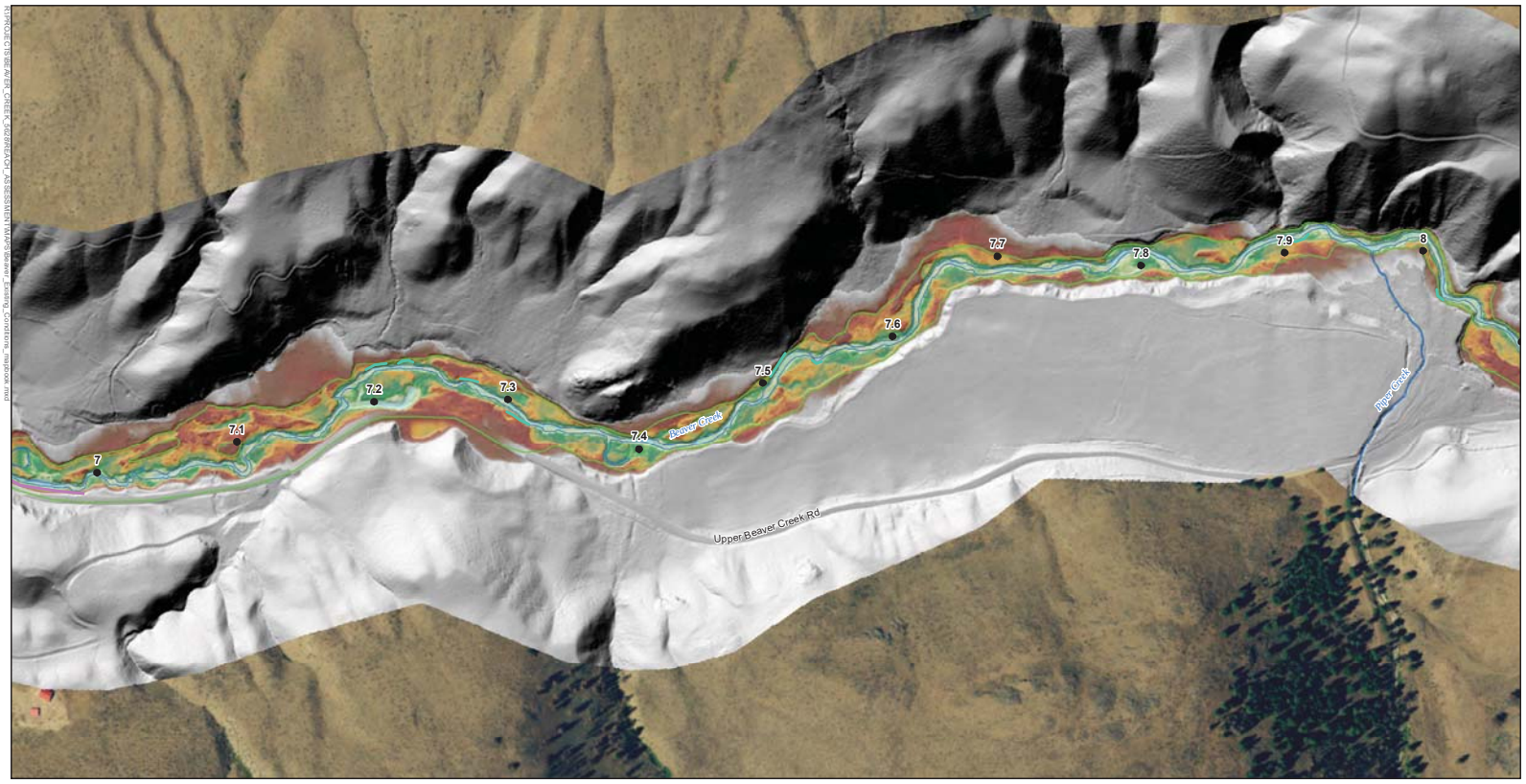
Figure B-1g

7 of 33

N
W
E
S

0 500 1,000
Feet

R:\PROJECTS\BEAVER_CREEK_5\628\REACH_ASSESSMENT\MAPS\Beaver_Existing_Conditions_mapbook.mxd



River Mile
Stream Gage
Irrigation Diversion
Armored Banks
Eroding Banks
Reach Breaks
Low Surface Boundary

Bathymetric LiDAR Flow Extent

Relative Elevation
- High : 115
- Low : 91.349

Source: 2016 Topobathymetric LiDAR (Appendix C)

Beaver Creek Reach Assessment

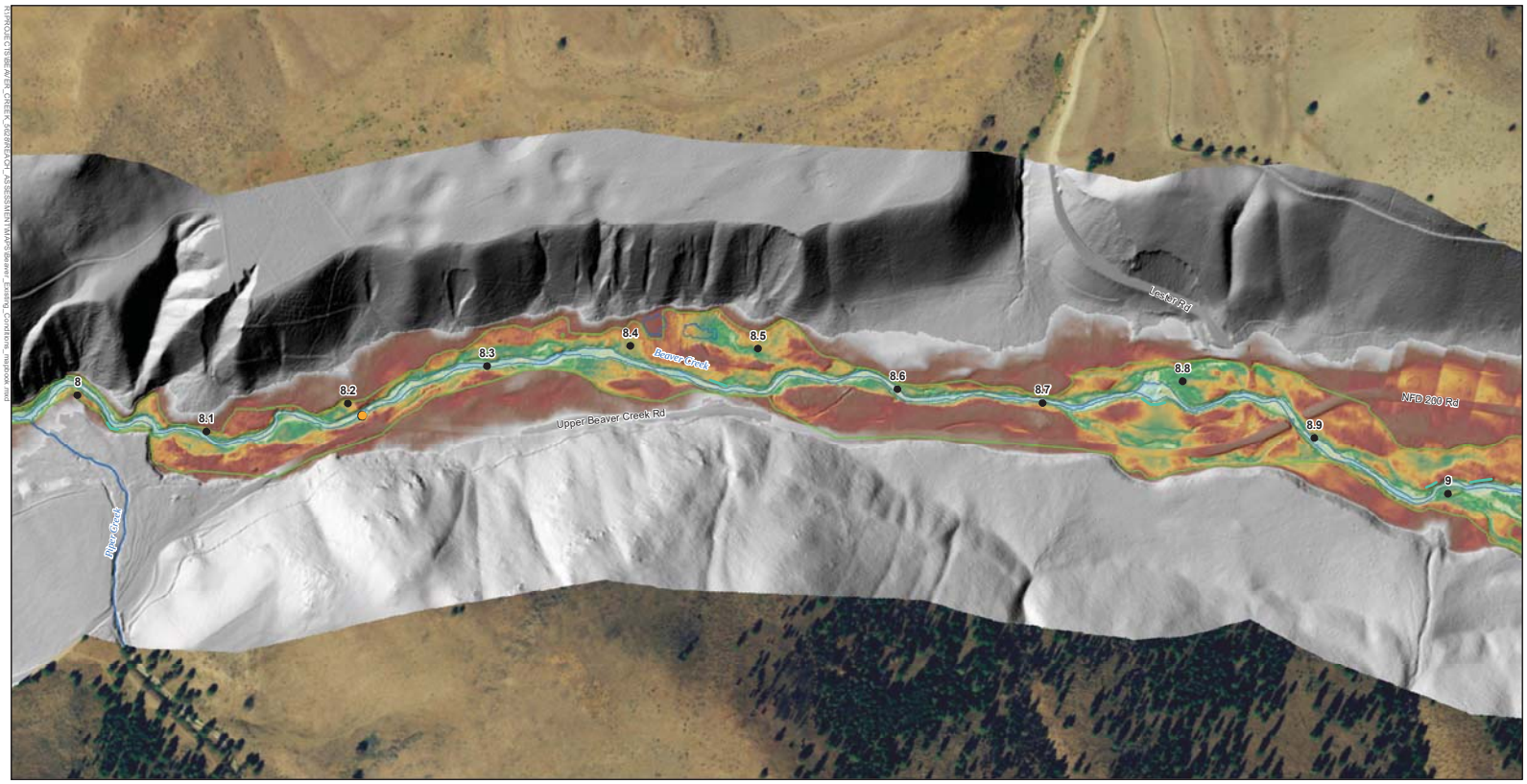
Survey Area Topography and Existing Features

Figure B-1h

8 of 33

W N S E

0 500 1,000
Feet



River Mile
Stream Gage
Irrigation Diversion
Armored Banks
Eroding Banks
Reach Breaks
Low Surface Boundary

Bathymetric LiDAR Flow Extent

Relative Elevation
- High : 115
- Low : 91.349

Source: 2016 Topobathymetric LiDAR (Appendix C)

Beaver Creek Reach Assessment

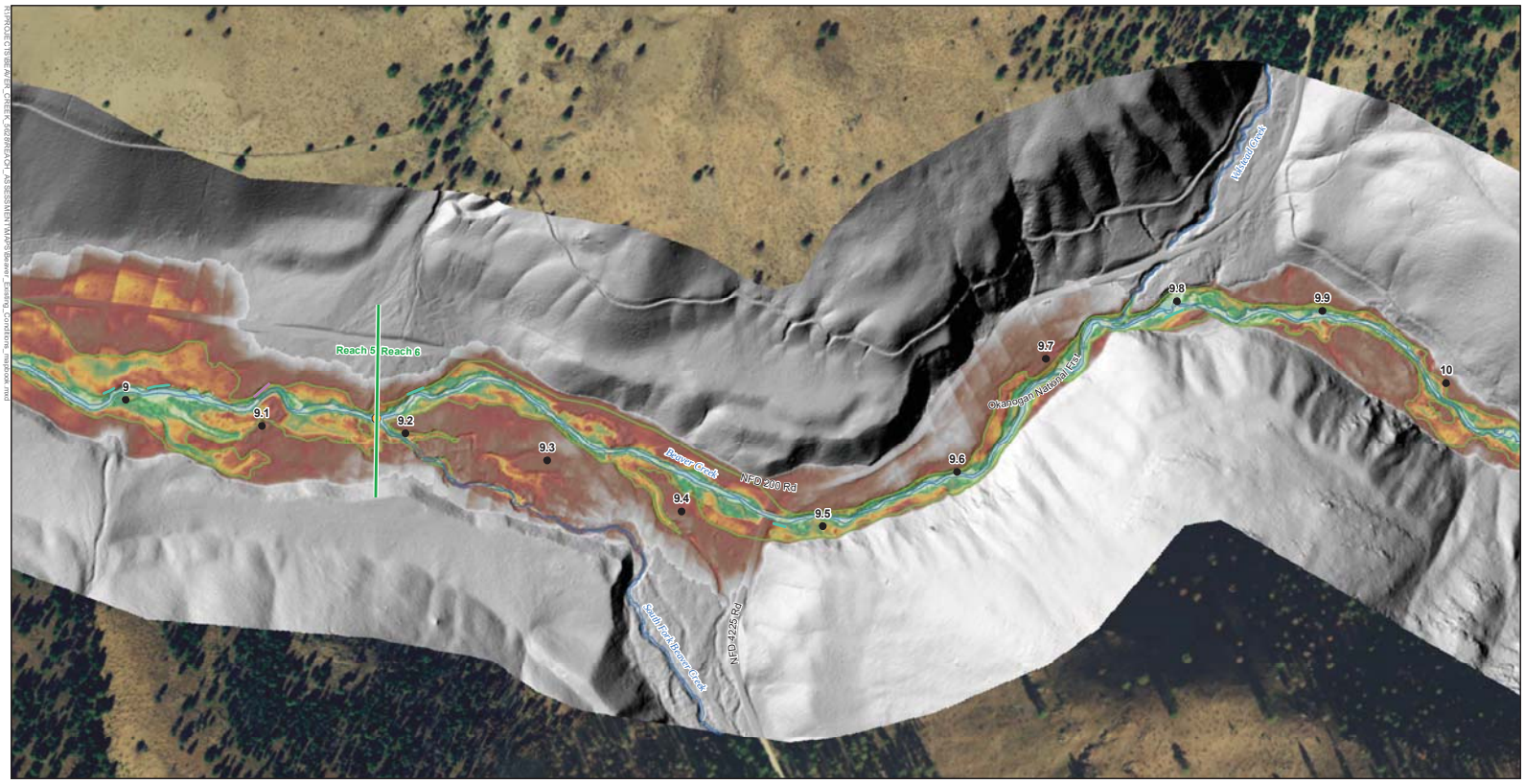
Survey Area Topography and Existing Features

Figure B-1i

9 of 33

0 500 1,000
Feet

R:\PROJECTS\BEAVER_CREEK_5628\REACH_ASSESSMENT\MAPS\Beaver_Existing_Conditions_mapbook.mxd



River Mile
Stream Gage
Irrigation Diversion
Armored Banks
Eroding Banks
Reach Breaks
Low Surface Boundary

Bathymetric LiDAR Flow Extent

Relative Elevation
- High : 115
- Low : 91.349

Source: 2016 Topobathymetric LiDAR (Appendix C)

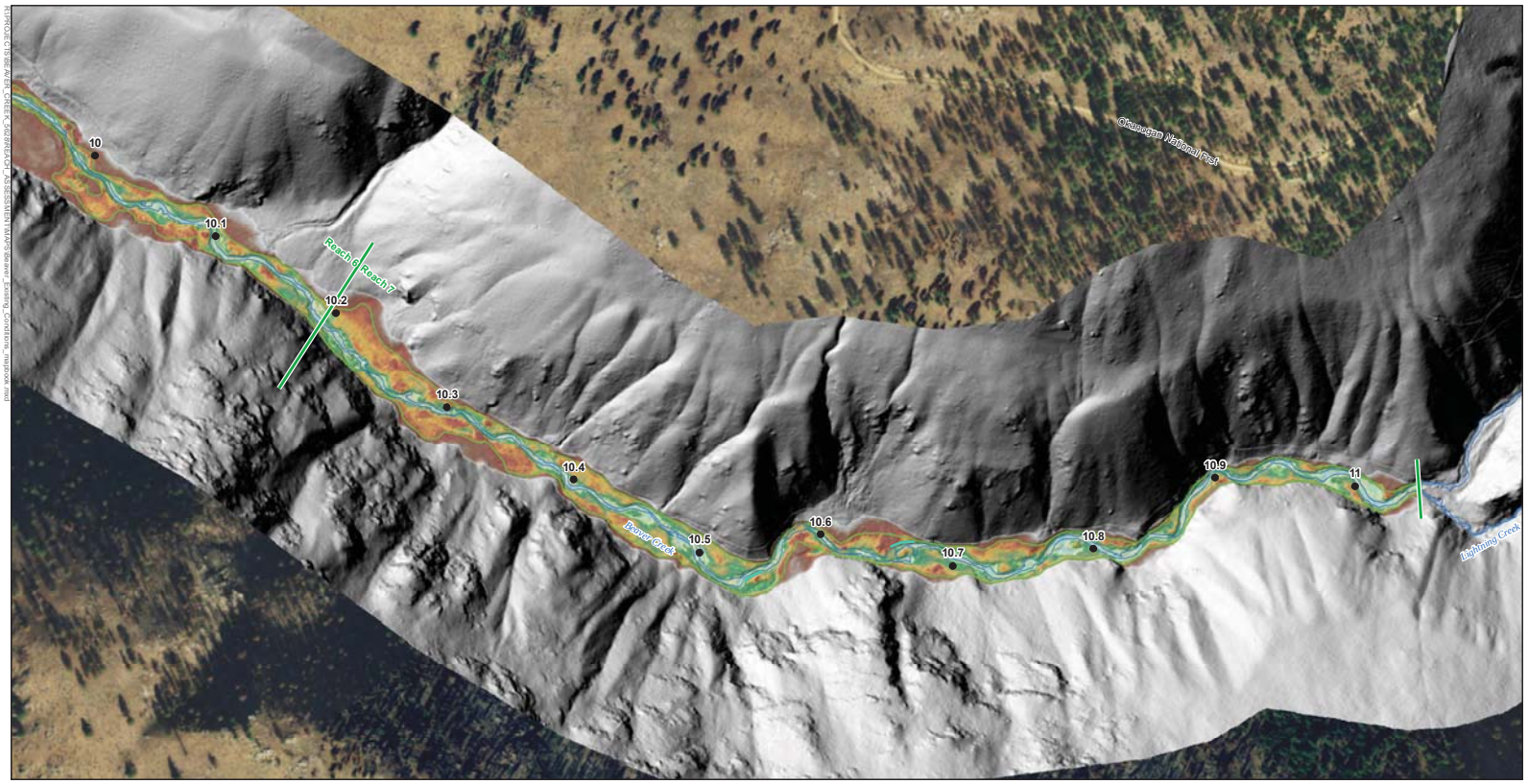
Beaver Creek Reach Assessment

Survey Area Topography and Existing Features

Figure B-1j

10 of 33

0 500 1,000
Feet



River Mile
Stream Gage
Irrigation Diversion
Armored Banks
Eroding Banks
Reach Breaks
Low Surface Boundary

Bathymetric LiDAR Flow Extent

Relative Elevation
- High : 115
- Low : 91.349

Source: 2016 Topobathymetric LiDAR (Appendix C)

Beaver Creek Reach Assessment

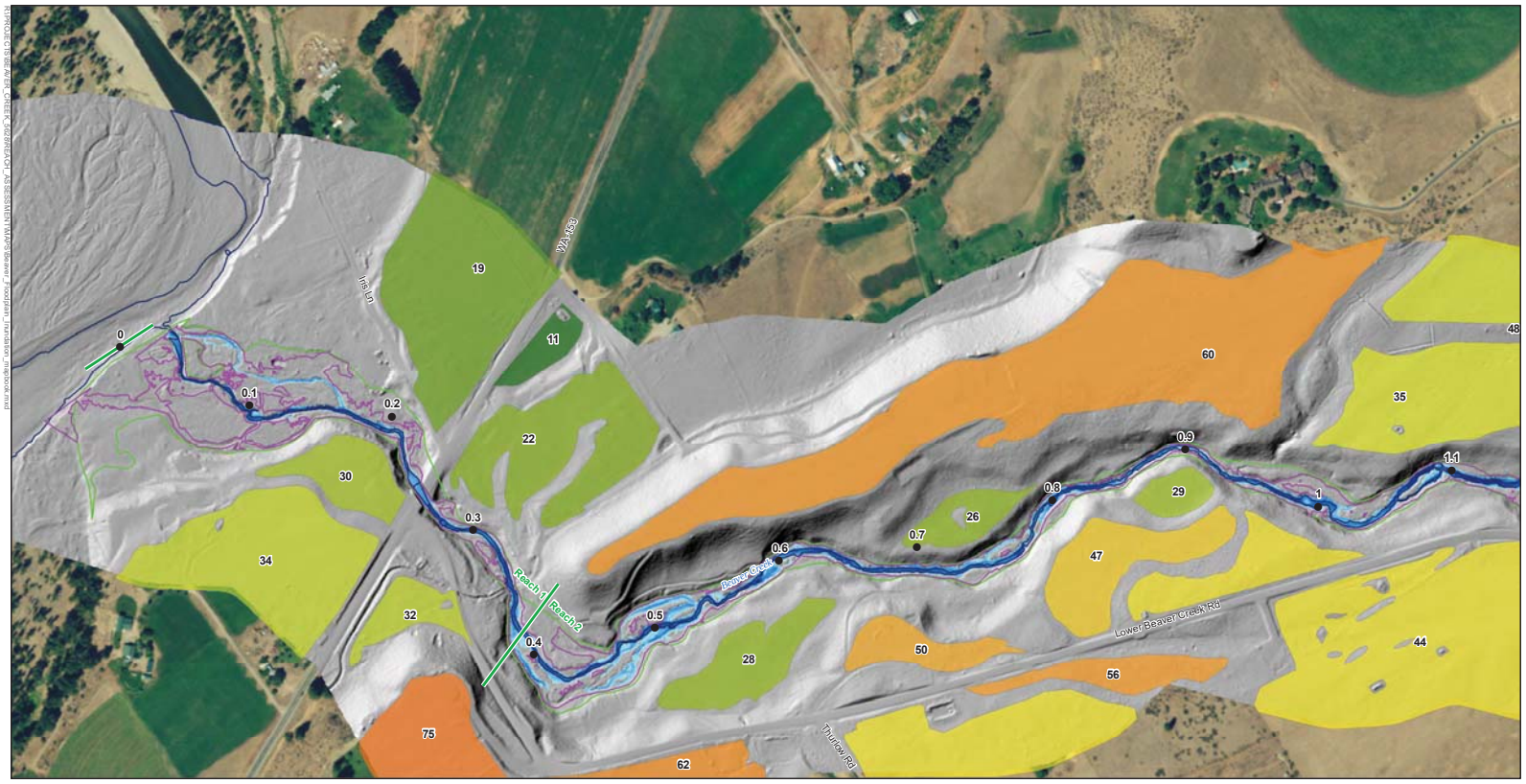
Survey Area Topography and Existing Features

Figure B-1k

11 of 33

0 500 1,000
Feet

R:\PROJECTS\BEAVER_CREEK_5162\REACH_ASSESSMENT\MAPS\Beaver_Existing_Conditions_mapbook.mxd



River Mile
Reach Breaks
Bathymetric LiDAR Flow Extent
100-Year Inundation Boundary
Low Surface Boundary

2-year Depth
High
Low

Terrace Height (ft)
High: 234
Low: 9

Source: 2016 Topobathymetric LiDAR (Appendix C)

Beaver Creek Reach Assessment

Floodplain Inundation and Terraces Map Series

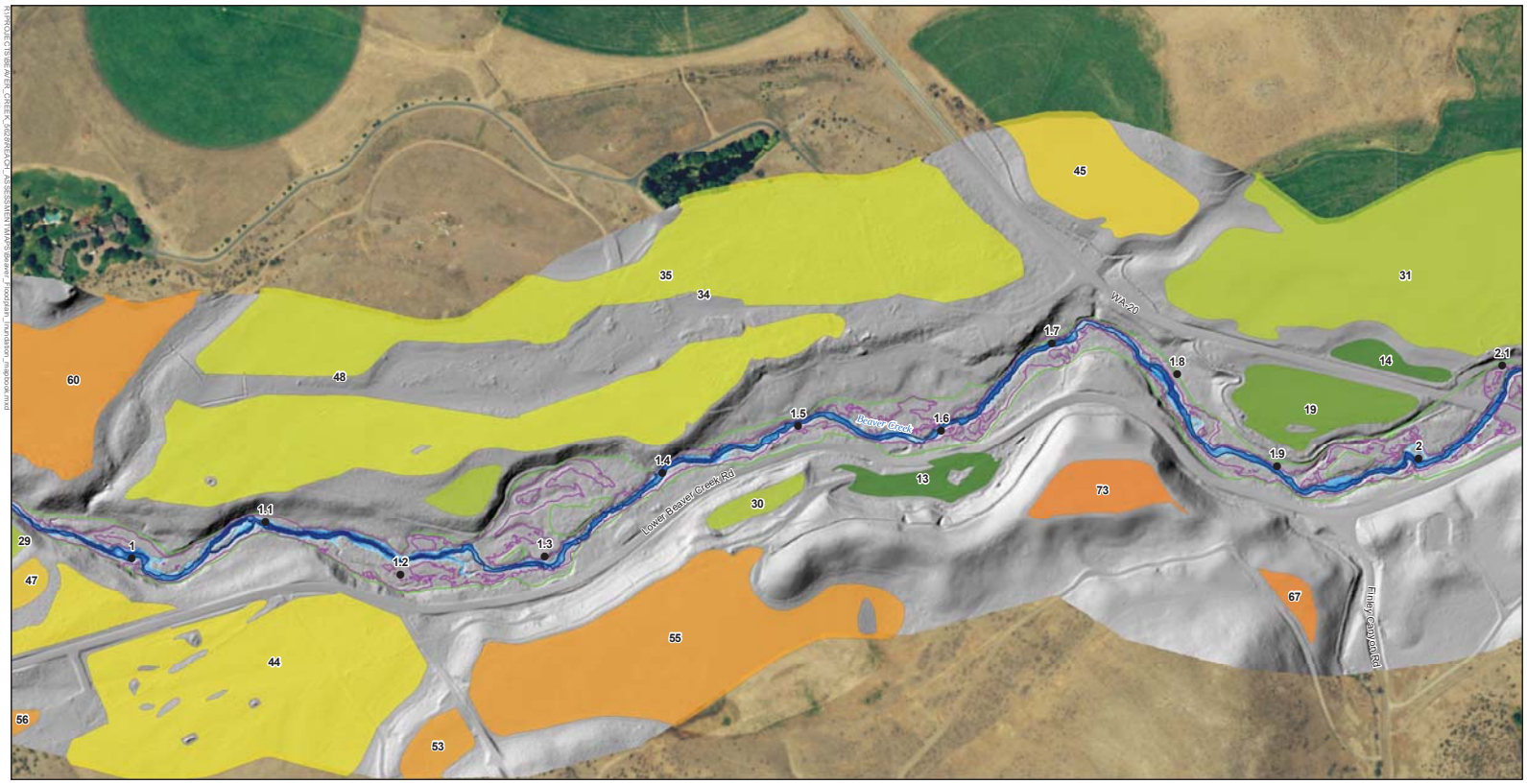
Figure B-2a

12 of 33

W N S E

0 500 1,000
Feet

R:\PROJECTS\BEAVER_CREEK_5922\REACH_ASSESSMENT\MAPS\Beaver_Floodplain_Inundation_mapbook.mxd



River Mile
Reach Breaks
Bathymetric LiDAR Flow Extent
100-Year Inundation Boundary
Low Surface Boundary

2-year Depth
High
Low

Terrace Height (ft)
High: 234
Low: 9

Source: 2016 Topobathymetric LiDAR (Appendix C)

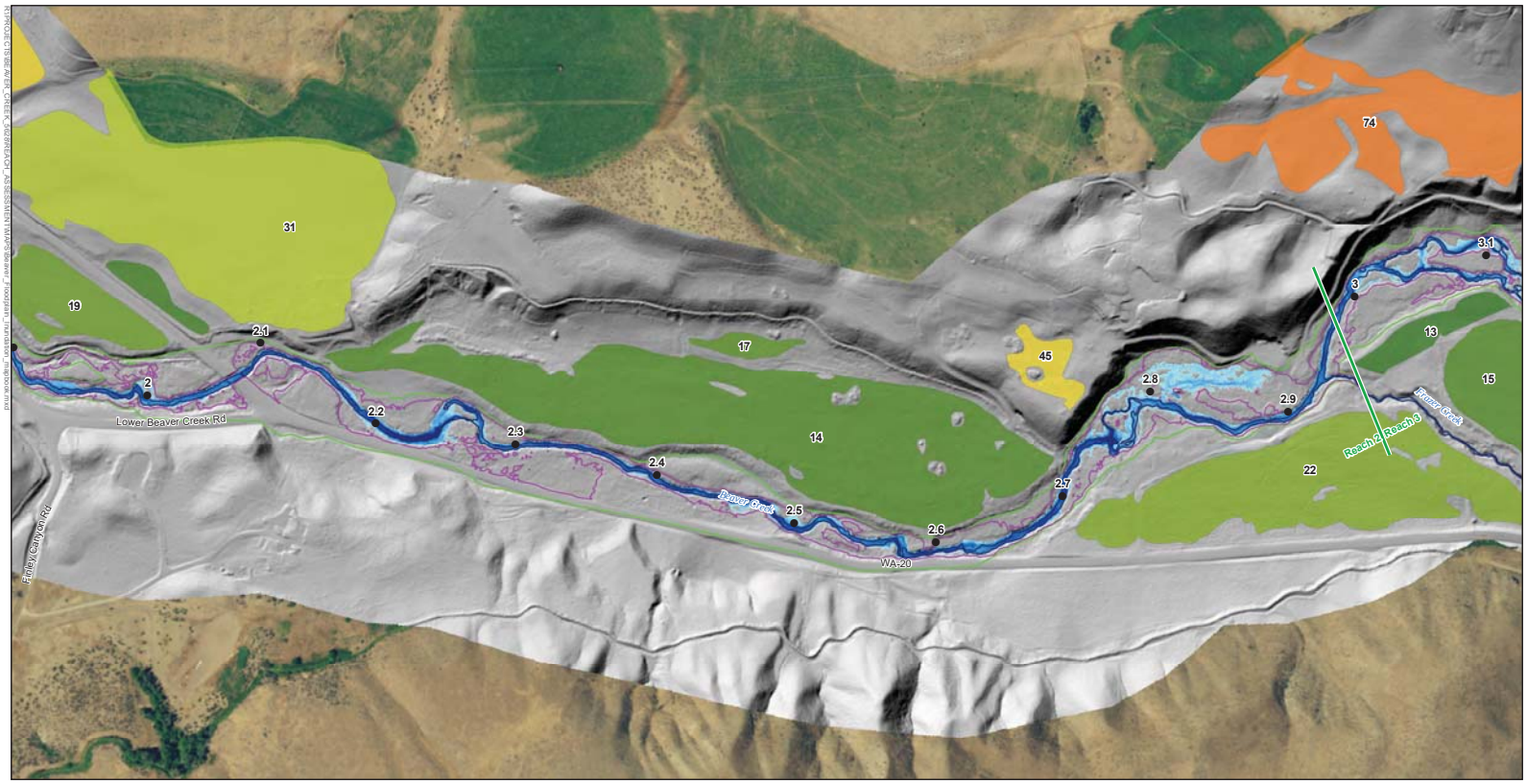
Beaver Creek Reach Assessment

Floodplain Inundation and Terraces Map Series

Figure B-2b

13 of 33

0 500 1,000
Feet



River Mile
Reach Breaks
Bathymetric LiDAR Flow Extent
100-Year Inundation Boundary
Low Surface Boundary

2-year Depth
High
Low

Terrace Height (ft)
High: 234
Low: 9

Source: 2016 Topobathymetric LiDAR (Appendix C)

Beaver Creek Reach Assessment

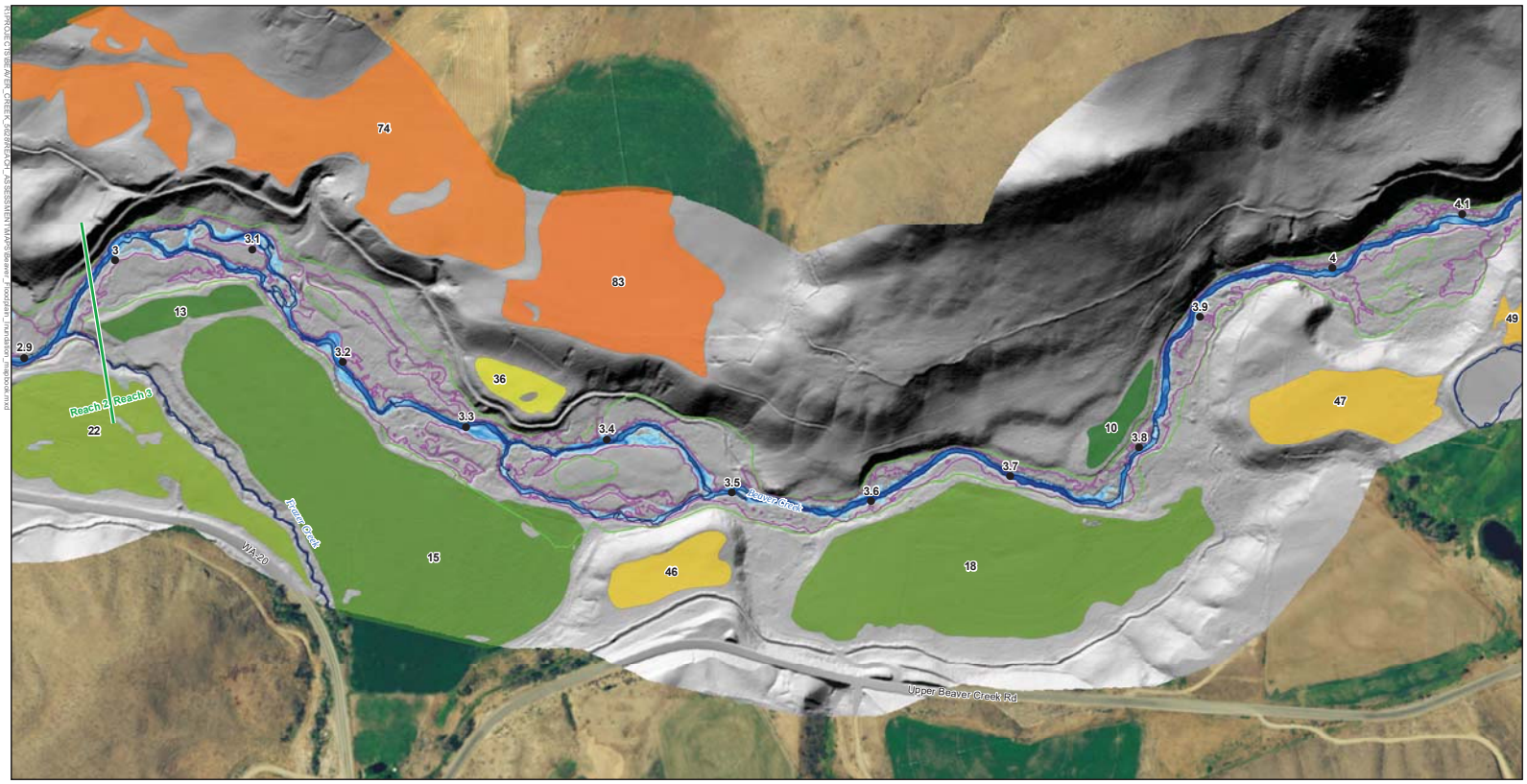
Floodplain Inundation and Terraces Map Series

Figure B-2c

14 of 33

W N S E

0 500 1,000
Feet



River Mile
Reach Breaks
Bathymetric LiDAR Flow Extent
100-Year Inundation Boundary
Low Surface Boundary

2-year Depth
High
Low

Terrace Height (ft)
High: 234
Low: 9

Source: 2016 Topobathymetric LiDAR (Appendix C)

Beaver Creek Reach Assessment

Floodplain Inundation and Terraces Map Series

Figure B-2d

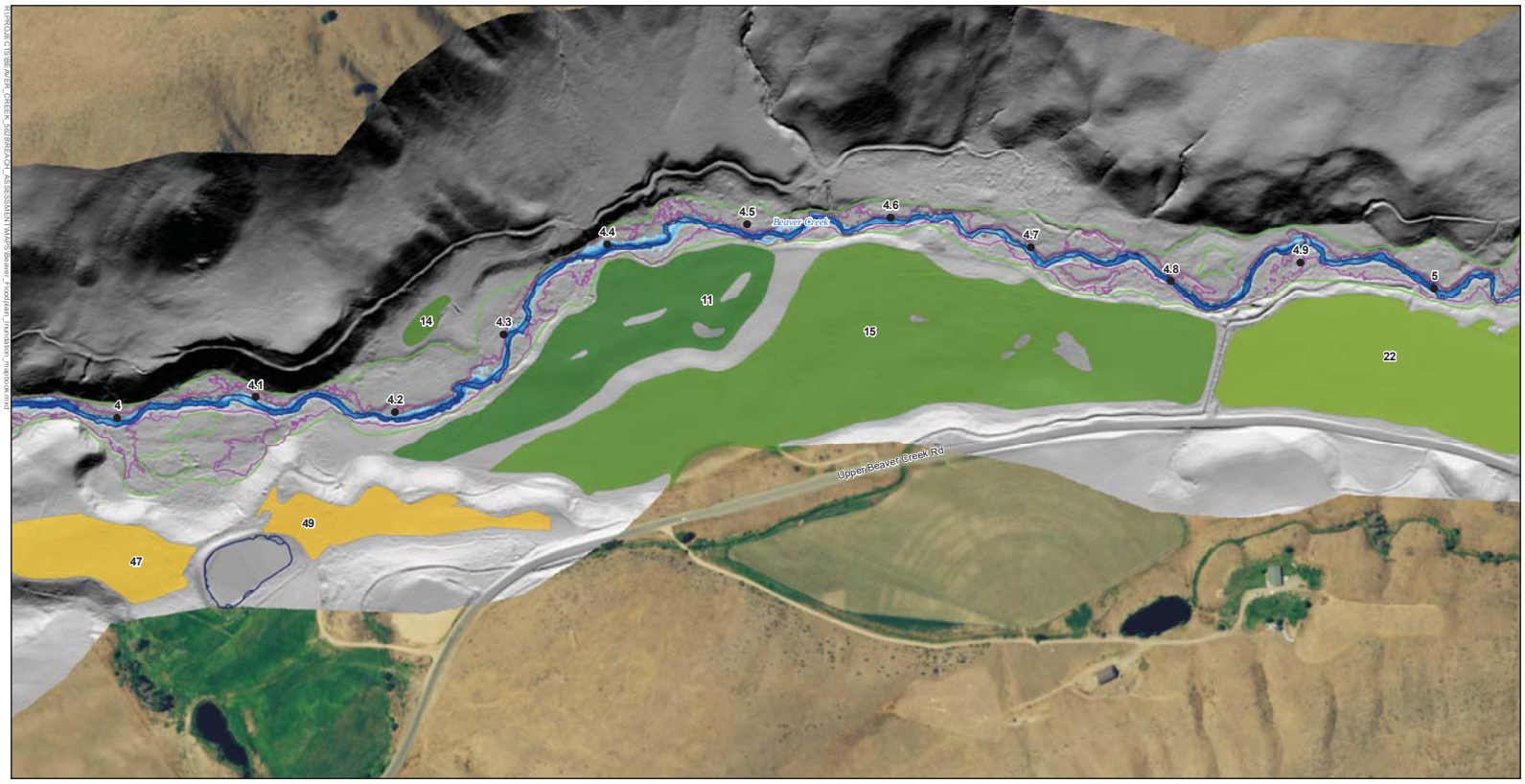
15 of 33

W
S
N
E

0 500 1,000
Feet

R:\PROJECTS\BEAVER_CREEK_5928\REACH_ASSESSMENT\MAPS\Beaver_Floodplain_Inundation_mapbook.mxd

R:\PROJECTS\BEAVER_CREEK_5928\REACH_ASSESSMENT\MAPS\Beaver_Floodplain_Inundation_mapbook.mxd



River Mile
Reach Breaks
Bathymetric LiDAR Flow Extent
100-Year Inundation Boundary
Low Surface Boundary

2-year Depth
High
Low

Terrace Height (ft)
High: 234
Low: 9

Source: 2016 Topobathymetric LiDAR (Appendix C)

Beaver Creek Reach Assessment

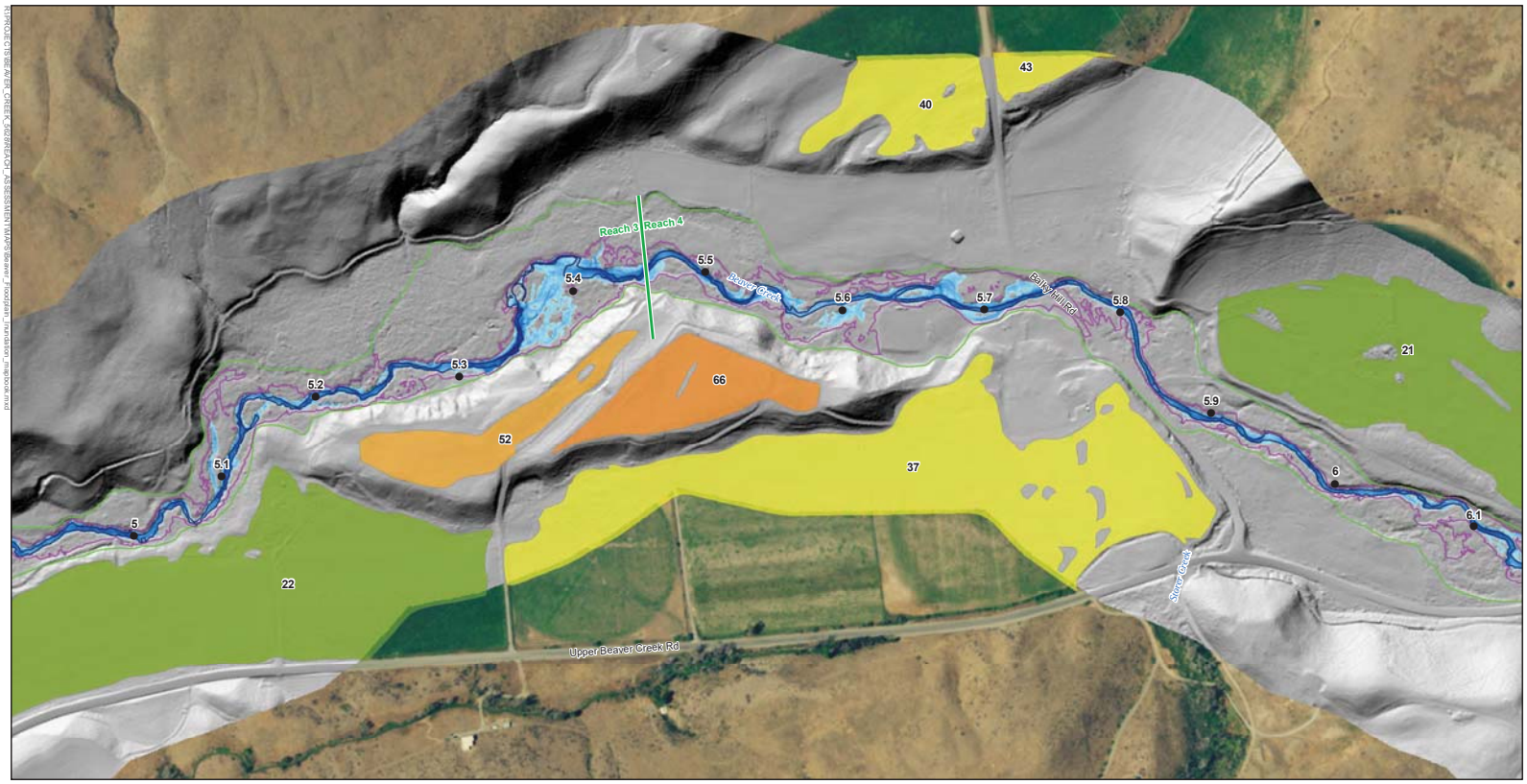
Floodplain Inundation and Terraces Map Series

Figure B-2e

16 of 33

W
S
N
E

0 500 1,000
Feet



River Mile
Reach Breaks
Bathymetric LiDAR Flow Extent
100-Year Inundation Boundary
Low Surface Boundary

2-year Depth
High
Low

Terrace Height (ft)
High: 234
Low: 9

Source: 2016 Topobathymetric LiDAR (Appendix C)

Beaver Creek Reach Assessment

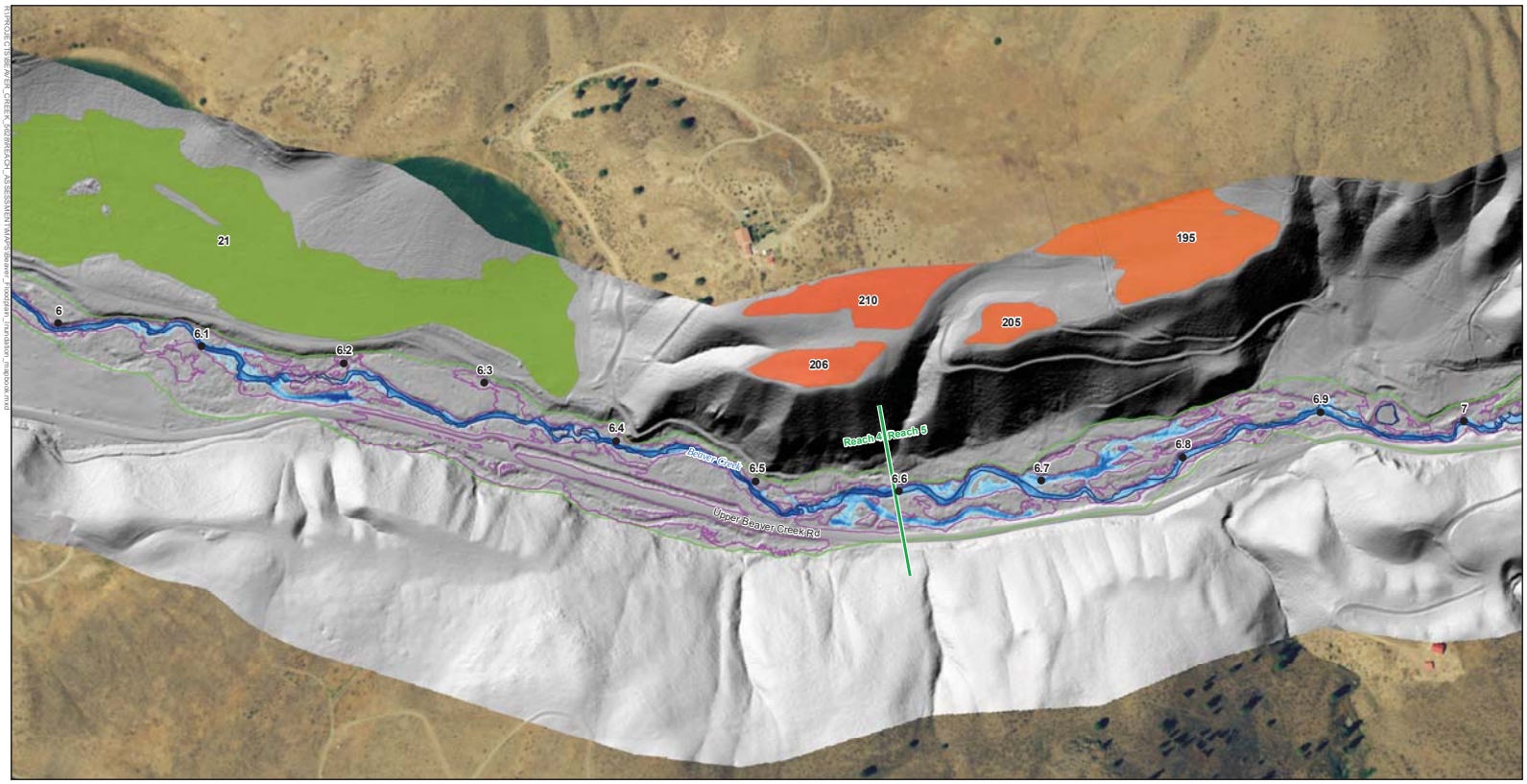
Floodplain Inundation and Terraces Map Series

Figure B-2f

17 of 33

0 500 1,000
Feet

R:\PROJECTS\BEAVER_CREEK_5928\REACH_ASSESSMENT\MAPS\Beaver_Floodplain_Inundation_mapbook.mxd



River Mile
Reach Breaks
Bathymetric LiDAR Flow Extent
100-Year Inundation Boundary
Low Surface Boundary

2-year Depth
High
Low

Terrace Height (ft)
High: 234
Low: 9

Source: 2016 Topobathymetric LiDAR (Appendix C)

Beaver Creek Reach Assessment

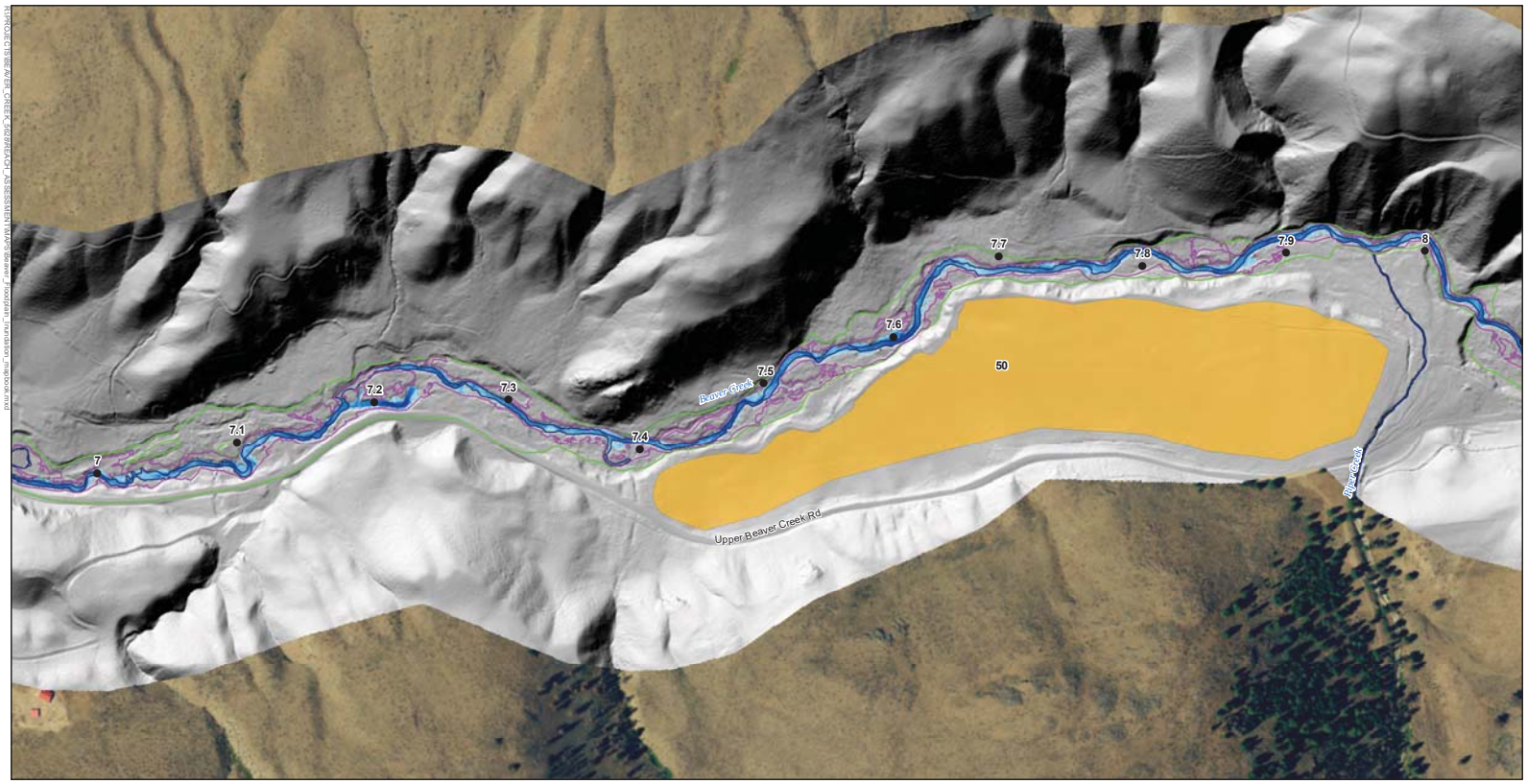
Floodplain Inundation and Terraces Map Series

Figure B-2g

18 of 33

N
S
E

0 500 1,000
Feet



River Mile
Reach Breaks
Bathymetric LiDAR Flow Extent
100-Year Inundation Boundary
Low Surface Boundary

2-year Depth
High
Low

Terrace Height (ft)
High: 234
Low: 9

Source: 2016 Topobathymetric LiDAR (Appendix C)

Beaver Creek Reach Assessment

Floodplain Inundation and Terraces Map Series

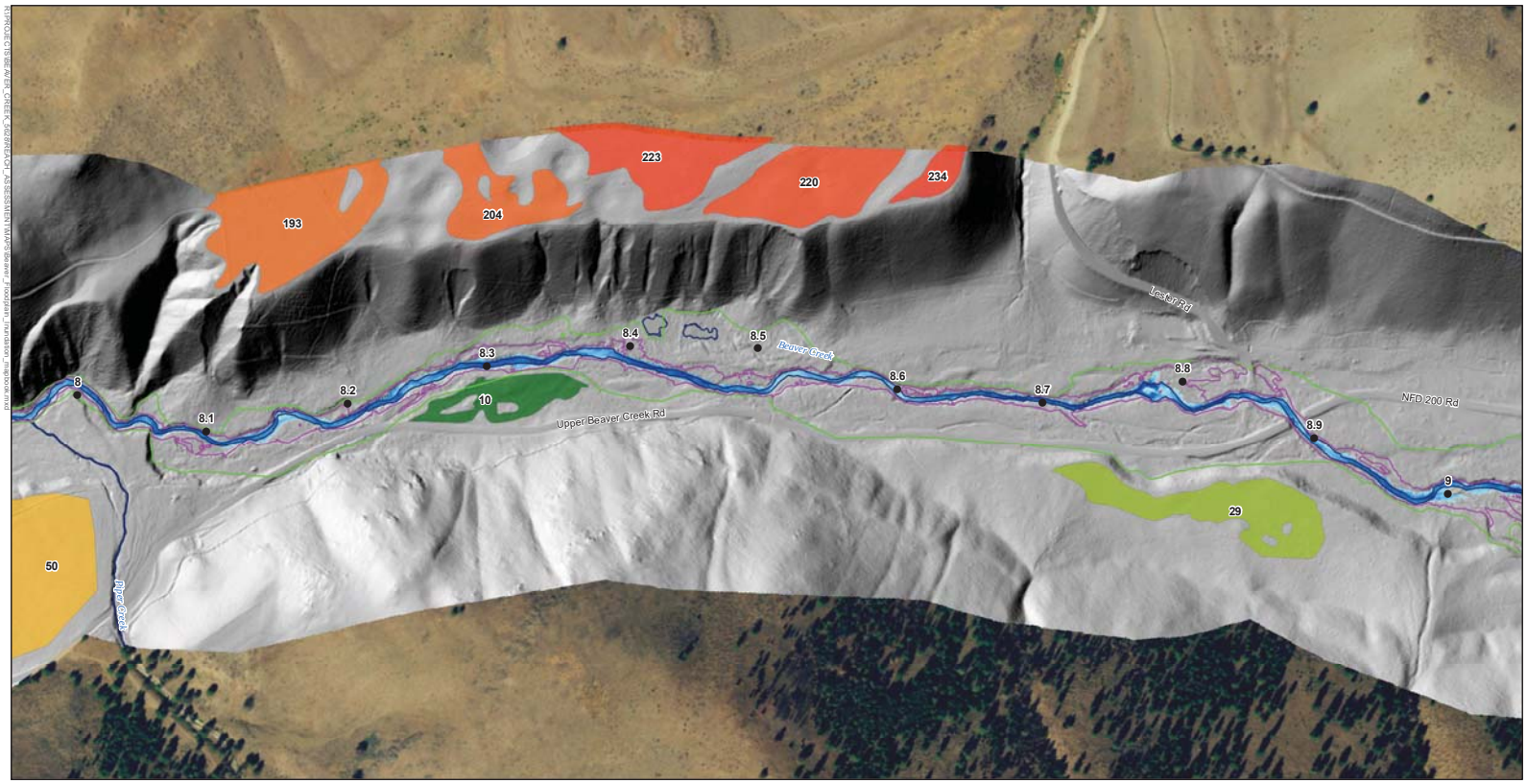
Figure B-2h

19 of 33

W N S E

0 500 1,000

Feet



- River Mile
- Reach Breaks
- Bathymetric LiDAR Flow Extent
- 100-Year Inundation Boundary
- Low Surface Boundary

2-year Depth
High
Low

Terrace Height (ft)
High: 234
Low: 9

Source: 2016 Topobathymetric LiDAR (Appendix C)

Beaver Creek Reach Assessment

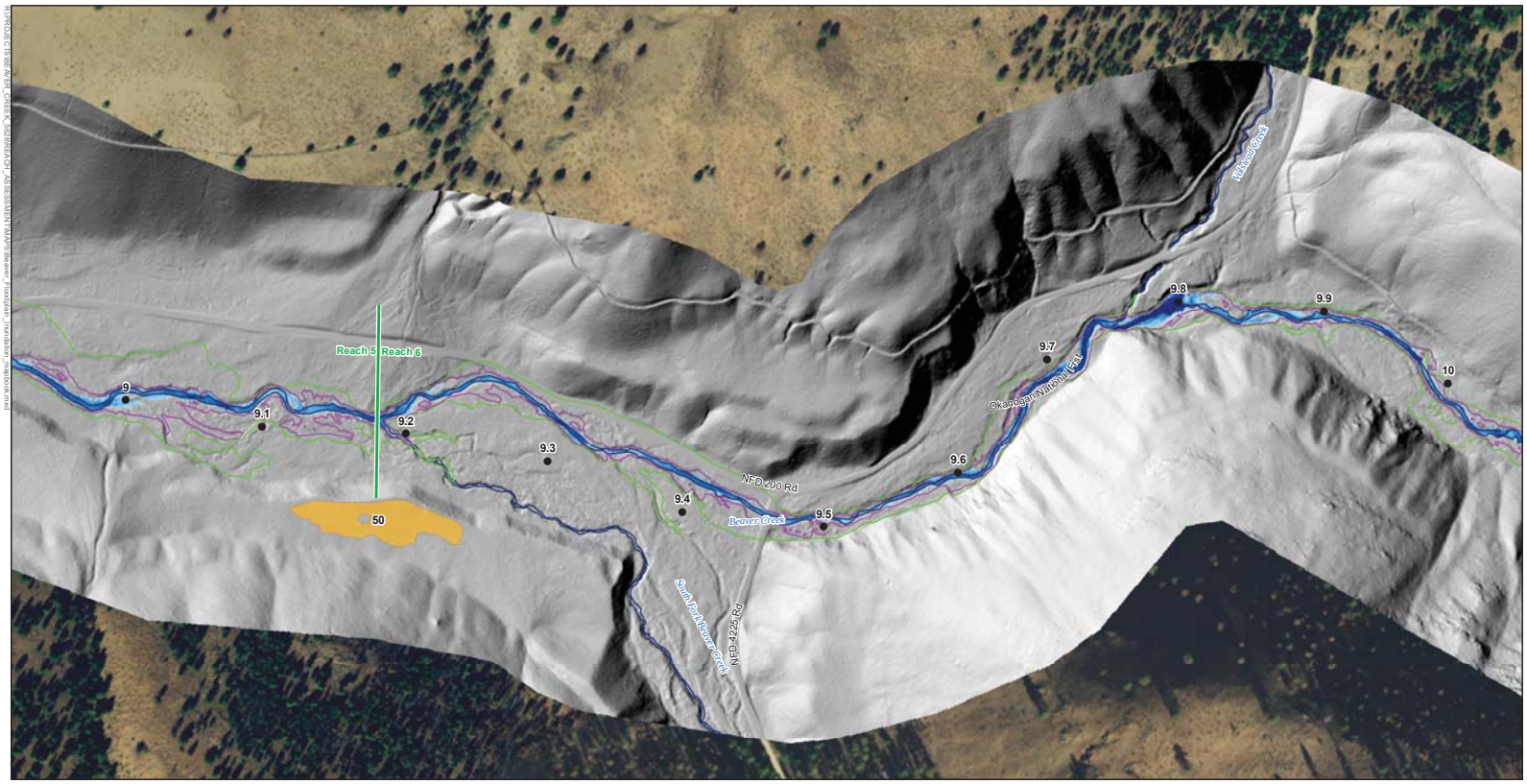
Floodplain Inundation and Terraces Map Series

Figure B-2i

20 of 33

0 500 1,000
Feet

R:\PROJECTS\BEAVER_CREEK_5628\REACH_ASSESSMENT\MAPS\Beaver_Floodplain_Inundation_mapbook.mxd



River Mile
Reach Breaks
Bathymetric LiDAR Flow Extent
100-Year Inundation Boundary
Low Surface Boundary

2-year Depth
High
Low

Terrace Height (ft)
High: 234
Low: 9

Source: 2016 Topobathymetric LiDAR (Appendix C)

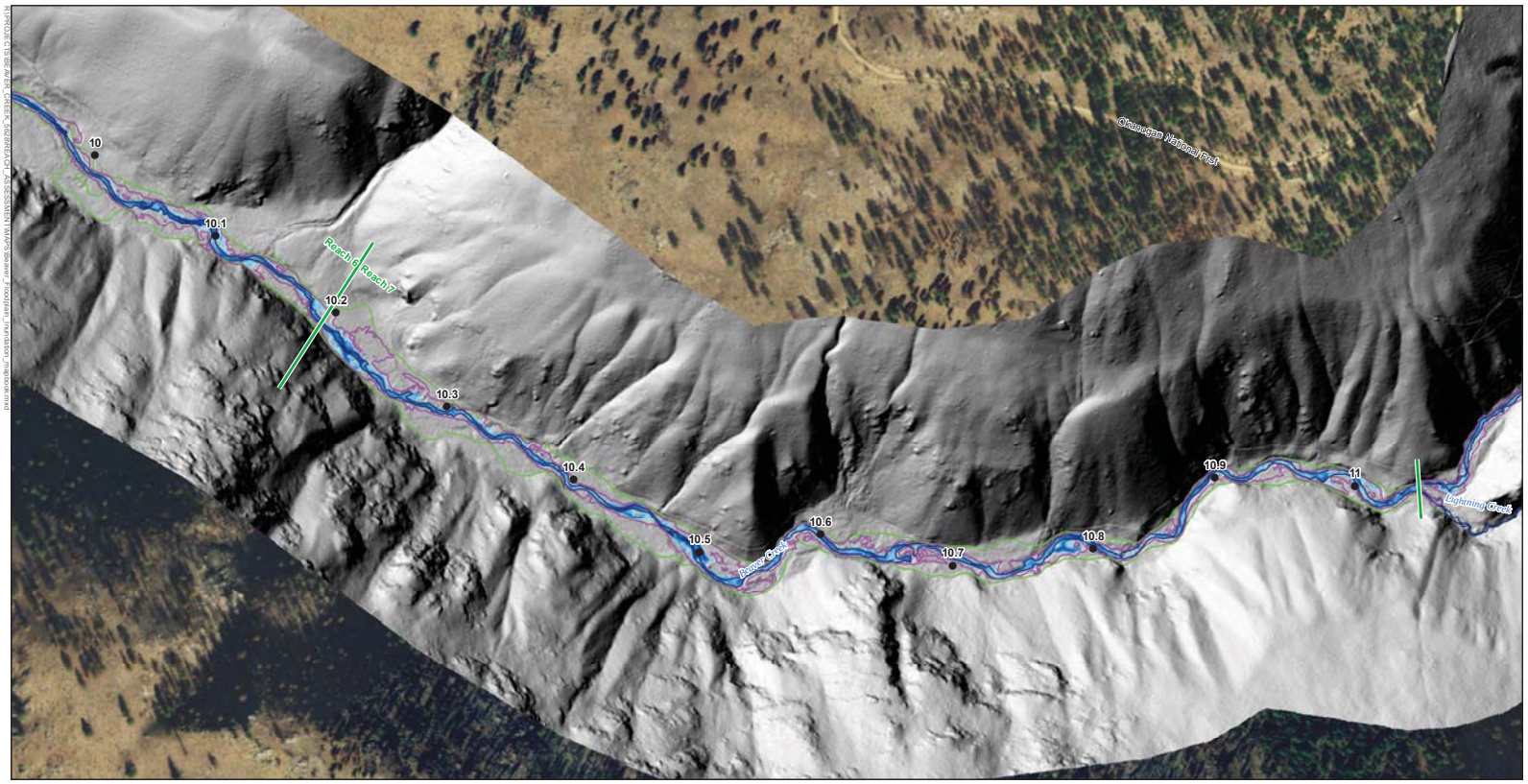
Beaver Creek Reach Assessment

Floodplain Inundation and Terraces Map Series

Figure B-2j

21 of 33

0 500 1,000
Feet



River Mile
Reach Breaks
Bathymetric LiDAR Flow Extent
100-Year Inundation Boundary
Low Surface Boundary

2-year Depth
High
Low

Terrace Height (ft)
High: 234
Low: 9

Source: 2016 Topobathymetric LiDAR (Appendix C)

Beaver Creek Reach Assessment

Floodplain Inundation and Terraces Map Series

Figure B-2k

22 of 33

0 500 1,000
Feet

R:\PROJECTS\BEAVER_CREEK_5922\REACH_ASSESSMENT\MAPS\Beaver_Floodplain_Inundation_mapbook.mxd

River Mile
Reach Breaks
Bathymetric LiDAR Flow Extent
Low Surface Boundary

Tree Height (feet)
0 - 3
3.1 - 25
25.1 - 50
50.1 - 75
75.1 - 100
100.1 - 150
150.1 - 189

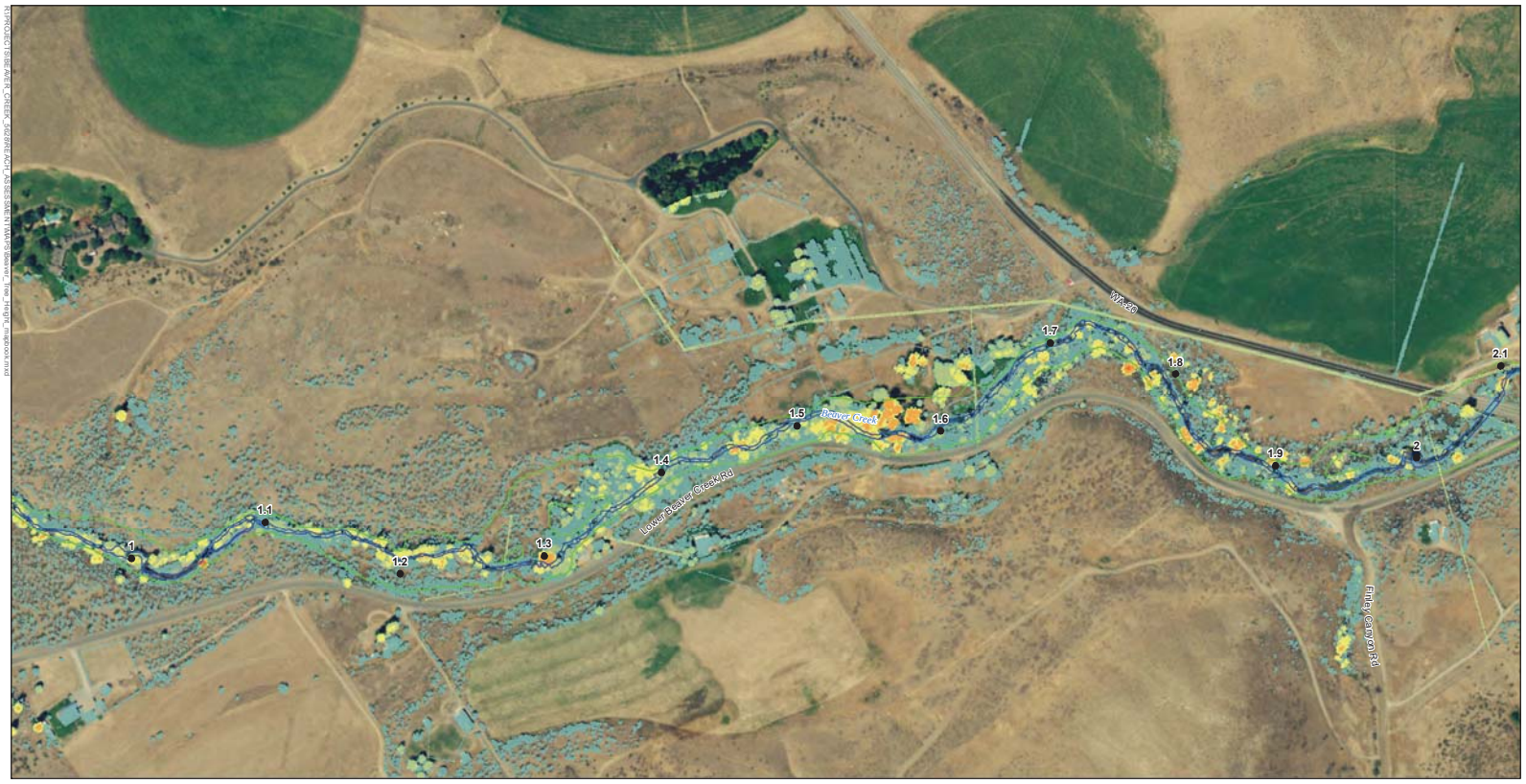
Beaver Creek Reach Assessment

Canopy Height Map Series

Figure B-3a

23 of 33

0 500 1,000
Feet



River Mile
Reach Breaks
Bathymetric LiDAR Flow Extent
Low Surface Boundary

Tree Height (feet)
0 - 3
3.1 - 25
25.1 - 50
50.1 - 75
75.1 - 100
100.1 - 150
150.1 - 189

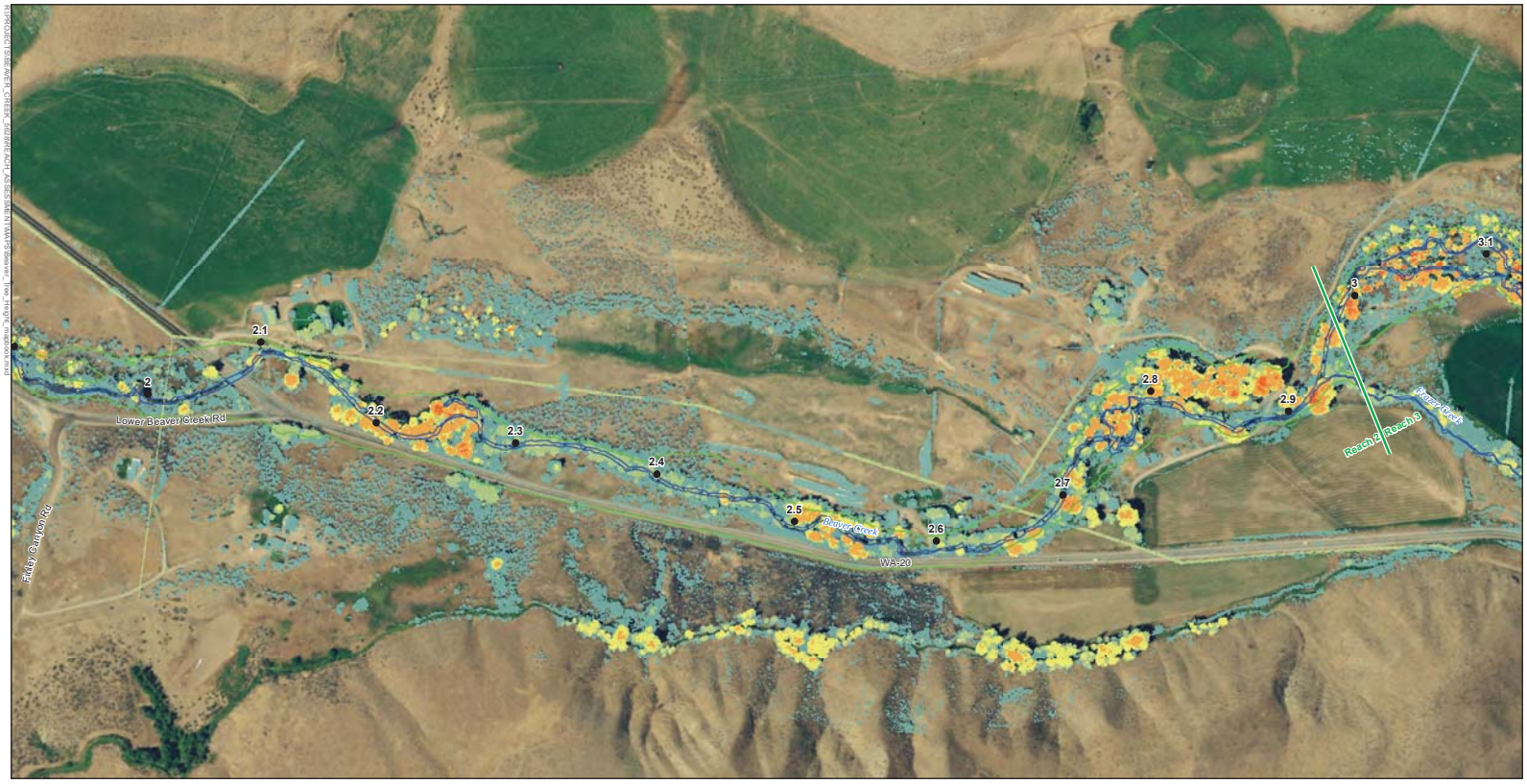
Beaver Creek Reach Assessment

Canopy Height Map Series

Figure B-3b

24 of 33

0 500 1,000
Feet



River Mile
Reach Breaks
Bathymetric LiDAR Flow Extent
Low Surface Boundary

Tree Height (feet)
0 - 3
3.1 - 25
25.1 - 50
50.1 - 75
75.1 - 100
100.1 - 150
150.1 - 189

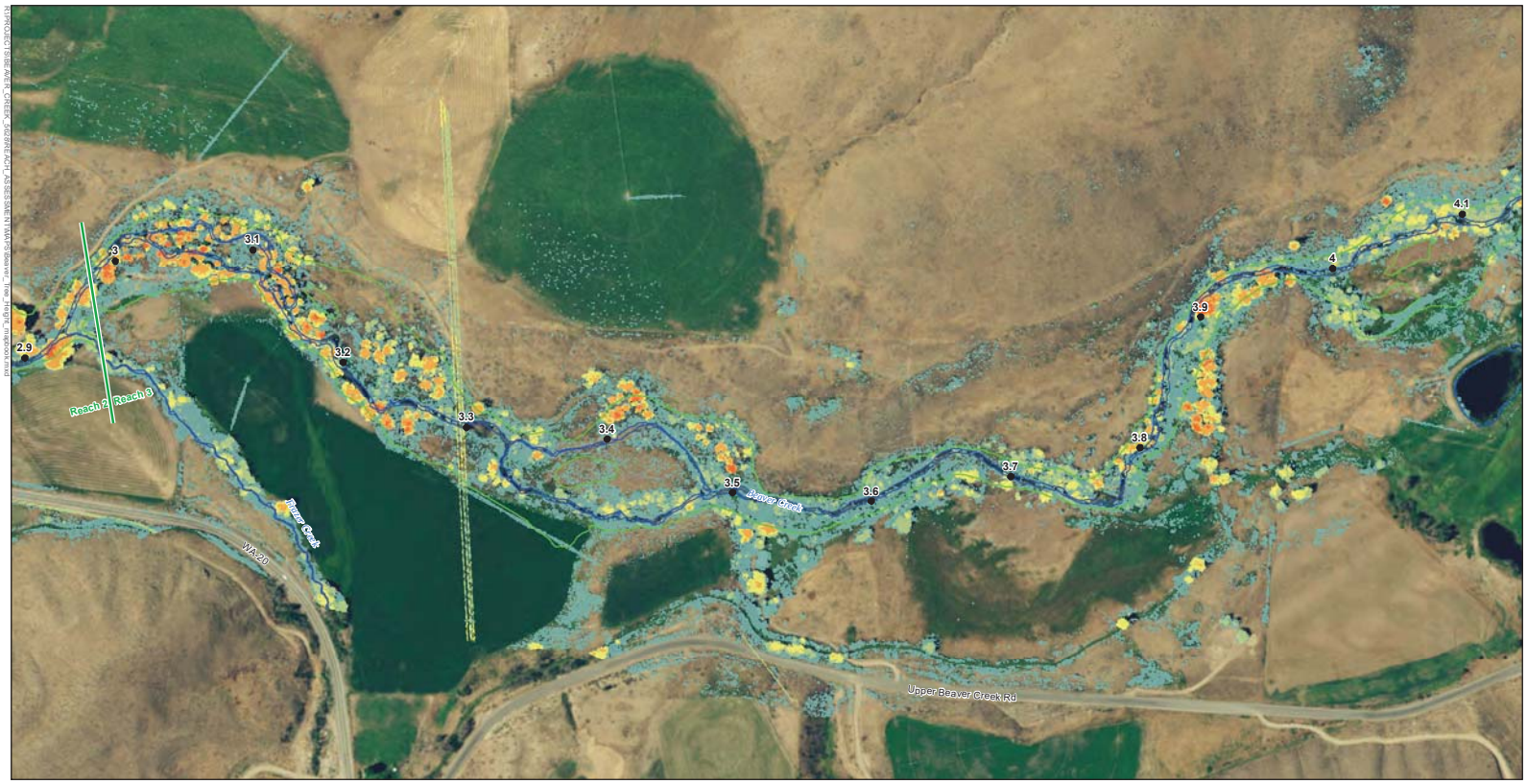
Beaver Creek Reach Assessment

Canopy Height Map Series

Figure B-3c

25 of 33

0 500 1,000
Feet



River Mile
Reach Breaks
Bathymetric LiDAR Flow Extent
Low Surface Boundary

Tree Height (feet)
0 - 3
3.1 - 25
25.1 - 50
50.1 - 75
75.1 - 100
100.1 - 150
150.1 - 189

Beaver Creek Reach Assessment

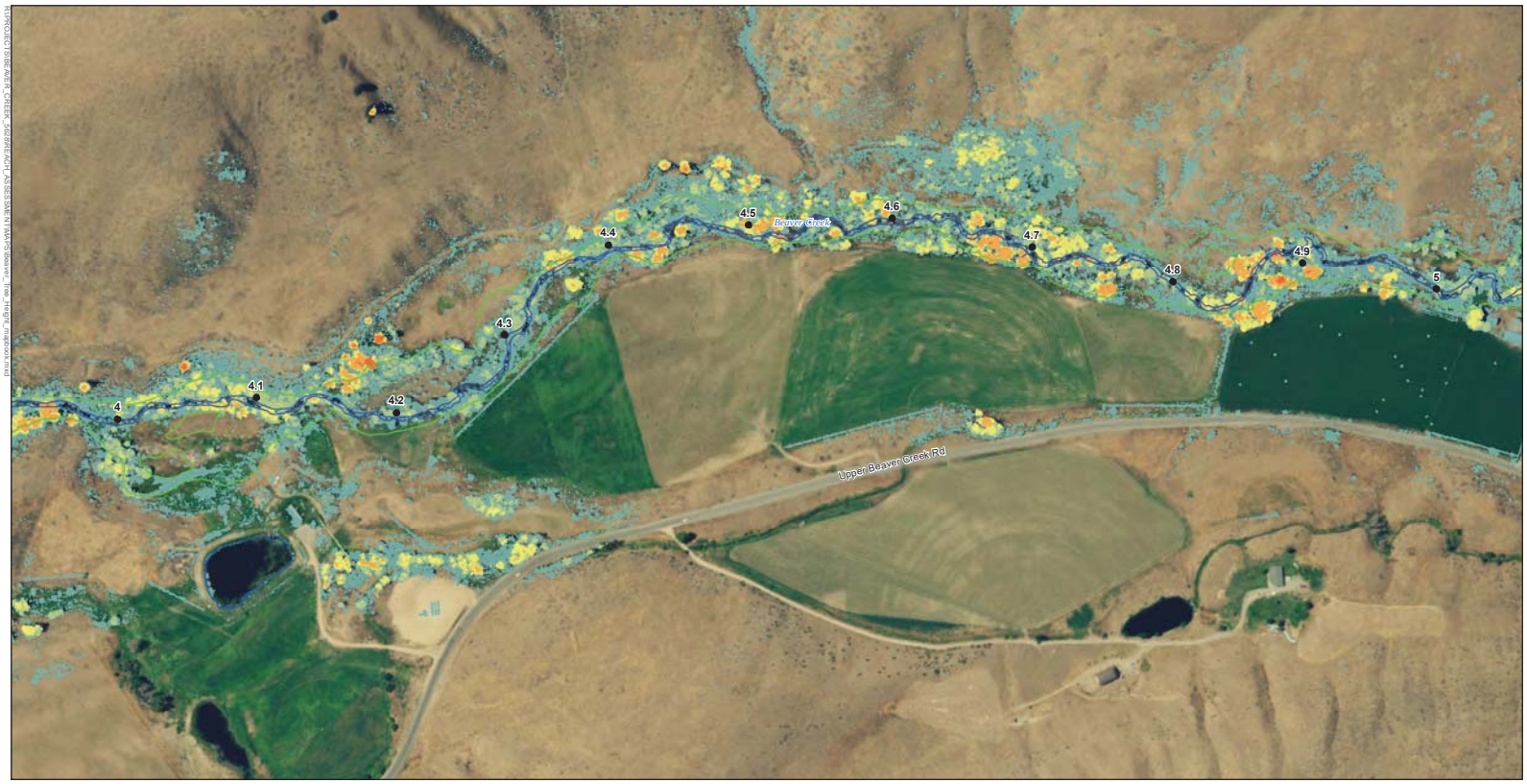
Canopy Height Map Series

Figure B-3d

26 of 33

W
S
N
E

0 500 1,000
Feet



River Mile
Reach Breaks
Bathymetric LiDAR Flow Extent
Low Surface Boundary

Tree Height (feet)
0 - 3
3.1 - 25
25.1 - 50
50.1 - 75
75.1 - 100
100.1 - 150
150.1 - 189

Beaver Creek Reach Assessment

Canopy Height Map Series

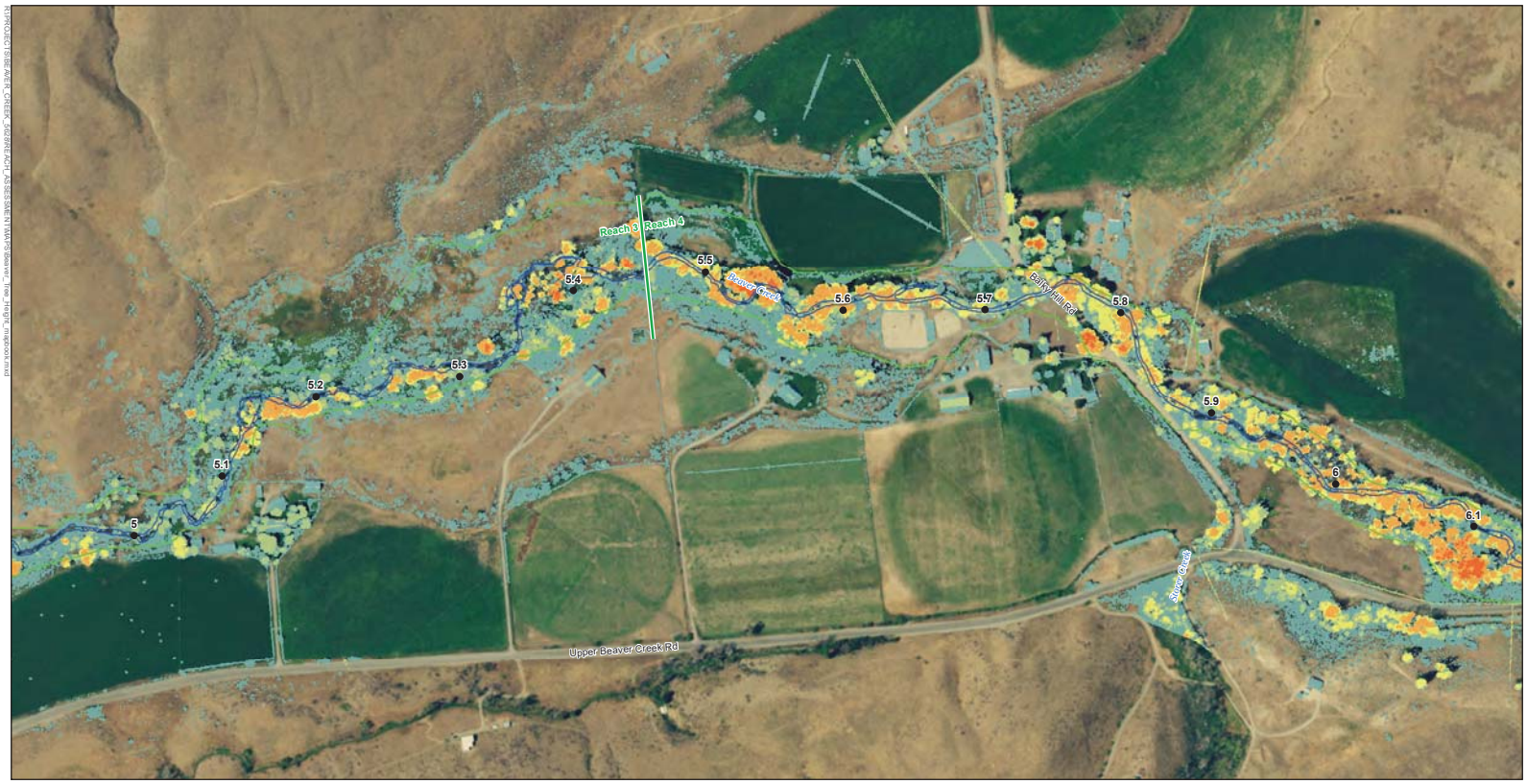
Figure B-3e

27 of 33

W
S
N
E

0 500 1,000
Feet

R:\PROJECTS\BEAVER_CREEK_0628\REACH_ASSESSMENT\MAPS\Beaver_Tree_Height_mapbook.mxd



River Mile
Reach Breaks
Bathymetric LiDAR Flow Extent
Low Surface Boundary

Tree Height (feet)
0 - 3
3.1 - 25
25.1 - 50
50.1 - 75
75.1 - 100
100.1 - 150
150.1 - 189

Beaver Creek Reach Assessment

Canopy Height Map Series

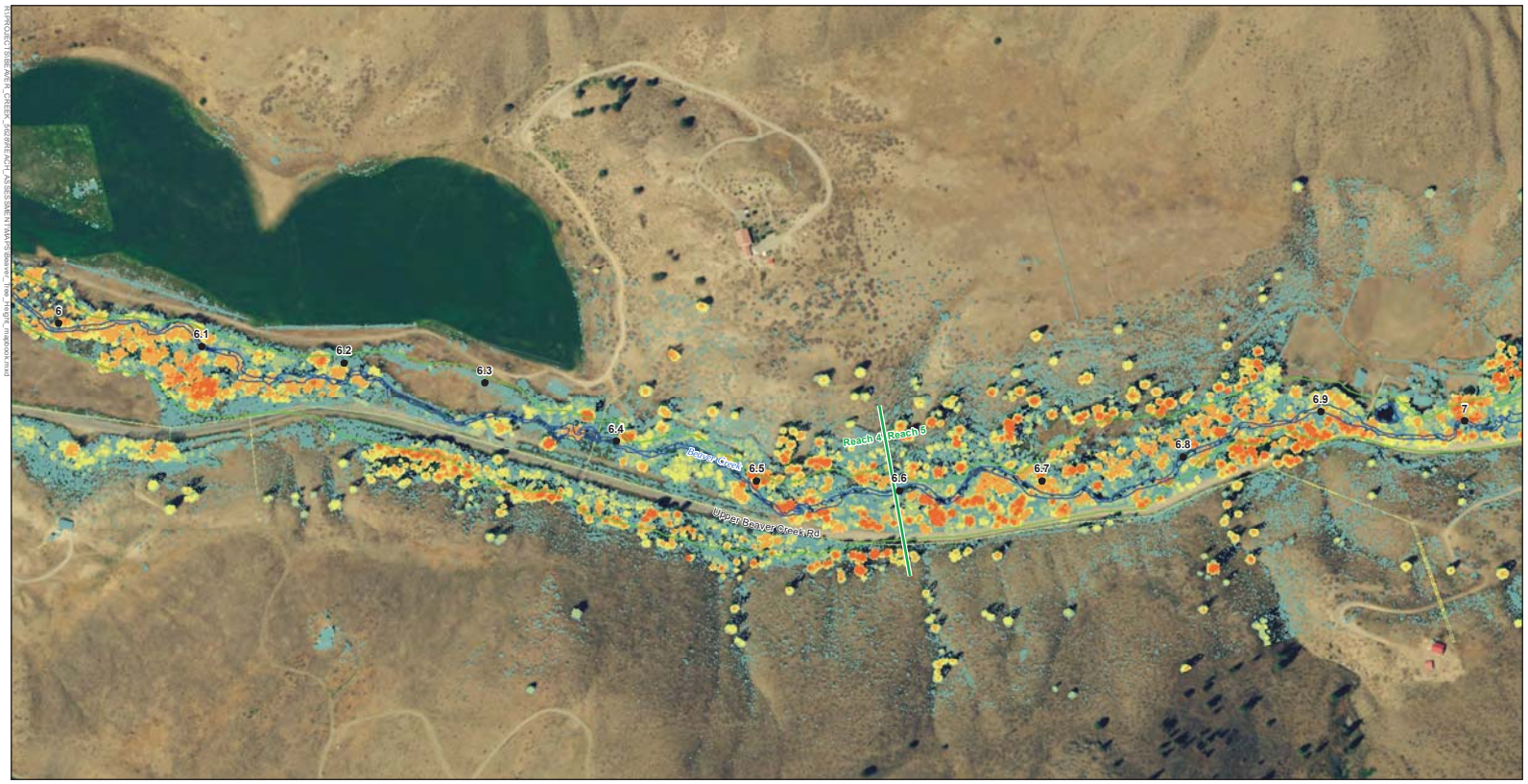
Figure B-3f

28 of 33

N
S
E
W

0 500 1,000
Feet

R:\PROJECTS\BEAVER_CREEK_5628\REACH_ASSESSMENT\MAPS\Beaver_Tree_Height_mxd\tool.mxd



River Mile
Reach Breaks
Bathymetric LiDAR Flow Extent
Low Surface Boundary

Tree Height (feet)
0 - 3
3.1 - 25
25.1 - 50
50.1 - 75
75.1 - 100
100.1 - 150
150.1 - 189

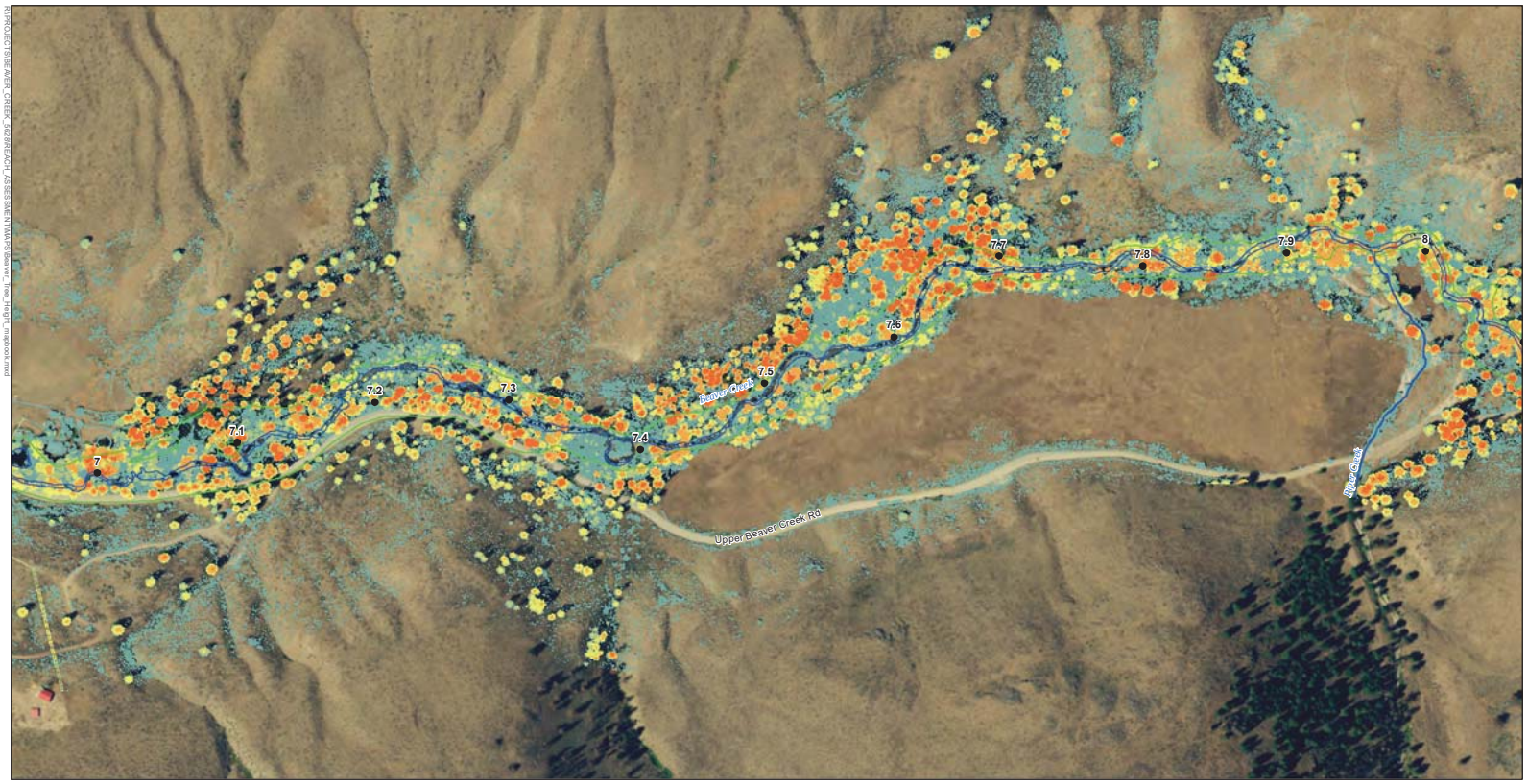
Beaver Creek Reach Assessment

Canopy Height Map Series

Figure B-3g

29 of 33

0 500 1,000
Feet



River Mile
Reach Breaks
Bathymetric LiDAR Flow Extent
Low Surface Boundary

Tree Height (feet)
0 - 3
3.1 - 25
25.1 - 50
50.1 - 75
75.1 - 100
100.1 - 150
150.1 - 189

Beaver Creek Reach Assessment

Canopy Height Map Series

Figure B-3h

30 of 33

0 500 1,000
Feet

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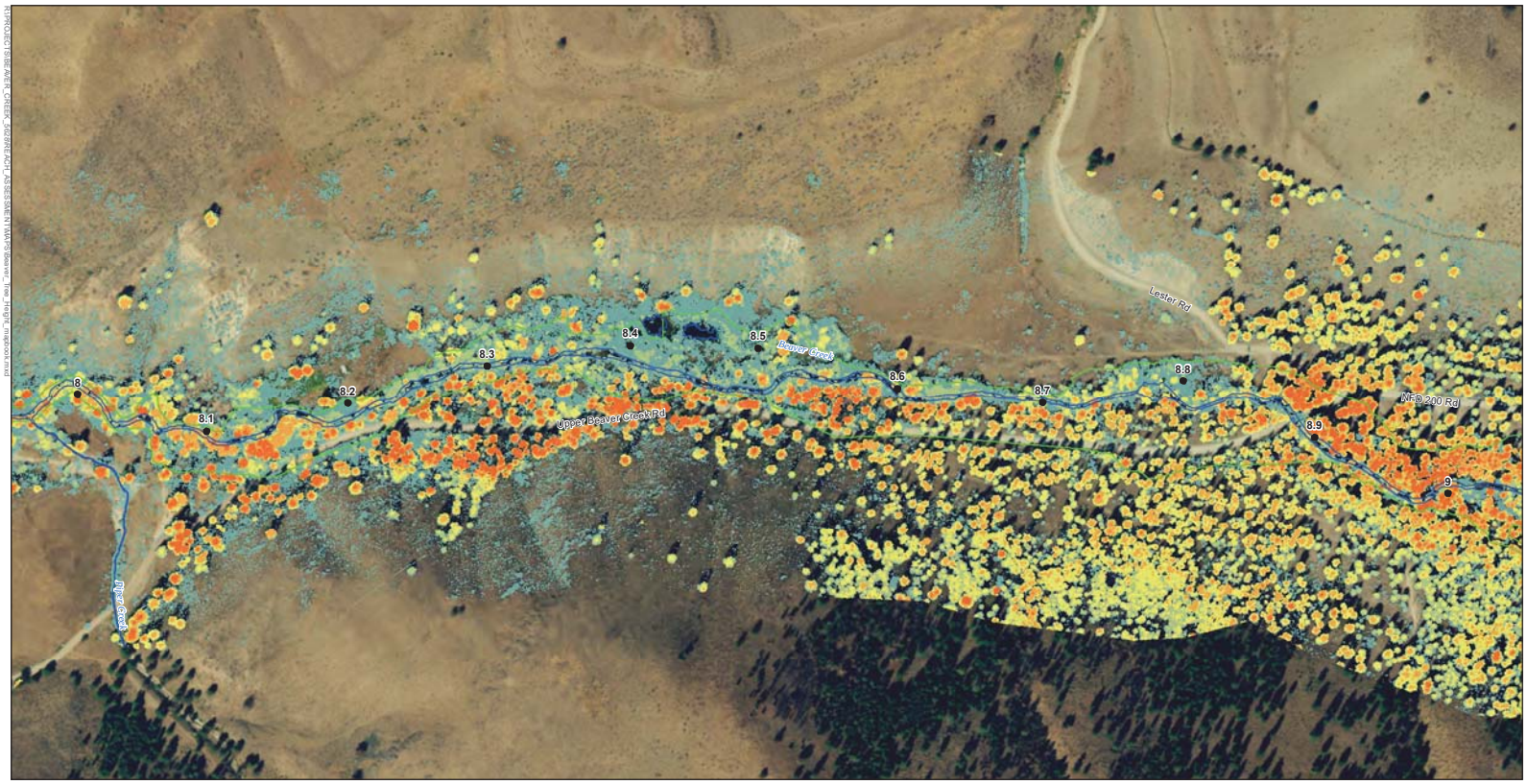


River Mile
Reach Breaks
Bathymetric LiDAR Flow Extent
Low Surface Boundary

Tree Height (feet)
0 - 3
3.1 - 25
25.1 - 50
50.1 - 75
75.1 - 100
100.1 - 150
150.1 - 189

Beaver Creek Reach Assessment

Canopy Height Map Series

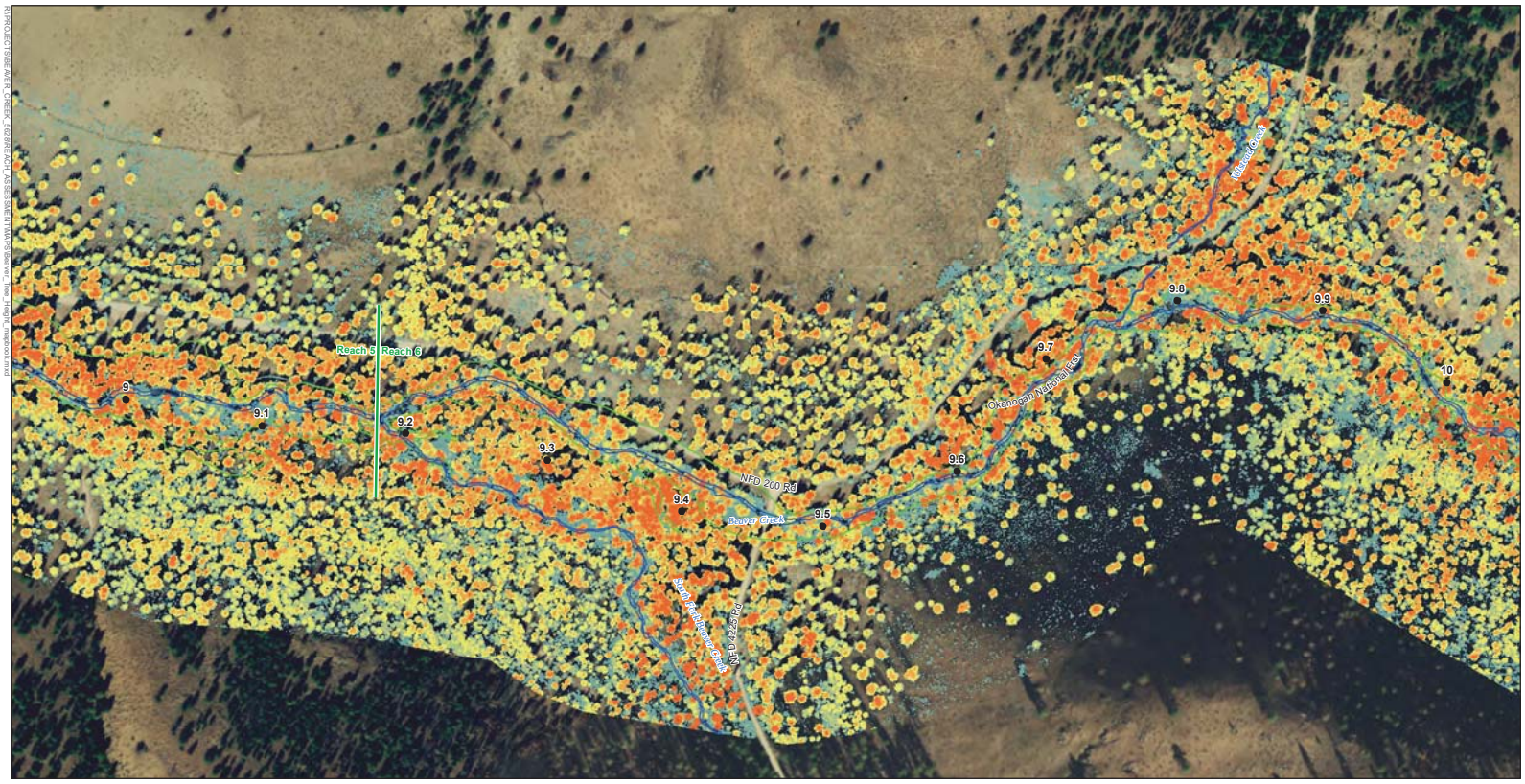
Figure B-3i

31 of 33

N
W
E
S

0 500 1,000
Feet

R:\PROJECTS\BEAVER_CREEK_5628\REACH_ASSESSMENT\MAPS\Beaver_Tree_Height_mxd\tool.mxd



River Mile
Reach Breaks
Bathymetric LiDAR Flow Extent
Low Surface Boundary

Tree Height (feet)
0 - 3
3.1 - 25
25.1 - 50
50.1 - 75
75.1 - 100
100.1 - 150
150.1 - 189

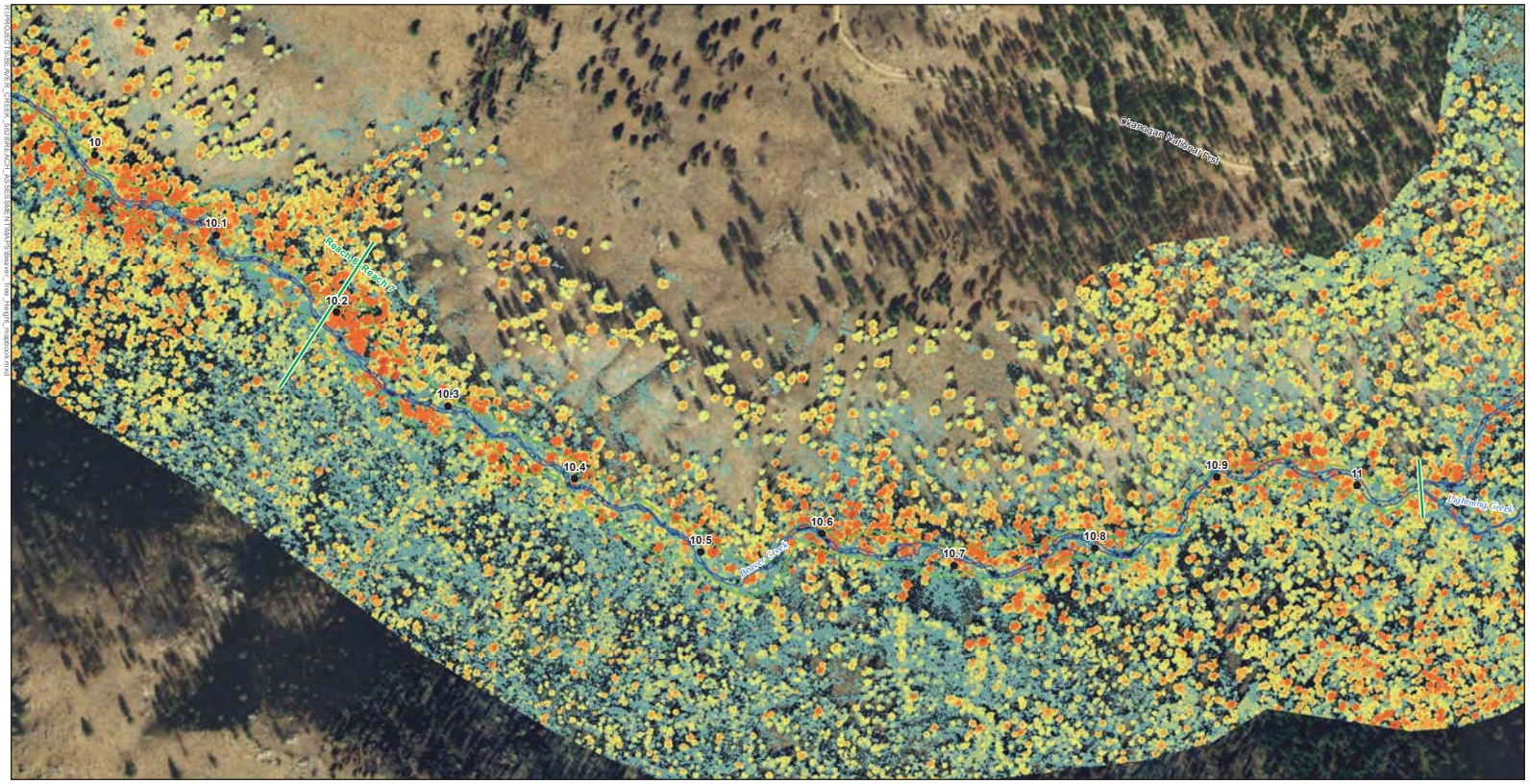
Beaver Creek Reach Assessment

Canopy Height Map Series

Figure B-3j

32 of 33

0 500 1,000
Feet



River Mile
Reach Breaks
Bathymetric LiDAR Flow Extent
Low Surface Boundary

Tree Height (feet)
0 - 3
3.1 - 25
25.1 - 50
50.1 - 75
75.1 - 100
100.1 - 150
150.1 - 189

Beaver Creek Reach Assessment

Canopy Height Map Series

Figure B-3k

33 of 33

N W E S

0 500 1,000
Feet

APPENDIX C

Beaver Creek Topobathymetric LiDAR Technical Data Report

(provided on DVD)

This appendix is provided separately.

APPENDIX D

Reach-Based Ecosystem Indicators (REI)

1. INTRODUCTION

This assessment of Reach-based Ecosystem Indicators (REI) provides a well-established and consistent means of evaluating biological and physical conditions in relation to criteria that represent known habitat requirements for aquatic biota. The REI assessment characterizes the state of geomorphic and ecological processes within the Beaver Creek drainage and within each of the 7 project area reaches. The REI criteria used in this assessment are based on the Matrix of Diagnostics/Pathways and Indicators (USFWS 1998), the National Oceanic and Atmospheric Administration National Marine Fisheries Service (NMFS) Matrix of Pathways and Indicators (1996), as well as more recent work conducted within the region by the Bureau of Reclamation and their adaptation of these indicators (USBR 2012).

Previous studies in Beaver Creek, data collected during the field habitat survey, observations, and reach assessment analyses informed this REI assessment. Specific analysis results are presented and discussed for each metric, and are used to assign a risk condition rating of "Adequate," "At Risk," or "Unacceptable." The criteria for rating categories are explained in detail for each indicator below.

2. PATHWAY: WATERSHED CONDITION

GENERAL INDICATOR: WATERSHED ROAD DENSITY AND EFFECTIVE DRAINAGE NETWORK

Metric Overview

Road density can be a good indicator of watershed condition, as it has been shown that high road density can result in altered drainage networks (Montgomery 1994; Wemple et al. 1996) which in turn often increases fine sediment load to streams and rivers (Reid and Dunne 1984; Goode et al. 2011). In addition, increased road density can result in greater mass wasting events and erosion than in a less disturbed watershed (Montgomery 1994; Wemple et al.1996). Increased sediment delivery to streams can have significant effects on aquatic systems, such as reducing suitable spawning habitat; smothering salmon eggs (Lisle 1989); clogging hyporheic flow paths (Boulton et al. 1998); reducing substrates for aquatic plants, biofilms, and aquatic invertebrates (Henley et al. 2000); as well as impacting channel morphology and water clarity (Waters 1995; Wood and Armitage 1997). Road density was calculated using an ArcGIS layer developed by compiling all open roads from USFS, ESRI Streetmap and Okanogan County roads shapefiles.

Criteria: From USFWS (1998), modified by USBR (2012).

Pathway	General Indicators	Specific Indicators	Adequate Condition	At Risk Condition	Unacceptable Risk Condition
Watershed Condition	Effective Drainage network and Watershed Road Density	Increase in Drainage Network/Road Density	Zero or minimum increase in active channel length correlated with human-caused disturbance **And** Road density <1 *miles/mile²*	Low to moderate increase in active channel length correlated with human-caused disturbance **And** Road density 1 to 2.4 *miles/mile²*	Greater than moderate increase in active channel length correlated with human-caused disturbance **And** Road density >2.4 *miles/mile²*

Assessment Results

Road density was assessed for the Beaver Creek drainage which is within the Middle Methow River Watershed (HUC-10 1702000806). The road density for the Beaver Creek drainage is 1.9 miles per square mile. In comparison, the road density for the Methow River Subbasin is 1.1 road miles per square mile (USBR 2011). Based on the rating criteria, the drainage is functioning at an **at risk** condition for this indicator.

REI Rating

Watershed Rating: **At Risk**

INDICATOR: DISTURBANCE REGIME (NATURAL & HUMAN-CAUSED)

Metric Overview

Disturbance is an integral part of natural systems (Ward 1998). Natural disturbance regimes create habitat and biological diversity (Nakamura et al. 2000; Ward 1998) that maintain the larger ecosystem processes. Natural disturbance regimes include events such as landslides, fire, flood, drought, and windstorms. Human activities such as flow regulation, channelization, bank stabilization, road construction, and land-use modifications (conversion to agriculture, development, etc.) can change how systems respond to natural events, frequency of events, and ability to recover (Waples et al. 2009).

Criteria: From USFWS (1998)

Pathway	General Indicators	Specific Indicators	Adequate	At Risk	Unacceptable
Watershed Condition	Disturbance Regime	Natural/Human Caused	Environmental disturbance is short lived; predictable hydrograph; high quality habitat and watershed complexity providing refuge and rearing space for all lifestages or multiple life-history forms. Natural processes are stable.	Scour events, debris torrents, or catastrophic fires are localized events that occur in several minor parts of the watershed. Resiliency of habitat to recover from environmental disturbance is moderate.	Frequent flood or drought producing highly variable and unpredictable flows, scour events, debris torrents, or high probability of catastrophic fire exists throughout a major part of the watershed. The channel is simplified, providing little hydraulic complexity in the form of pools or side channels. Natural processes are unstable.

Assessment Results

Alterations in the Beaver Creek Watershed include past human disturbance as well as on-going disturbances that limit the resiliency of habitat to recover from disturbance events. For example, land use and development have constrained channel migration, disconnected habitat, and decreased large woody debris abundance. Due to these alterations, the channel is incised, simplified, and has reduced hydraulic complexity in many areas.

Land use activities including riparian and hillslope timber harvest, mining, grazing, agriculture and road construction as well as land management actions including fire suppression have changed the composition, structure, and function of riparian and upland forests in the Beaver Creek Watershed. These changes have modified the behavior of disturbances events and increased the risk of potential severe disturbance. Multiple large, catastrophic, wildfires have occurred in the Beaver Creek Watershed in recent years including the 2006 Tripod Complex Fire and the 2014 Carlton Complex Fire. Based on the rating criteria the watershed is functioning at an **unacceptable** condition for this indicator.

REI Rating

Watershed Rating: **Unacceptable**

INDICATOR: STREAMFLOW (CHANGE IN PEAK/BASE FLOW)

Metric Overview

The magnitude, timing, duration, and frequency of stream flows within a watershed are important drivers within the ecological system. Stream discharge and channel morphology are directly linked to these processes and largely controlled by climate, vegetation, geology, and human alterations and impacts. Alterations to the natural hydrology of a watershed can affect timing and magnitude of peak flow and low flow events. The frequency of high-flow events can also be dramatically affected by human actions, potentially decreasing due to flow regulation (e.g., dams) and water withdrawals (e.g., for irrigation), or increasing from widespread timber harvest, increased impervious surfaces, or extensive road networks.

Criteria: From USFWS (1998), modified by USBR (2012).

Pathway	General Indicators	Specific Indicators	Adequate	At Risk	Unacceptable
Watershed Condition	Streamflow	Change in Peak flows	Magnitude, timing, duration and frequency of peak flows within a watershed are not altered relative to natural conditions of an undisturbed watershed of similar size, geology, and geography.	Some evidence of altered magnitude, timing, duration and frequency of peak flows relative to natural conditions of an undisturbed watershed of similar size, geology, and geography.	Pronounced evidence of altered magnitude, timing, duration and frequency of peak flows relative to natural conditions of an undisturbed watershed of similar size, geology, and geography.

Assessment Results

The hydrology of the Beaver Creek drainage is driven by precipitation and snowmelt. Snowmelt in spring and early summer is the primary source of peak flow events typically occurring from April through July, with the highest rates in May and June. Peak flows typically recede relatively quickly, returning to low-flow conditions from August to February. Infrequent rain-on-snow events and high intensity precipitation events can also cause short duration increases in peak flows.

Beaver Creek meets all of Washington State Department of Ecology's Water Quality Program Policy criteria for 303(d) listing for low instream flows. During late summer the stream has been observed to go dry downstream of RM 1.5 as a result of demand for irrigation.

Climate change projections indicate that rainfall in Washington may increase considerably by 2080 (e.g., Mote and Salanthe 2009). Climate change models also predict dramatic changes in spring snowpack and a shift from snow and mixed-rain-and-snow to rain-dominant systems across most of the Pacific Northwest (Hamlet et al. 2013) and an increase in winter stream flows, earlier and lower peak runoff, and lower summer baseflows (CIG 2009). These analyses suggest that human-induced climate change is likely to alter the magnitude, timing, duration, and frequency of peak flows. Based on the potential effects of climate change on criteria for watershed hydrology, and existing infrastructure and channel modification, this indicator is rated **unacceptable**.

REI Rating

Watershed Rating: **Unacceptable**

3. PATHWAY: REACH-SCALE HABITAT ACCESS

INDICATOR: PHYSICAL BARRIERS – MAIN CHANNEL BARRIERS

Metric Overview

Physical barriers restrict movement of aquatic species, such as salmonids, throughout a watershed. This can result in reduced genetic diversity within populations and reduced distribution of marine derived nutrients throughout the system, and may also impact transport of woody debris and bedload downstream from source areas. This metric evaluates mainstem fish passage barriers in Beaver Creek.

Criteria: From USFWS (1998), modified by USBR (2012).

Pathway	General Indicators	Specific Indicators	Adequate	At Risk	Unacceptable
Habitat Access	Physical Barriers	Main Channel Barriers	No manmade barriers present in the mainstem that limit upstream or downstream fish passage at any flows	Manmade barriers present in the mainstem that prevent upstream or downstream migration at some flows that are biologically significant	Manmade barriers present in the mainstem that prevent upstream or downstream migration at multiple or all flows

Assessment Results

No complete mainstem fish passage barriers are present on Beaver Creek. There have been a number of fish passage improvement projects completed on Beaver Creek since 2001 (TU 2015). The USGS in partnership with USBR have conducted habitat restoration effectiveness monitoring from 2004 to 2013. Monitoring results indicate that restoration actions to remove fish passage barriers have enabled upstream passage (Martens and Connolly 2010; Martens et al. 2014). However, the continued, long-term fish passage effectiveness of the replaced diversion structures has been identified as a concern requiring ongoing monitoring and potential maintenance (UCRTT 2014).

Based on the rating criteria Reaches 2, 3 and 4 are rated as **at risk** condition for this indicator because diversion structures have the potential to be limiting juvenile migration at some flows. Reaches 1, 5, 6 and 7 are rated as **adequate** condition because no barriers are present that limit upstream or downstream fish passage at any flows.

Main Channel Barriers REI Rating

Reach 1	Reach 2	Reach 3	Reach 4	Reach 5	Reach 6	Reach 7
Adequate	At Risk	At Risk	At Risk	Adequate	Adequate	Adequate

4. PATHWAY: REACH-SCALE HABITAT QUALITY

INDICATOR: SUBSTRATE – DOMINANT SUBSTRATE FINE SEDIMENT

Metric Overview

Stream substrate is important for salmon spawning, egg incubation, and rearing. High-quality spawning areas generally include gravel/cobble dominated substrates with relatively low amounts of interstitial fine sediments. These factors provide conditions suitable for egg incubation (proper aeration and not smothered by fines) and young-of-the year rearing (available interstitial spaces for cover and refuge). Streambed substrate was evaluated based on pebble counts in Reaches 1, 2, 3, 5, and 7 and ocular estimates of substrate composition for each channel unit in all reaches.

Criteria: Modified from USFWS (1998) and USBR (2012).

Pathway	General Indicators	Specific Indicators	Adequate	At Risk	Unacceptable
Habitat Quality	Substrate	Dominant Substrate/Fine Sediment	Dominant Substrate is gravel or cobble (interstitial spaces clear), or embeddedness < 20%, <12% fines (<0.85mm) in spawning gravel or <12% surface fines of <6mm	Gravel and Cobble is subdominant, or if dominant, embeddedness is 20-30%; 12-17% fines (<0.85mm) in spawning gravel or 12-20% surface fines of <6mm	Bedrock, sand, silt, or small gravel dominant, or if gravel and cobble dominant, embeddedness > 30%; >17% fines (<0.85mm) in spawning gravel or >20% surface fines of <6mm

Assessment Results

Reaches 1 through 3 and 5 are rated as **unacceptable** (Reaches 1 and 2) or **at risk** (Reaches 3 and 5) based on the degree of embeddedness. Reaches 4, 6and 7 are rated as **adequate.** They are dominated by coarse cobbles with isolated areas of spawning-sized sized gravels and an increasing proportion of boulders in the upstream direction.

Substrate Size Class Distribution and Percent Embedded by Reach

Substrate Size Class	Reach 1	Reach 2	Reach 3	Reach 4	Reach 5	Reach 6	Reach 7
Sand (<2 mm)	8%	13%	9%	8%	6%	5%	3%
Gravel (2 to 64 mm)	25%	21%	33%	25%	24%	19%	14%
Cobble (64 to 256 mm)	52%	45%	58%	53%	54%	51%	56%
Boulder (256 to 4096 mm)	15%	21%	1%	15%	17%	25%	27%
Bedrock	0%	0%	0%	0%	0%	0%	0%
Percent Embedded	33%	39%	29%	11%	19%	10%	10%

Dominant Substrate/Fine Sediment REI Rating

Reach 1	Reach 2	Reach 3	Reach 4	Reach 5	Reach 6	Reach 7
Unacceptable	Unacceptable	At Risk	Adequate	At Risk	Adequate	Adequate

INDICATOR: LARGE WOODY DEBRIS (LWD)

Metric Overview

Large woody debris (LWD) provides critical habitat structure and helps create and sustain channel complexity over time. Large pieces and log jams can generate quality pools, offer refuge, and provide potential food sources for salmonids. This metric evaluates the quantity of LWD in pieces per mile. Although the federal targets for properly functioning are 20 pieces per mile (USFWS 1998), Fox and Bolton (2007) determined that standard was low since larger eastern Washington streams (16 to 164 feet bankfull width) surveyed in unmanaged forested basins had an average of 42.5 pieces per mile. In addition, other inventories on eastern Washington streams have found LWD quantities much higher at over 140 pieces per mile (Inter-Fluve 2012). The criterion of 42.5 pieces per mile was chosen for the purposes of this analysis. LWD pieces and jams were inventoried during field surveys for the reach assessment using the methods of the USFS Stream Inventory Protocols (USFS 2016).

Criteria: Modified from USBR (2012) and Fox and Bolton (2007).

Pathway	General Indicators	Specific Indicators	Adequate	At Risk	Unacceptable
Habitat Quality	Large Woody Debris (LWD)	Pieces per mile at bankfull	>42.5 pieces/mile >12" dbh > 35' length; and adequate sources of woody debris available for both long- and short-term recruitment.	Current levels meet piece frequency standard for **Adequate**, but lacks potential sources from riparian areas for wood debris recruitment to maintain that standard.	Does not meet standards for **Adequate** and lacks potential large woody material recruitment.

Assessment Results

Due to the relatively small size of functional wood in Beaver Creek, qualifying LWD and non-qualifying wood (i.e. smaller than indicator criteria) were both inventoried but tallied separately. All reaches of Beaver Creek were rated as **unacceptable** due to a lack of LWD meeting the indicator criteria of 42.5 pieces per mile. Reaches 1 through 4 have limited future recruitment potential due to insufficient riparian vegetation (see Pathway: Riparian Condition below). Reaches 5 through 7 have higher recruitment potential due to the recent 2014 Carlton Complex Fire; however, the increase in recruitment potential will be relatively short-team, while long-term recruitment potential will be limited by a loss of mature trees. Reaches 2 through 7 also have a high proportion of non-qualifying wood that is either less than 35 feet in length, less than 12 inches dbh, or both, and therefore were not included in the qualifying pieces per mile calculation because they do not meet the size criteria.

Large Woody Debris Pieces per Mile

Instream Wood	Reach 1	Reach 2	Reach 3	Reach 4	Reach 5	Reach 6	Reach 7
Small Wood (pieces per mile)[1/]	10.1	41.1	65.2	86.7	99.8	144.6	167.7
Medium Wood (pieces per mile)[2/]	12.7	10.6	25.2	17.3	28.5	48.8	81.2
Large Wood (pieces per mile)[3/]	2.5	0.4	0.4	1.6	3.2	7.2	12.7
Qualifying LWD (pieces/mile)[4/]	5.1	6.4	3.5	3.2	6.8	12.7	26.4
Log Jams (jams/mile)	0.0	3.5	6.0	2.4	5.0	1.8	5.3

1/ Small Wood: > 6 inches dbh and > 6.5 ft length
2/ Medium Wood: > 12 inches dbh and > 6.5 to <35 feet length
3/ Large Wood: > 20 inches dbh and > 6.5 to <35 feet length
4/ Qualifying LWD: > 12 inches dbh and > 35 feet in length

LWD REI Rating

Reach 1	Reach 2	Reach 3	Reach 4	Reach 5	Reach 6	Reach 7
Unacceptable	Unacceptable	Unacceptable	Unacceptable	Unacceptable	Unacceptable	Unacceptable

INDICATOR: POOLS – POOL FREQUENCY & QUALITY

Metric Overview

Pools are well recognized as providing key habitat for salmonids. Pool frequency tends to increase in lower gradient channels and with increasing abundance of wood (Montgomery et al. 1995; Beechie and Sibley, 1997). In channels with high wood abundance pool spacing is typically around 1 channel-width between pools. However, in steeper channels, pool spacing tends to be controlled by the formation of steps at a spacing of about 2 channel-widths per pool (Montgomery et al. 1995). Pools were inventoried during field surveys for the reach assessment using the methods of the USFS Stream Inventory Protocols (USFS 2016).

Criteria: Adapted from USFWS (1998).

Pathway	General Indicators	Specific Indicators	Adequate	At Risk	Unacceptable
Habitat Quality	Pools	Pool Frequency and Quality	Pool frequency in a reach closely approximates: **Wetted width (ft)** — **#pools/mile** 0-5 — 39 5-10 — 60 10-15 — 48 15-20 — 39 20-30 — 23 30-35 — 18 35-40 — 10 40-65 — 9 65-100 — 4 Also, pools have good cover and cool water, and only minor reduction of pool volume by fine sediment	Pool frequency is similar to values in "adequate", but pools have inadequate cover/ temperature, and/or there has been a moderate reduction of pool volume by fine sediment	Pool frequency is considerably lower than values desired for "functioning appropriately"; also cover/ temperature is inadequate, and there has been a major reduction of pool volume by fine sediment

Assessment Results

Reaches 1 through 6 are rated **unacceptable** because the pools per mile frequency was considerably lower than the criteria for this indicator. High stream temperatures and a reduction of pool volume by fine sediment are also impacting these pools, particularly in the lower reaches. The pool frequency in Reach 7 is rated as **at risk** because of pool frequencies similar to the criteria for this indicator as well as good stream temperature and cover with little fine sediment accumulation in pools. The geomorphic conditions and lack of disturbance in Reach 7 suggest the pools in this reach (dominated by plunge pools) closely approximate natural conditions.

Pool Characteristics by Reach

Characteristics	Reach 1	Reach 2	Reach 3	Reach 4	Reach 5	Reach 6	Reach 7
Wetted Width (feet)	13.4	17.5	19.9	18.6	20.4	17.3	18.6
Pool Frequency (pools/mile)	27.9	10.6	8.9	11.0	5.3	20.8	30.6

Pool Frequency and Quality REI Rating

Reach 1	Reach 2	Reach 3	Reach 4	Reach 5	Reach 6	Reach 7
Unacceptable	Unacceptable	Unacceptable	Unacceptable	Unacceptable	Unacceptable	At Risk

INDICATOR: OFF-CHANNEL HABITAT

Metric Overview

Off-channel habitats, sloughs, wetlands, oxbow lakes, backwaters, floodplain channels, blind and flow-through side-channels can provide important rearing habitat for juvenile salmonids (Roni et al. 2002). These areas can provide high-flow refugia, temperature refuge, and protection from predators, as well as productive feeding areas. Side channels were identified during field surveys for the reach assessment and desktop assessment using the 2016 LiDAR data.

Criteria: Modified from USFWS (1998) and USBR (2012).

Pathway	General Indicators	Specific Indicators	Adequate	At Risk	Unacceptable
Habitat Quality	Off-Channel Habitat	Connectivity with main channel	Reach has ponds, oxbows, backwaters, and other low-energy off-channel areas with cover; similar to conditions that would be expected in the absence of human disturbance	Reach has some ponds, oxbows, backwaters, and other low-energy off-channel areas with cover; but availability or access is less than what would be expected in the absence of human disturbance	Reach has few or no ponds, oxbows, backwaters, or other off-channel areas relative to what would be expected in the absence of human disturbance.

Assessment Results

Beaver Creek is incised in many areas and generally lacks off-channel habitat. Reaches 1 and 4 are rated **unacceptable** due to being deeply incised and cut off from side-channels and off-channel areas. Reaches 2, 3 and 5 are rated **at risk** with some connected side channels but less than would be expected prior to human development due to channel incision and infrastructure limiting the amount of off-channel habitat. Reaches 6 and 7 are rated **adequate** for this indicator because they are naturally confined and would not be expected to have considerably more off-channel habitat in the absence of human disturbance.

Connectivity with Main Channel Habitat REI Rating

Reach 1	Reach 2	Reach 3	Reach 4	Reach 5	Reach 6	Reach 7
Unacceptable	At Risk	At Risk	Unacceptable	At Risk	Adequate	Adequate

5. PATHWAY: CHANNEL FORMS & PROCESSES

INDICATOR: CHANNEL DYNAMICS – FLOODPLAIN CONNECTIVITY

Metric Overview

Floodplains serve a number of significant geomorphic and ecological functions including conveyance of flood waters, sediment source and storage, supply of large wood, and development of diverse habitat for aquatic and terrestrial species (e.g., Allen 1970; Zwolinski 1992; Nanson and Croke 1992). Floodplain connectivity was evaluated based on the results from the hydraulic modeling, floodplain inundation and geomorphic mapping.

Criteria: Modified from USFWS (1998).

Pathway	General Indicators	Specific Indicators	Adequate	At Risk	Unacceptable
Channel	Dynamics	Floodplain Connectivity	Floodplain areas are frequently hydrologically linked to main channel; overbank flows occur and maintain wetland functions, riparian vegetation and succession	Reduced linkage of wetlands, floodplains, and riparian areas to main channel; overbank flows are reduced relative to historic frequency, as evidenced by moderate degradation of wetland function, riparian vegetation/succession	Severe reduction in hydrologic connectivity between off-channel wetland, floodplain, and riparian areas; wetland extent drastically reduced and riparian vegetation/succession altered significantly

Assessment Results

As stated above, Beaver Creek is incised in many areas which limits floodplain connectivity. Reaches 1 and 4 are rated **unacceptable** for floodplain connectivity due to being deeply incised resulting in off-channel areas, wetlands, floodplains, and riparian area hydrologic connectivity being drastically reduced. In Reach 1 main channel incision has caused considerable disconnection from the distributary channels. Reaches 2, 3 and 5 are rated **at risk** due to channel incision and infrastructure limiting floodplain connectivity relative to historic conditions. In Reaches 6 and 7 floodplain connectivity is considered **adequate** with floodplain connectivity similar to what would be expected in natural conditions.

Floodplain Connectivity REI Rating

Reach 1	Reach 2	Reach 3	Reach 4	Reach 5	Reach 6	Reach 7
Unacceptable	At Risk	At Risk	Unacceptable	At Risk	Adequate	Adequate

INDICATOR: BANK STABILITY/CHANNEL MIGRATION

Metric Overview

Channel migration and bank erosion are natural processes that maintain river habitats by recruiting substrate, LWD, and introduction of new channel dynamics. Natural channel migration rates are a result of numerous physical and biological processes including hydrologic regime, underlying geology, sediment supply, streambank vegetation, and floodplain hydraulic roughness. Human actions can affect these processes, which subsequently can alter channel migration rates and erosion locations. Bank armoring, levee construction, and channelization restrict flow to generally more straightened paths as well as limiting where erosion can occur; water withdrawals

and dams can alter the hydrologic regime, affecting when and how much water interacts with the channel margins; and changes in riparian vegetation such as removal of streambank vegetation and development within the floodplain can affect channel migration rates. Bank armoring and eroding banks were mapped during field surveys for the reach assessment.

Criteria: From USBR (2012)

Pathway	General Indicators	Specific Indicators	Adequate	At Risk	Unacceptable
Channel	Dynamics	Bank Stability/ Channel Migration	Channel is migrating at or near natural rates.	Limited amount of channel migration is occurring at a faster/slower rate relative to natural rates, but significant change in channel width or planform is not detectable; large woody debris is still being recruited.	Little or no channel migration is occurring because of human actions preventing reworking of the floodplain and large woody debris recruitment; or channel migration is occurring at an accelerated rate such that channel width has a least doubled, possibly resulting in a channel planform change, and sediment supply has noticeably increased from bank erosion.

Assessment Results

Channel incision and bank armoring have reduced the ability of Beaver Creek to migrate laterally in some reaches. Reaches 1and 4 are rated as **unacceptable** for this indicator because channel incision and human actions are substantially limiting channel migration even though the percent of eroding banks is higher in these reaches. The higher rates of bank erosion in these reaches is due to channel incision, channel straightening, and bank armoring, not natural channel migration processes, in most areas. Reaches 2, 3 and 5 are rated as **at risk** because there is a limited amount of channel migration occurring but migration processes are impacted by channel incision and infrastructure. Channel migration typically occurs through channel avulsions in these reaches. Reaches 6 and 7 are rated as **adequate** because channel is migrating at or near natural rates.

Bank Characteristics by Reach

Bank Characteristics	Reach 1	Reach 2	Reach 3	Reach 4	Reach 5	Reach 6	Reach 7
Armored Banks	0.0%	0.9%	0.2%	5.7%	1.3%	0.0%	0.0%
Eroding Banks	44.6%	3.8%	1.8%	14.8%	2.9%	1.4%	1.3%

Bank Stability/ Channel Migration REI Rating

Reach 1	Reach 2	Reach 3	Reach 4	Reach 5	Reach 6	Reach 7
Unacceptable	At Risk	At Risk	Unacceptable	At Risk	Adequate	Adequate

INDICATOR: VERTICAL CHANNEL STABILITY

Metric Overview

Under natural conditions, alluvial river systems tend towards a balanced state in which some erosion and deposition occurs during sediment transporting events but no net change in dimension, pattern and profile over the course of years. These systems are frequently referred to as regime channels and are in a state of dynamic equilibrium in which there is a continuous inflow and output water and sediment. Changes in the conditions

including sediment supply, channel form modification, flow, or bank strength can upset the balance leading to higher rates and a trend of aggradation or incision. This can result in or disconnection from the floodplain due to incision. Channel form modification can be the result of human actions including bank armoring, removal of riparian vegetation, levee building, channel straightening, and channelization which can reduce vertical channel stability.

Criteria: From USBR (2012).

Pathway	General Indicators	Specific Indicators	Adequate	At Risk	Unacceptable
Channel	Dynamics	Vertical Channel Stability	No measurable trend of aggradation or incision and no visible change in channel planform.	Measurable trend of aggradation or incision that has the potential to but not yet caused disconnection of the floodplain or a visible change in channel planform (e.g., single thread to braided).	Enough incision that the floodplain and off-channel habitat areas have been disconnected; or, enough aggradation that a visible change in channel planform has occurred (e.g., single thread to braided).

Assessment Results

Channel incision and aggradation upstream of large jams are impacting the vertical channel stability if of Beaver Creek in some reaches. Reaches 1 through 5 are rated as **unacceptable** for this indicator because there is considerable channel incision throughout these reaches, particularly in Reach 1, and areas of aggradation upstream of large jams. Reaches 6 and 7 are rated as **adequate** because there is no trend of aggradation or incision, in part due to the higher proportion of boulders in the channel bed substrate.

Vertical Channel Stability REI Rating

Reach 1	Reach 2	Reach 3	Reach 4	Reach 5	Reach 6	Reach 7
Unacceptable	Unacceptable	Unacceptable	Unacceptable	Unacceptable	Adequate	Adequate

6. PATHWAY: RIPARIAN CONDITION

INDICATOR: STRUCTURE

Metric Overview

Riparian areas have many important geomorphic and ecological roles within the river system. Intact riparian corridors help maintain streambank stability, provide large wood material, water filtration processes, organic input, streamside habitat and cover, hydraulic regulation, and temperature fluctuation modification (Gregory et al. 1991). The structure of riparian areas indicates how intact the riparian system is currently. This metric is evaluated based on how well the seral stage, species composition, and complexity approximate natural conditions that would be expected in the absence of human alterations. The analysis used a combination of data collected during the reach assessment field survey and professional judgement evaluating LiDAR mapping of canopy height and fire impacts.

Criteria: From USBR (2012).

Pathway	General Indicators	Specific Indicators	Adequate	At Risk	Unacceptable
Riparian Vegetation	Condition	Structure	>80% species composition, seral stage, and structural complexity are consistent with potential native community.	50-80% species composition, seral stage, and structural complexity are consistent with potential native community.	<50% species composition, seral stage, and structural complexity are consistent with potential native community.

Assessment Results

Overall, riparian vegetation along the lower reaches of Beaver Creek is sparse (see Indicator: Canopy Cover below) and the 2006 Tripod Complex and the 2014 Carlton Complex fires have substantially impacted riparian structure in burned areas (Johnson and Molesworth 2015). The riparian stands in Beaver Creek are a mix of hardwood and conifer species with the proportion of conifers increasing in upstream reaches, particularly in Reaches 5 through 7. Reaches 1 through 4 were rated as **unacceptable** because of limited structural complexity and fire related impacts to species composition. Land use activities, particularly related to agricultural practices, have also reduced the structural complexity in these reaches. Reaches 5 through 7 have had less human disturbance than downstream reaches but were rated as **at risk** condition because fire related impacts are resulting in riparian vegetation structure that is less than would be expected in the absence of human alterations.

Riparian Structure REI Rating

Reach 1	Reach 2	Reach 3	Reach 4	Reach 5	Reach 6	Reach 7
Unacceptable	Unacceptable	Unacceptable	Unacceptable	At Risk	At Risk	At Risk

INDICATOR: DISTURBANCE (HUMAN)

Metric Overview

Human disturbance changes how a river interacts with its floodplain and riparian areas. Often human disturbance in the floodplain results in reduced occurrence of mature seral stages of vegetation and riparian

structure, and limits channel migration and erosion processes. This can affect riparian processes including bank stability, wood recruitment, shade, and water quality. Riparian disturbance was assessed using information from the habitat assessment and an analysis of development and road densities within the 100-year floodplain. Road density was calculated using an ArcGIS layer developed by compiling all open roads from USFS, ESRI Streetmap and Okanogan County roads shapefiles.

Criteria: From USBR (2012).

Pathway	General Indicators	Specific Indicators	Adequate	At Risk	Unacceptable
Riparian Vegetation	Condition	Disturbance (human)	>80% mature trees (medium-large) in the riparian buffer zone (defined as a 30 m belt along each bank) that are available for recruitment by the river via channel migration; <20% disturbance in the floodplain (e.g., agriculture, residential, roads, etc.); <2 mi/mi^2 road density in the floodplain.	50-80% mature trees (medium-large) in the riparian buffer zone (defined as a 30 m belt along each bank) that are available for recruitment by the river via channel migration; 20-50% disturbance in the floodplain (e.g., agriculture, residential, roads, etc.); 2-3 mi/mi^2 road density in the floodplain.	<50% mature trees (medium-large) in the riparian buffer zone (defined as a 30 m belt along each bank) that are available for recruitment by the river via channel migration; >50% disturbance in the floodplain (e.g., agriculture, residential, roads, etc.); >3 mi/mi^2 road density in the floodplain.

Assessment Results

As discussed above, mature trees are sparse along the lower reaches of Beaver Creek. Based on that aspect of the above criteria, all reaches would be rated at risk or unacceptable. Taking into account the current development and road density. Reaches 1 through 4 are considered **unacceptable** for this indicator. Reaches 5 and 6 are rated **at risk** because of a higher proportion of mature trees but also high road density within the historic floodplain. Reach 7 is rated as **adequate** because of a high proportion of mature trees (although they are impacted by fire) and no roads or development.

Despite the development along the creek, there have been improvements to the riparian corridor from cattle exclusion, property acquisitions, and acquisition of conservation easements. These management actions have improved riparian condition and aquatic habitat through robust vegetation growth, fine sediment reduction, and long-term wood recruitment. Additionally, these actions will continue to support recovery of ESA-listed salmon and steelhead.

Disturbance (Human) REI Rating

Reach 1	Reach 2	Reach 3	Reach 4	Reach 5	Reach 6	Reach 7
Unacceptable	Unacceptable	Unacceptable	Unacceptable	At Risk	At Risk	Adequate

INDICATOR: CANOPY COVER

Metric Overview

Riparian canopies provide shade and moderate light availability and quality to the stream and riverbed. This affects water temperature and algae growth. Water temperature is a main driver of the health, productivity, and

life cycles of many aquatic organisms, including salmonids. High water temperatures during the summer and fall can often be a factor limiting habitat quality for rearing and spawning salmonids. The percentage canopy cover is based on the extent of canopy closure within riparian areas (100-foot buffer approximating one site potential tree height), not the percentage of the stream that is covered. Canopy cover was estimated using the first return data from the 2016 LiDAR dataset to estimate tree height. Tree heights of greater than 15 feet were included in the canopy coverage area.

Criteria: Modified from USFWS (1998) and USBR (2012).

Pathway	General Indicators	Specific Indicators	Adequate	At Risk	Unacceptable
Riparian	Condition	Canopy Cover	Trees and shrubs within one site potential tree height distance have >80% canopy cover that provides thermal shading to the river.	Trees and shrubs within one site potential tree height distance have 50-80% canopy cover that provides thermal shading to the river.	Trees and shrubs within one site potential tree height distance have <50% canopy cover that provides thermal shading to the river.

Assessment Results

The amount of canopy cover has been impacted by the 2014 Carlton Complex Fire in burned areas. Land use activities, particularly related to agricultural practices, have also reduced the structural complexity in the downstream reaches. Canopy cover is rated as **unacceptable** condition for reaches 1 through 4 with canopy cover percentages ranging from 20% to 44% and **at risk** condition for Reaches 5 through 7 with percentages ranging from 53% to 67%.

Canopy Cover Percentage within 100 Feet of Stream Bank

Canopy Cover	Reach 1	Reach 2	Reach 3	Reach 4	Reach 5	Reach 6	Reach 7
Percent coverage	20%	30%	29%	44%	53%	67%	62%

Canopy Cover REI Rating

Reach 1	Reach 2	Reach 3	Reach 4	Reach 5	Reach 6	Reach 7
Unacceptable	Unacceptable	Unacceptable	Unacceptable	At Risk	At Risk	At Risk

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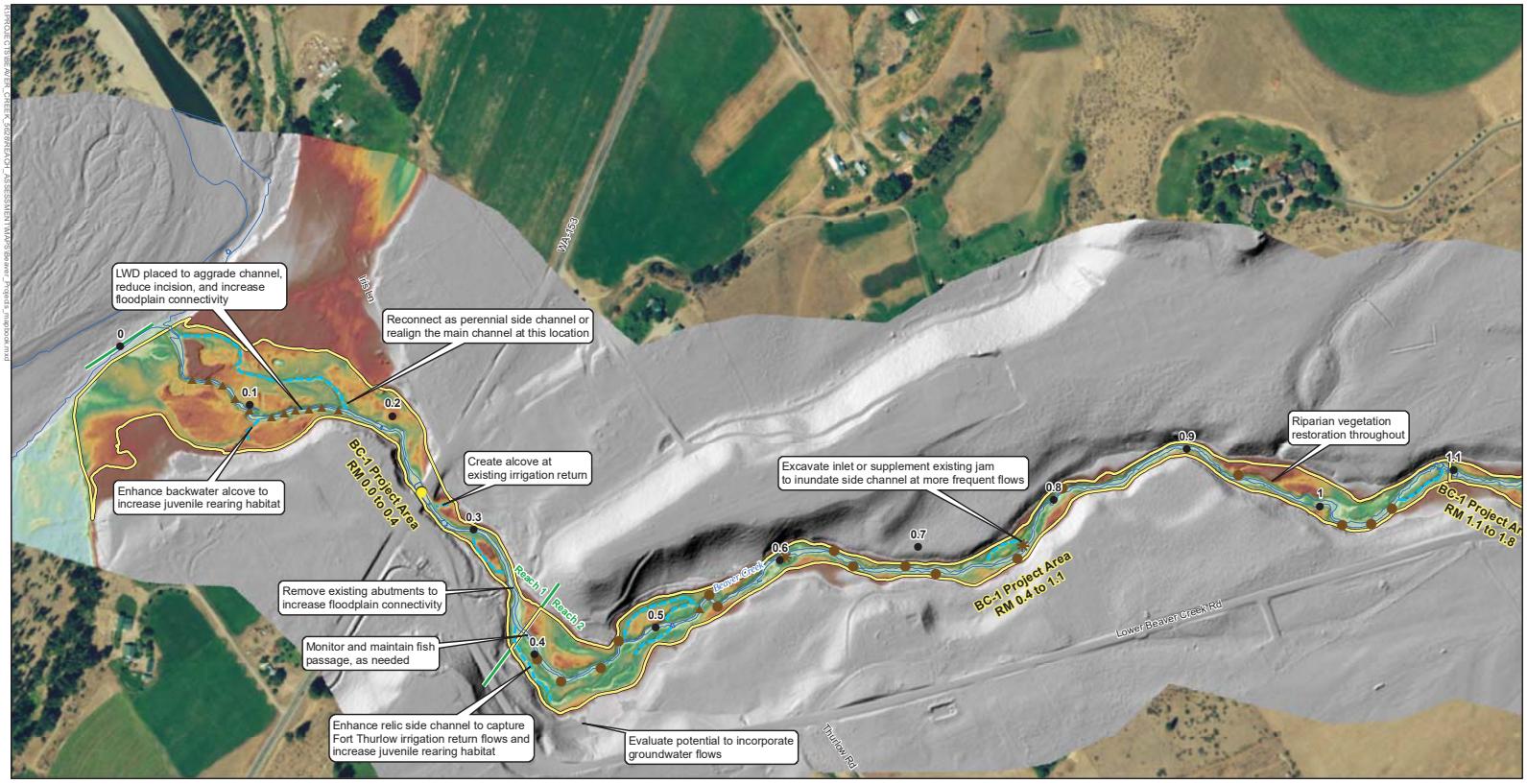
APPENDIX E

Project Area Descriptions and Map Series

List of Figures



- River Mile
- Road Crossing

Proposed LWD Type

- Mid Channel Jam
- Bank Jam
- Supplemental LWD

- Side Channel
- Reach Breaks
- Project Areas
- Bathymetric LiDAR Flow Extent
- Potential Wetland Enhancement

Relative Elevation
High : 115
Low : 91.349

Source: 2016 Topobathymetric LiDAR (Appendix C)

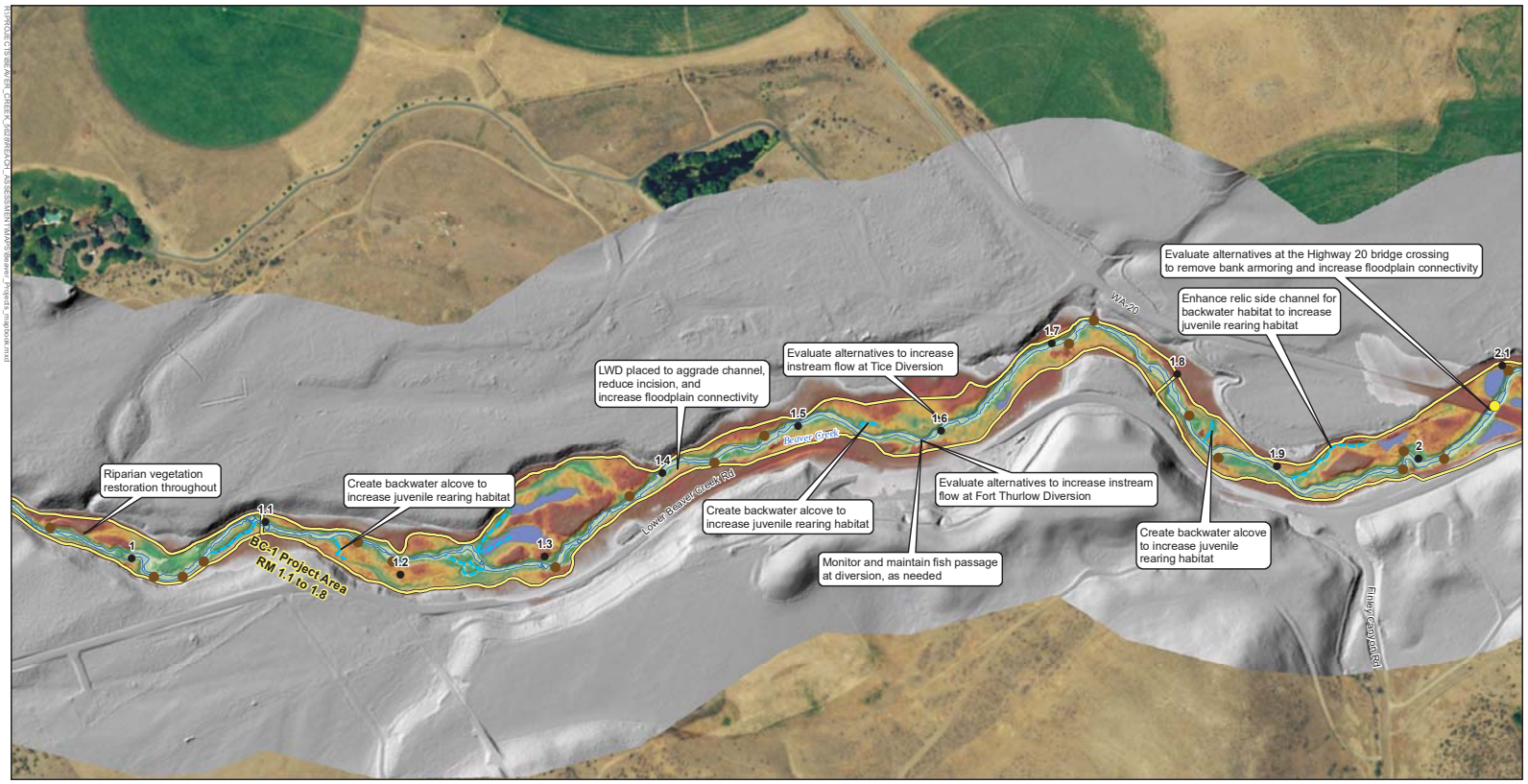
Beaver Creek Reach Assessment

Project Area Map Series

Figure E-1a

1 of 11

0 500 1,000
Feet



River Mile
Road Crossing

Proposed LWD Type
Mid Channel Jam
Bank Jam
Supplemental LWD

Side Channel
Reach Breaks
Project Areas
Bathymetric LiDAR Flow Extent
Potential Wetland Enhancement

Relative Elevation
High : 115
Low : 91.349

Source: 2016 Topobathymetric LiDAR (Appendix C)

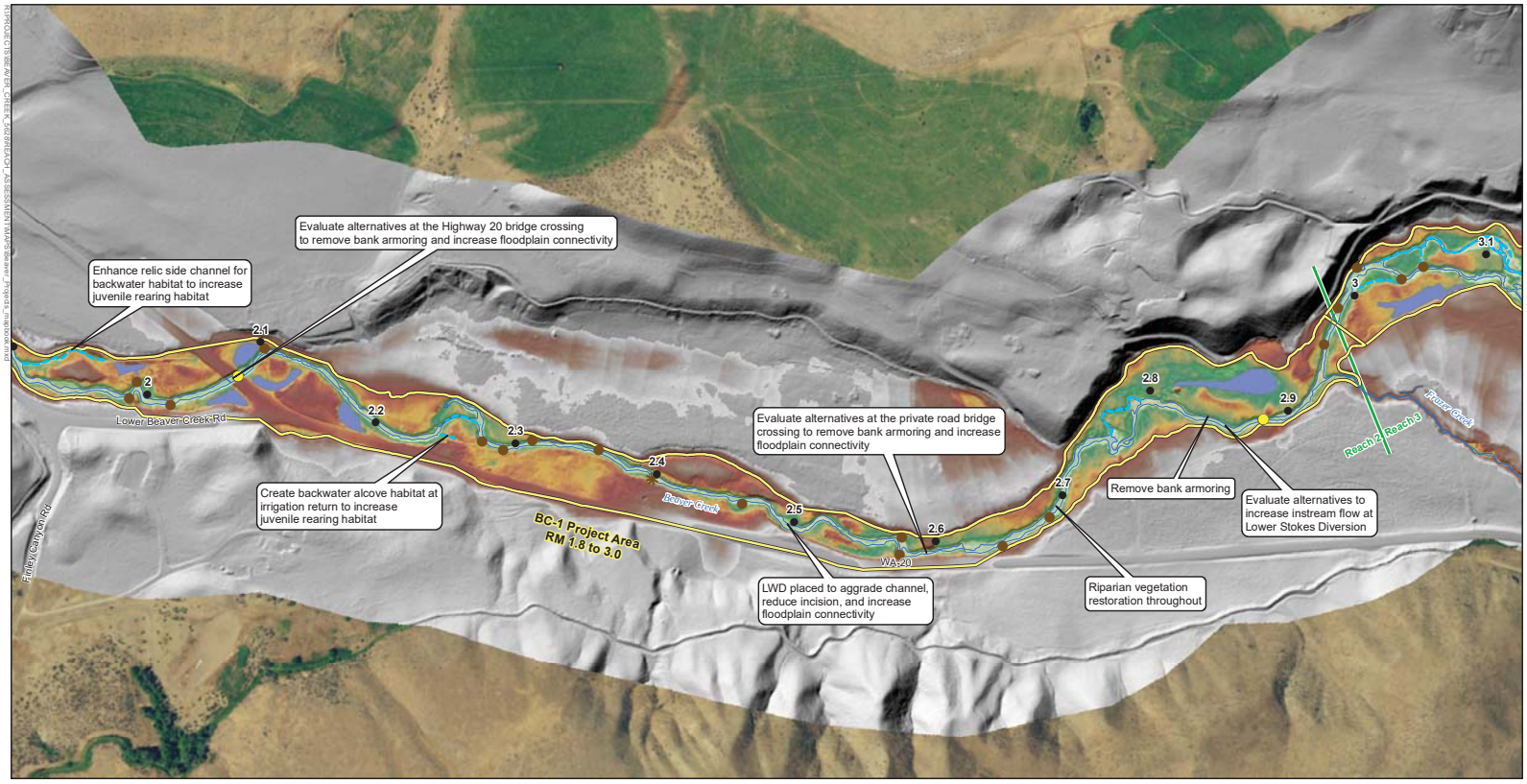
Beaver Creek Reach Assessment

Project Area Map Series

Figure E-1b

2 of 11

0 500 1,000
Feet



River Mile
Road Crossing

Proposed LWD Type
Mid Channel Jam
Bank Jam
Supplemental LWD

Side Channel
Reach Breaks
Project Areas
Bathymetric LiDAR Flow Extent
Potential Wetland Enhancement

Relative Elevation
High : 115
Low : 91.349

Source: 2016 Topobathymetric LiDAR (Appendix C)

Beaver Creek Reach Assessment

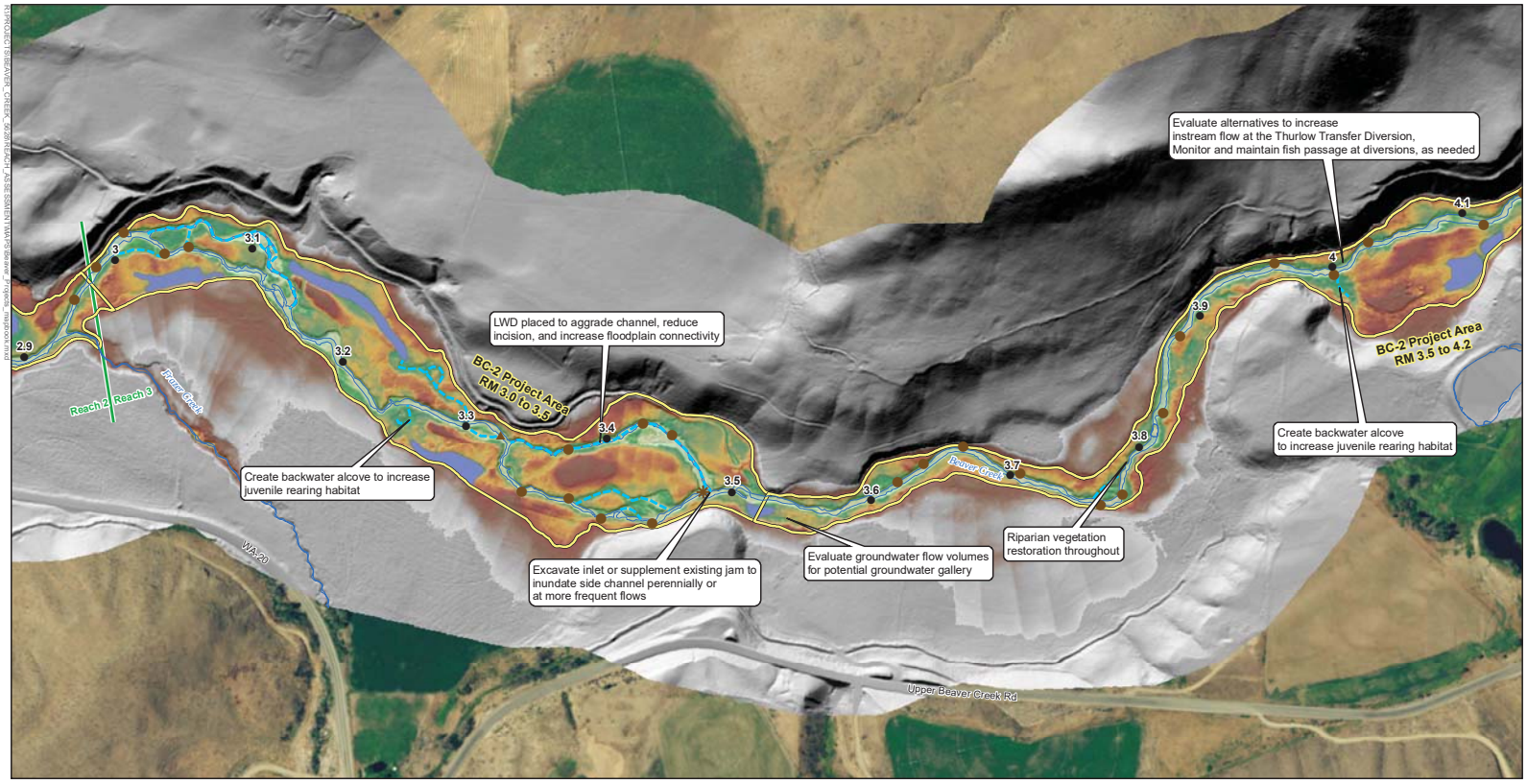
Project Area Map Series

Figure E-1c

3 of 11

N
W
E
S

0 500 1,000
Feet



River Mile
Road Crossing
Proposed LWD Type
Mid Channel Jam
Bank Jam
Supplemental LWD
Side Channel
Reach Breaks
Project Areas
Bathymetric LiDAR Flow Extent
Potential Wetland Enhancement
Relative Elevation
High : 115
Low : 91.349

Source: 2016 Topobathymetric LiDAR (Appendix C)

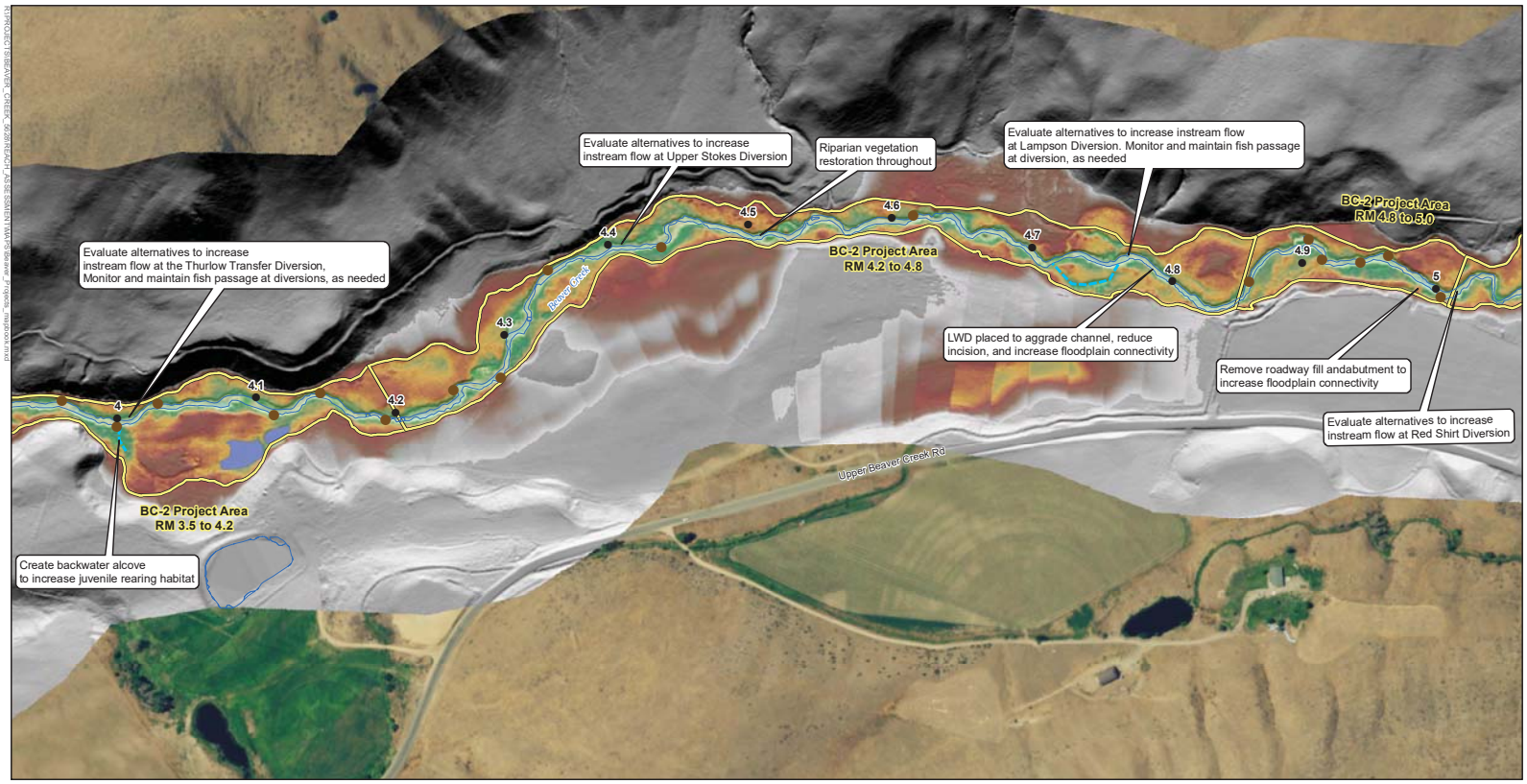
Beaver Creek Reach Assessment

Project Area Map Series

Figure E-1d

4 of 11

0 500 1,000
Feet



- River Mile
- Road Crossing

Proposed LWD Type

- Mid Channel Jam
- Bank Jam
- Supplemental LWD

- Side Channel
- Reach Breaks
- Project Areas
- Bathymetric LiDAR Flow Extent
- Potential Wetland Enhancement

Relative Elevation
High : 115
Low : 91.349

Source: 2016 Topobathymetric LiDAR (Appendix C)

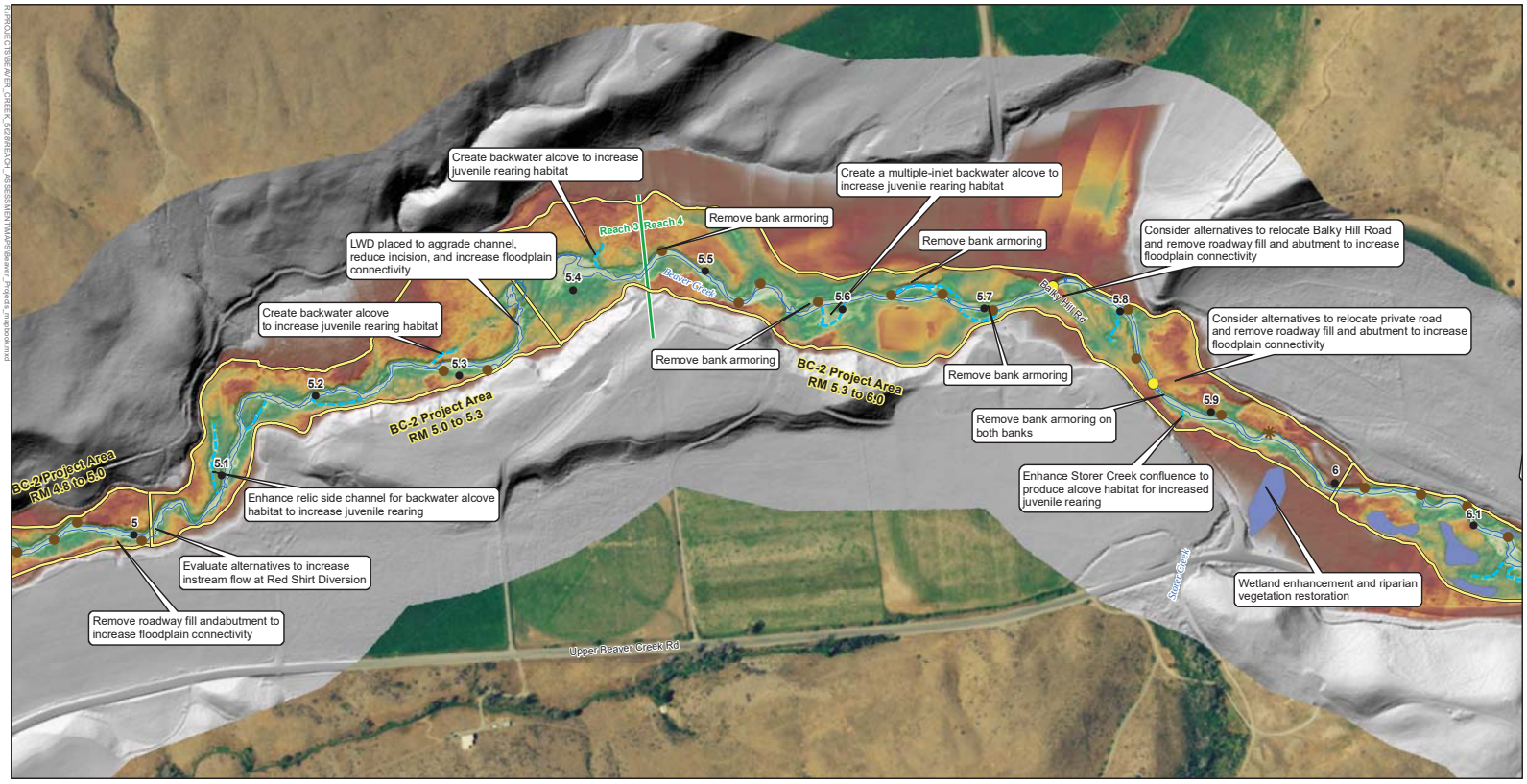
Beaver Creek Reach Assessment

Project Area Map Series

Figure E-1e

5 of 11

0 500 1,000
Feet



- River Mile
- Road Crossing

Proposed LWD Type
- Mid Channel Jam
- Bank Jam
- Supplemental LWD

- Side Channel
- Reach Breaks
- Project Areas
- Bathymetric LiDAR Flow Extent
- Potential Wetland Enhancement

Relative Elevation
High : 115
Low : 91.349

Source: 2016 Topobathymetric LiDAR (Appendix C)

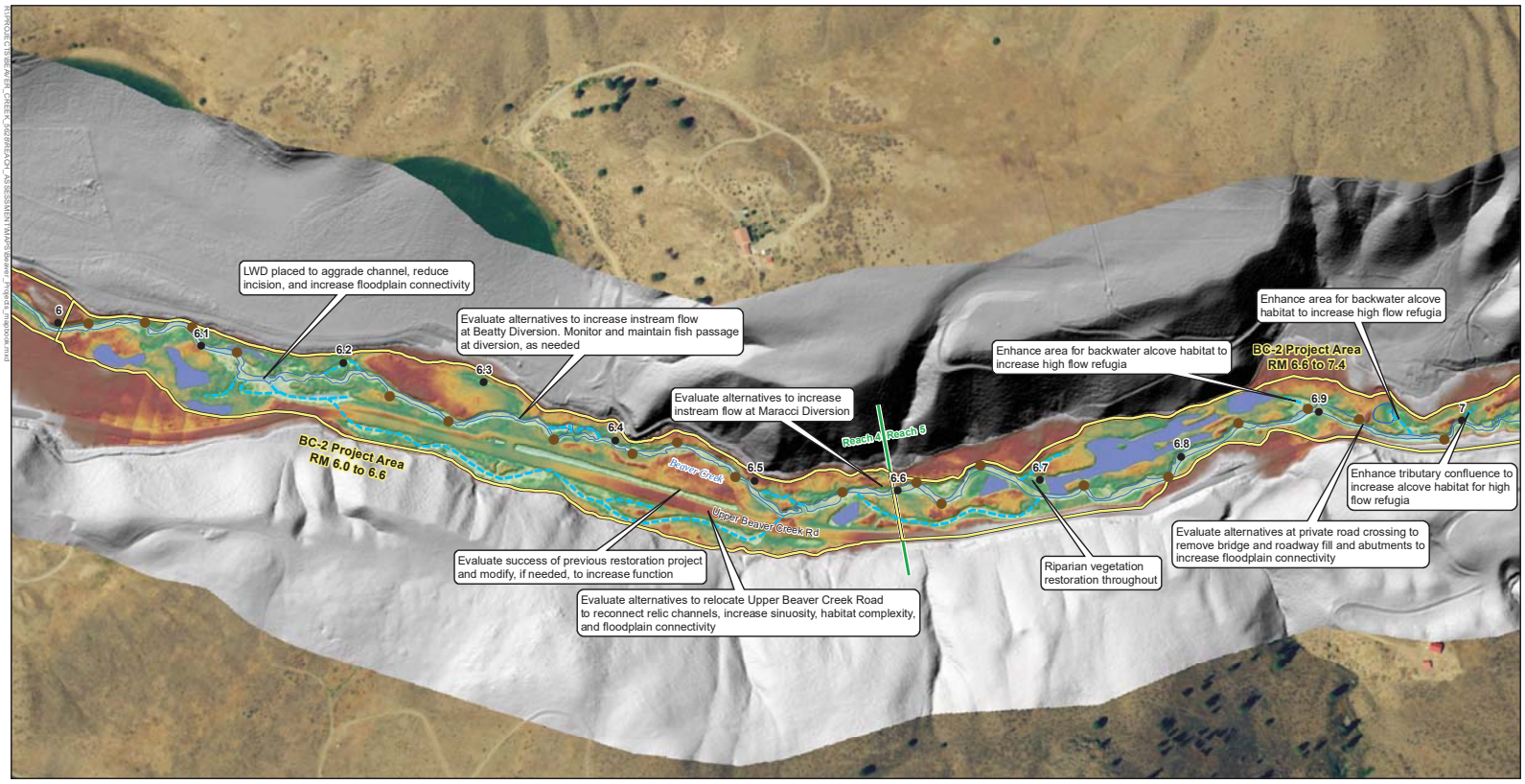
Beaver Creek Reach Assessment

Project Area Map Series

Figure E-1f

6 of 11

0 500 1,000
Feet



River Mile
Road Crossing
Proposed LWD Type
Mid Channel Jam
Bank Jam
Supplemental LWD

Side Channel
Reach Breaks
Project Areas
Bathymetric LiDAR Flow Extent
Potential Wetland Enhancement

Relative Elevation
High : 115
Low : 91.349

Source: 2016 Topobathymetric LiDAR (Appendix C)

Beaver Creek Reach Assessment

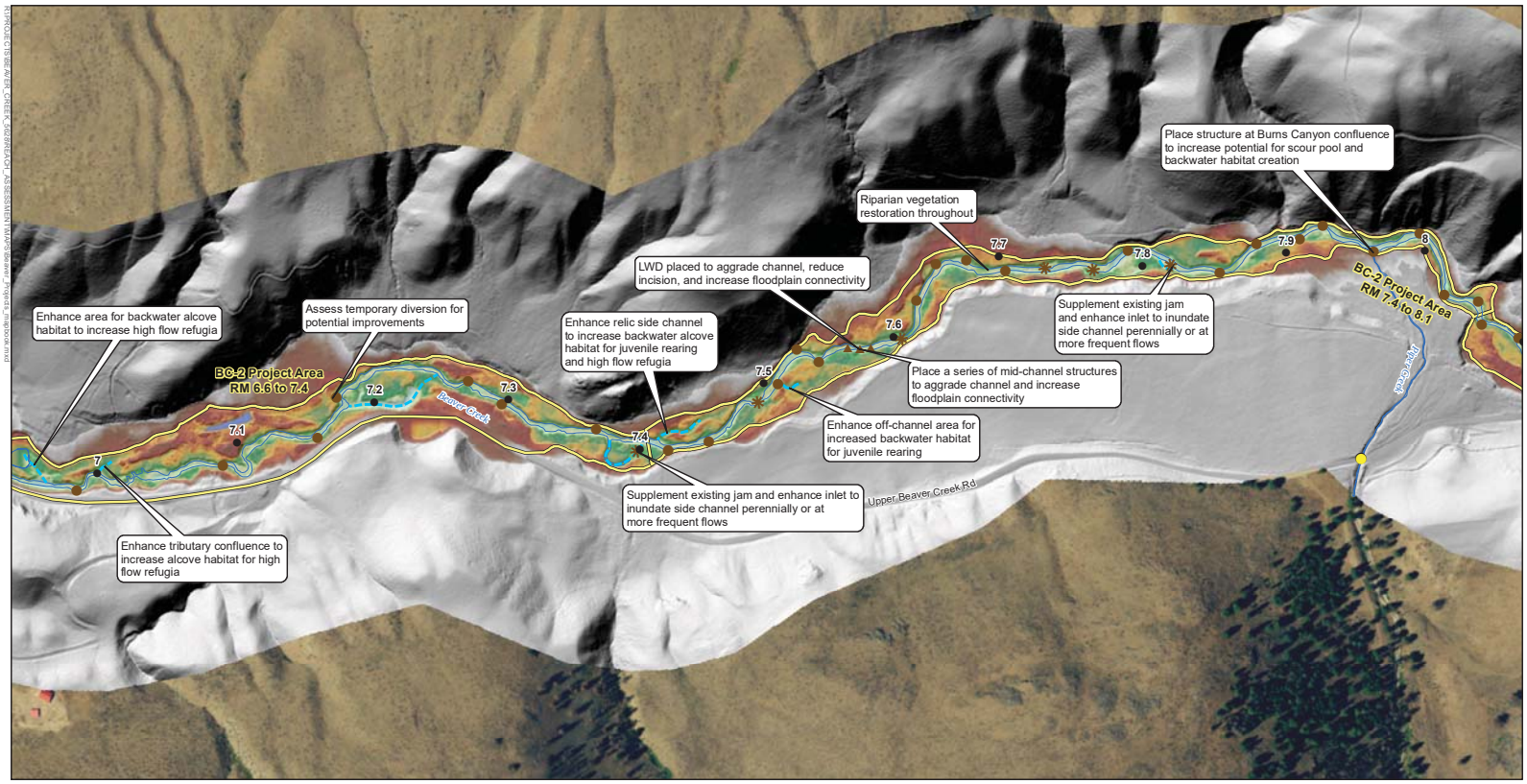
Project Area Map Series

Figure E-1g

7 of 11

N
S
E

0 500 1,000
Feet



- River Mile
- Road Crossing

Proposed LWD Type

- Mid Channel Jam
- Bank Jam
- Supplemental LWD

- Side Channel
- Reach Breaks
- Project Areas
- Bathymetric LiDAR Flow Extent
- Potential Wetland Enhancement

Relative Elevation
High : 115
Low : 91.349

Source: 2016 Topobathymetric LiDAR (Appendix C)

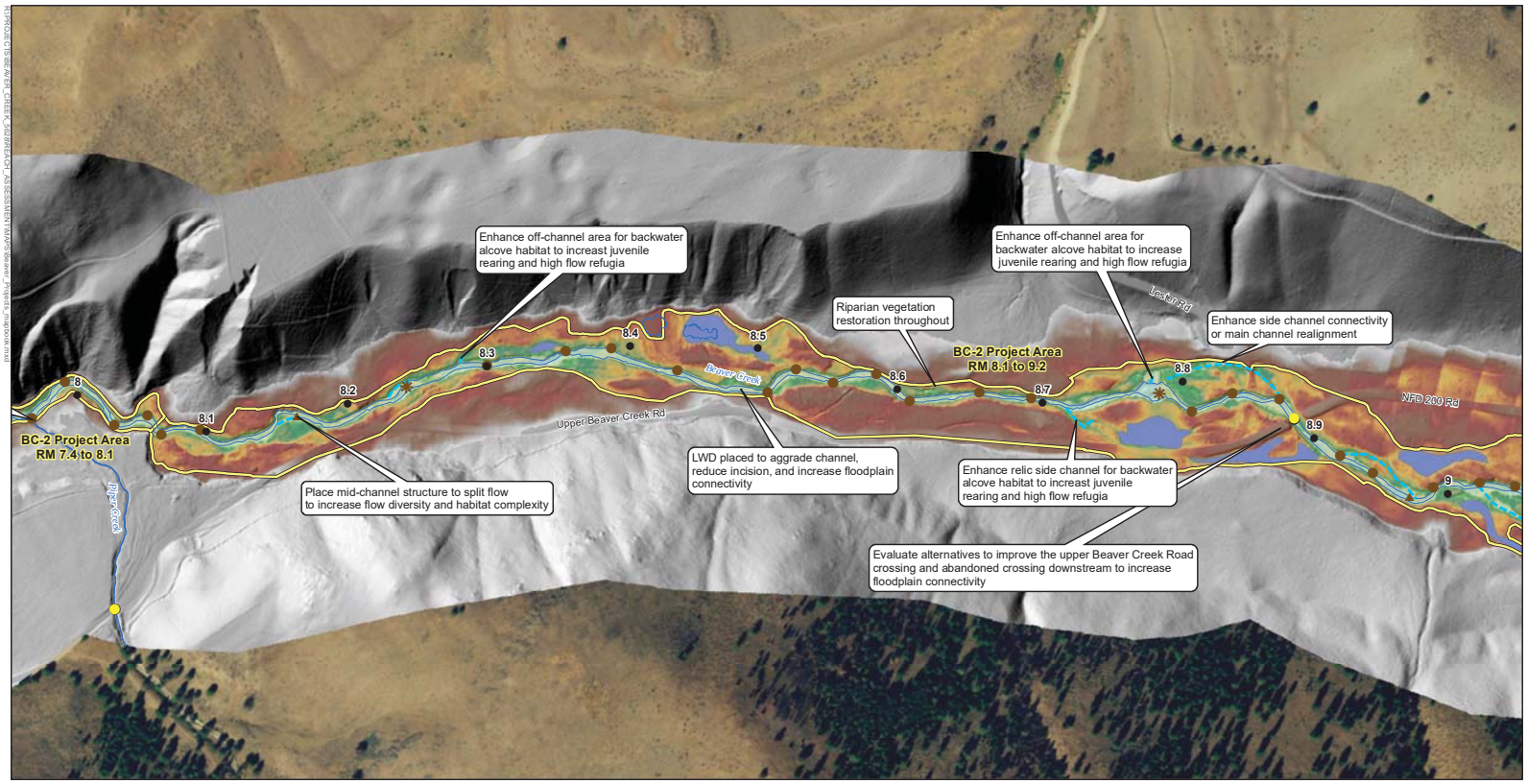
Beaver Creek Reach Assessment

Project Area Map Series

Figure E-1h

8 of 11

0 500 1,000
Feet



- River Mile
- Road Crossing

Proposed LWD Type

- Mid Channel Jam
- Bank Jam
- Supplemental LWD

- Side Channel
- Reach Breaks
- Project Areas
- Bathymetric LiDAR Flow Extent
- Potential Wetland Enhancement

Relative Elevation
High : 115
Low : 91.349

Source: 2016 Topobathymetric LiDAR (Appendix C)

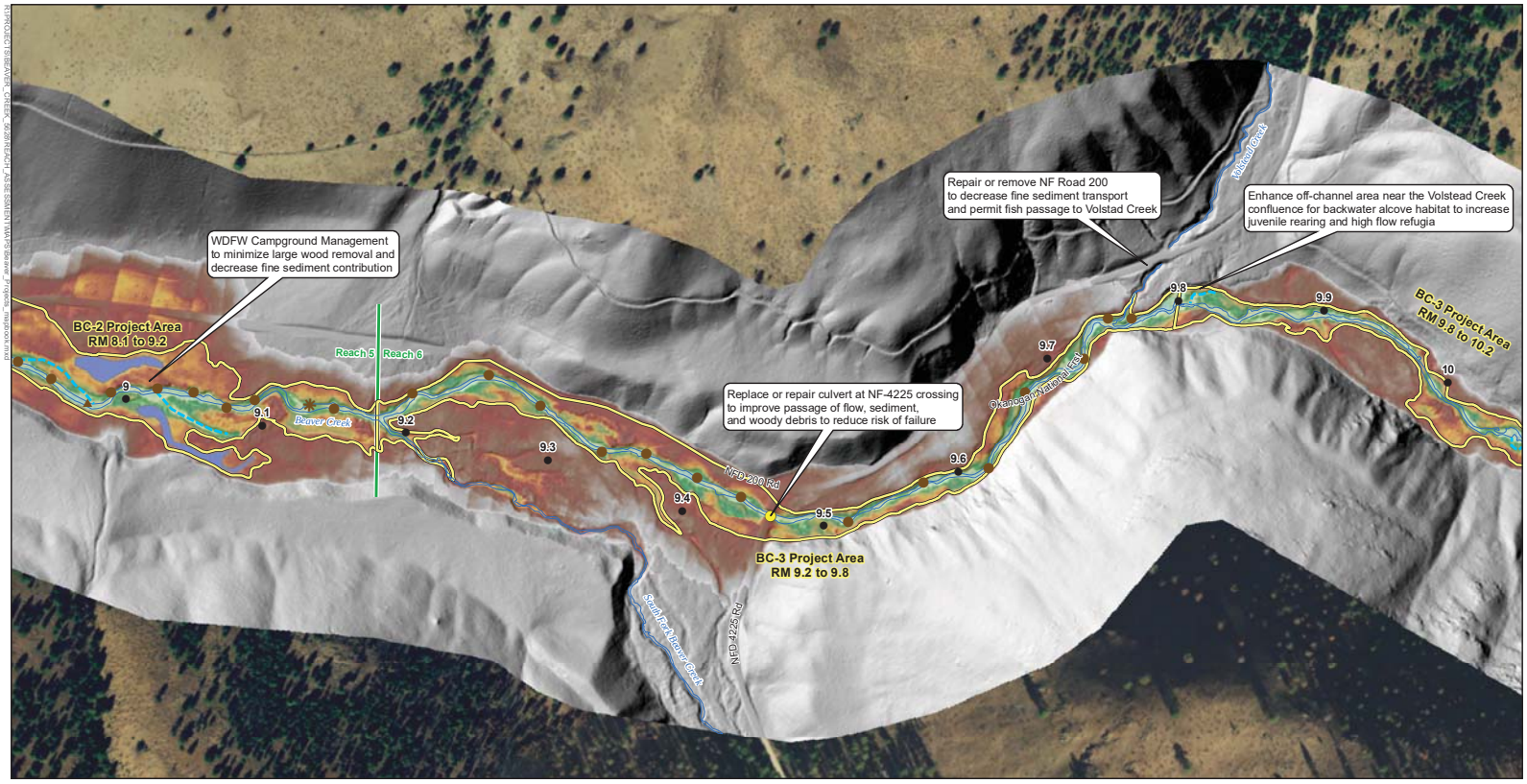
Beaver Creek Reach Assessment

Project Area Map Series

Figure E-1i

9 of 11

0 500 1,000
Feet



- River Mile
- Road Crossing

Proposed LWD Type

- Mid Channel Jam
- Bank Jam
- Supplemental LWD

- Side Channel
- Reach Breaks
- Project Areas
- Bathymetric LiDAR Flow Extent
- Potential Wetland Enhancement

Relative Elevation
High : 115
Low : 91.349

Source: 2016 Topobathymetric LiDAR (Appendix C)

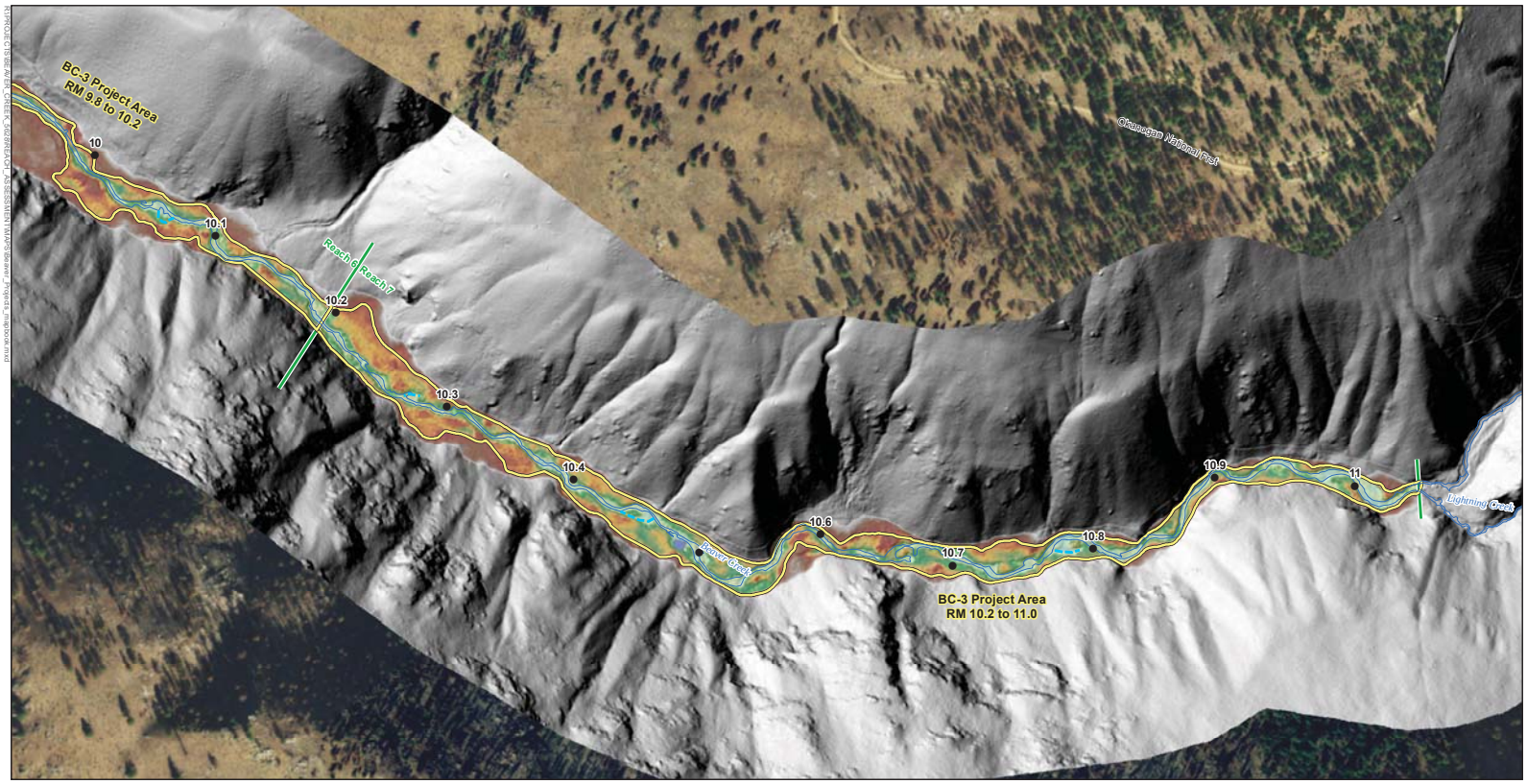
Beaver Creek Reach Assessment

Project Area Map Series

Figure E-1j

10 of 11

0 500 1,000
Feet



- River Mile
- Road Crossing

Proposed LWD Type

- Mid Channel Jam
- Bank Jam
- Supplemental LWD

- Side Channel
- Reach Breaks
- Project Areas
- Bathymetric LiDAR Flow Extent
- Potential Wetland Enhancement

Relative Elevation
High : 115
Low : 91.349

Source: 2016 Topobathymetric LiDAR (Appendix C)

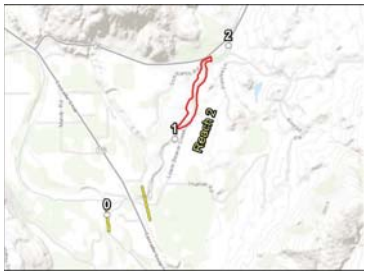
Beaver Creek Reach Assessment

Project Area Map Series

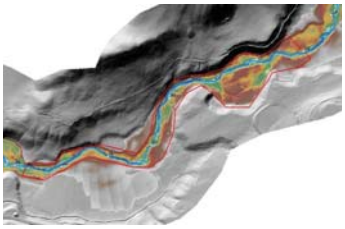
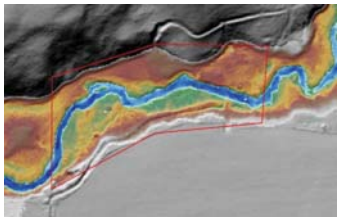
Figure E-1k

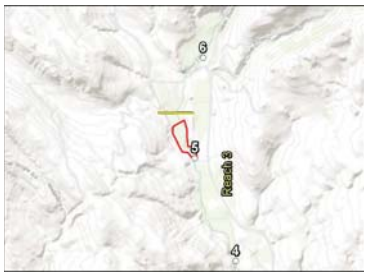
11 of 11

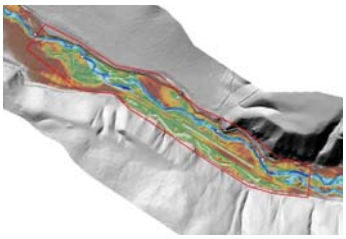
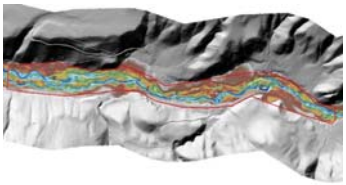
0 500 1,000
Feet

Geomorphic Reach	Project Opportunity Location	Name	Potential Restoration Actions	Description and Rationale	Rank	Photo/Imagery
Reach 1		Project Area 1 – RM 0.0 to 0.4	- Remove non-native plants - Riparian planting - Remove bank armoring - Install LWD structures (whole trees, jams, etc.) - Remove and/or relocate floodplain infrastructure - Perennial side channel creation/enhancement - Secondary channel (non-perennial) creation/enhancement - Alcove creation/enhancement - Pool creation/enhancement - Channel realignment/reconstruction	Main channel incised and lacks complex instream habitat and cover. Multiple existing side channels disconnected from main channel at bankfull flows. Install large wood habitat structures at frequent spacing in main channel to aggrade channel, create habitat complexity and cover, and access to side channels; minor excavation at inlet to side channels may be needed. Remove bank armoring and abandoned bridge abutments upstream of the Methow Valley Highway crossing. Potential for main channel realignment into existing side channel or channel reconstruction downstream of the Methow Valley Highway crossing.	1	
Reach 2		Project Area 2 – RM 0.4 to 1.1	- Remove non-native plants - Riparian planting - Install LWD structures (whole trees, jams, etc.) - Reconnect/enhance cold water springs - Alcove creation/enhancement - Groundwater fed off-channel habitat enhancement - Pool creation/enhancement - Evaluate fish passage at diversions	Main channel is valley confined, with a small number of side channels inundated at 2-yr flow. Install large wood habitat structures in main channel to create habitat complexity and hydraulic diversity through scour pool creation and improved sediment sorting. Construct perennial side channels/alcoves for juvenile rearing habitat. Monitor and maintain fish passage at diversion, as needed. Evaluate the potential to incorporate groundwater flows on the left bank near the downstream end of the project area where the Fort-Thurlow irrigation return flows in a relic side channel.	2	
		Project Area 3 – RM 1.1 to 1.8	- Remove non-native plants - Riparian planting - Install LWD structures (whole trees, jams, etc.) - Perennial side channel creation/enhancement - Secondary channel (non-perennial) creation/enhancement - Wetland creation/enhancement - Alcove creation/enhancement - Pool creation/enhancement - Evaluate fish passage at diversions	Single thread channel, slightly incised, with disconnected side channels present in lower portion of project area. Seasonal juvenile barrier at Fort-Thurlow diversion. Install large wood habitat structures to enhance scour pools, and encourage floodplain connectivity to create habitat complexity and hydraulic diversity. Construct large perennial side channels in lower portion of project area for juvenile rearing. Monitor and maintain fish passage, at the Fort-Thurlow Diversion, as needed.	3	

Geomorphic Reach	Project Opportunity Location	Name	Potential Restoration Actions	Description and Rationale	Rank	Photo/Imagery
Reach 2		Project Area 4 – RM 1.8 to 3.0	- Remove non-native plants - Riparian planting - Bank stabilization with LWD and bioengineering - Install LWD structures (whole trees, jams, etc.) - Remove and/or relocate floodplain infrastructure - Perennial side channel creation/enhancement - Secondary channel (non-perennial) creation/enhancement - Wetland creation/enhancement - Alcove creation/enhancement - Pool creation/enhancement	Slightly more sinuous main channel in broad valley. Highway 20 and private driveway crossings result in disrupted floodplain connectivity. Large available floodplain in upper project area. Install large wood habitat structures to enhance scour pools to create habitat complexity and place structures to encourage floodplain inundation. Construct large seasonal side channels in lower portion of project area for high-flow refugia. Construct perennial alcove at Frazer Creek confluence. Evaluate alternatives at the Highway 20 and private drive bridge crossings to remove bank armoring and increase floodplain connectivity. Install large wood structures in conjunction with minor excavation to reconnect floodplain in upper project area.	4	
Reach 3		Project Area 5 – RM 3.0 to 3.5	- Remove non-native plants - Riparian planting - Install LWD structures (whole trees, jams, etc.) - Remove and/or relocate floodplain infrastructure - Reconnect/enhance cold water springs - Perennial side channel creation/enhancement - Secondary channel (non-perennial) creation/enhancement - Wetland creation/enhancement - Alcove creation/enhancement - Groundwater fed off-channel habitat enhancement - Pool creation/enhancement - Reconnect/enhance abandoned meander	Braided main channel in lower section of project area due to large jam complex. Long disconnected side channels on valley right in middle and upper sections of project area. Install large wood structures in conjunction with minor excavation to reconnect side channels in middle and upper project areas. Install large wood habitat structures to enhance scour pools for habitat complexity and place structures to encourage increased floodplain inundation for hydraulic diversity. Create perennial alcove(s) in middle section of project area. Evaluate potential to incorporate groundwater flows throughout this project area.	8	

Geomorphic Reach	Project Opportunity Location	Name	Potential Restoration Actions	Description and Rationale	Rank	Photo/Imagery
Reach 3		Project Area 6 – RM 3.5 to 4.2	- Remove non-native plants - Riparian planting - Install LWD structures (whole trees, jams, etc.) - Remove and/or relocate floodplain infrastructure - Reconnect/enhance cold water springs - Perennial side channel creation/enhancement - Secondary channel (non-perennial) creation/enhancement - Wetland creation/enhancement - Alcove creation/enhancement - Groundwater fed off-channel habitat enhancement - Pool creation/enhancement	Little known about this project area as access was not granted at time of field survey. From a desktop assessment, there appear to be multiple locations for opportunities to reconnect small floodplain areas with wood placement. Locations for perennial and/or seasonal side channels and/or alcoves. Options for perennial and/or seasonal side channel reconnections. Install large wood habitat structures in main channel to create habitat complexity and hydraulic diversity. Evaluate the potential to incorporate groundwater flows particularly on the left bank floodplain near RM 3.5. Monitor and maintain fish passage, as needed, at the Thurlow Transfer Diversion.	9	
		Project Area 7 – RM 4.2 to 4.8	- Install LWD structures (whole trees, jams, etc.) - Perennial side channel creation/enhancement - Secondary channel (non-perennial) creation/enhancement - Wetland creation/enhancement - Alcove creation/enhancement - Groundwater fed off-channel habitat enhancement - Pool creation/enhancement - Evaluate fish passage at diversions	Project area includes the Lower Schoolhouse restoration project. The channel is moderately confined with short braided sections throughout. Install large wood habitat structures in areas that have not received restoration actions to increase floodplain connectivity upstream of existing project to create habitat complexity and hydraulic diversity. Construct perennial alcoves in areas that have not received restoration actions throughout project area for juvenile rearing. Monitor and maintain fish passage, as needed, at the Lampson Diversion	10	
		Project Area 8 – RM 4.8 to 5.0	- Remove non-native plants - Riparian planting - Install LWD structures (whole trees, jams, etc.) - Remove and/or relocate floodplain infrastructure - Pool creation/enhancement	Little known about this project area as access was not granted at time of field survey. Based on a desktop assessment, there appear to be multiple opportunities to reconnect small floodplain areas with wood placement. Install large wood habitat structures in main channel to create habitat complexity and hydraulic diversity.	11	

Geomorphic Reach	Project Opportunity Location	Name	Potential Restoration Actions	Description and Rationale	Rank	Photo/Imagery
Reach 3		Project Area 9 – RM 5.0 to 5.3	- Install LWD structures (whole trees, jams, etc.) - Secondary channel (non-perennial) creation/enhancement - Alcove creation/enhancement - Pool creation/enhancement	Project area includes Upper Schoolhouse restoration project, large complex jam at upper end of project area. Install large wood habitat structures in areas that have not received restoration actions to increase floodplain connectivity, create habitat complexity and hydraulic diversity. Construct perennial side channels and alcoves in areas that have not received restoration actions to create juvenile rearing habitat.	17	
Reach 4		Project Area 10 – RM 5.3 to 6.0	- Road grading and drainage improvements - Road decommissioning or abandonment - Remove non-native plants - Riparian planting - Remove bank armoring - Install LWD structures (whole trees, jams, etc.) - Remove and/or relocate floodplain infrastructure - Reconnect/enhance cold water springs - Perennial side channel creation/enhancement - Secondary channel (non-perennial) creation/enhancement - Wetland creation/enhancement - Alcove creation/enhancement - Groundwater fed off-channel habitat enhancement - Pool creation/enhancement	Project area has been confined by anthropogenic actions and straightened in many areas, with disconnected side channels. Install large wood habitat structures to increase floodplain connectivity, create habitat complexity and hydraulic diversity. Remove bank armoring where feasible throughout project area. Consider alternatives to relocate Balky Hill Road and private drive crossings and remove road fill and abutment construction to increase floodplain connectivity. Evaluate bridge crossings in project area for potential improvements to floodplain connectivity. Construct perennial alcoves in relic channel meanders in road fill removal locations and at confluence of Storer Creek to provide juvenile rearing. Improve road drainage systems at Storer Creek and other areas of the Upper Beaver Creek Road to reduce chronic sediment inputs.	5	

Geomorphic Reach	Project Opportunity Location	Name	Potential Restoration Actions	Description and Rationale	Rank	Photo/Imagery
Reach 4		Project Area 11 – RM 6.0 to 6.6	- Road grading and drainage improvements - Road decommissioning or abandonment - Remove non-native plants - Riparian planting - Install LWD structures (whole trees, jams, etc.) - Remove and/or relocate floodplain infrastructure - Perennial side channel creation/enhancement - Secondary channel (non-perennial) creation/enhancement - Wetland creation/enhancement - Alcove creation/enhancement - Pool creation/enhancement - Reconnect/enhance abandoned meander - Evaluate fish passage at diversions	Project area includes Upper Beaver Creek Habitat Improvement project, with large section of floodplain disconnected by Upper Beaver Creek Road, channel that has been relocated to valley right, and Beatty diversion at top of project area that is possible juvenile barrier. Evaluate success of previous restoration and modify, if needed, to increase function. Monitor and maintain fish passage, as needed, at the Beatty diversion. Install large wood habitat structures to increase pool habitat through scour pool formation and place to encourage floodplain inundation for increased habitat complexity and hydraulic diversity. Evaluate alternatives to relocate Upper Beaver Creek Road to reconnect relic channels, increase sinuosity, habitat complexity, and floodplain connectivity. Construct seasonal side channels for high-flow refugia. Construct perennial alcoves for juvenile rearing habitat.	6	
Reach 5		Project Area 12 – RM 6.6 to 7.4	- Road grading and drainage improvements - Road decommissioning or abandonment - Bank stabilization with LWD and bioengineering - Install LWD structures (whole trees, jams, etc.) - Remove and/or relocate floodplain infrastructure - Perennial side channel creation/enhancement - Secondary channel (non-perennial) creation/enhancement - Wetland creation/enhancement - Alcove creation/enhancement - Groundwater fed off-channel habitat enhancement - Pool creation/enhancement	Project area has a mixture of public and private ownership and has multiple relict channel scars and side channels currently disconnected, with increased bank erosion from fire, and Parmley diversion within project area. Install large wood habitat structures for increased pool habitat and place for increased floodplain inundation to create habitat complexity and hydraulic diversity. Possible excavation of inlets to old side channels with large wood habitat structures to increase habitat complexity. Evaluate alternatives to relocate Upper Beaver Creek Road to remove existing bank armoring and artificial confinement in order to increase floodplain connectivity. Construct a series of perennial side channels and alcoves for high-flow refugia and juvenile rearing.	12	

Geomorphic Reach	Project Opportunity Location	Name	Potential Restoration Actions	Description and Rationale	Rank	Photo/Imagery
Reach 5		Project Area 13 – RM 7.4 to 8.1	- Road grading and drainage improvements - Install LWD structures (whole trees, jams, etc.) - Reconnect/enhance cold water springs - Perennial side channel creation/enhancement - Secondary channel (non-perennial) creation/enhancement - Alcove creation/enhancement - Pool creation/enhancement	Channel confined in tight valley, limited floodplain and side channels, exposed bedrock throughout project area. Install large wood habitat structures to increase scour pool habitat for habitat complexity. Place large wood structures to aggrade channel for increased floodplain connectivity and to access relic side channels at more frequent flows. Construct perennial alcove at Piper Creek confluence for juvenile rearing and high-flow refugia. Improve road drainage systems at Burns Creek and other areas of the Upper Beaver Creek Road to reduce chronic sediment inputs.	13	
		Project Area 14 – RM 8.1 to 9.2	- Road grading and drainage improvements - Install LWD structures (whole trees, jams, etc.) - Remove and/or relocate floodplain infrastructure - Perennial side channel creation/enhancement - Secondary channel (non-perennial) creation/enhancement - Wetland creation/enhancement - Alcove creation/enhancement - Groundwater fed off-channel habitat enhancement - Pool creation/enhancement	Single thread channel with increased floodplain availability, disconnected side channels present, and historic road grade that is disrupting hydrologic floodplain connectivity. Install large wood habitat structures to aggrade channel, increase floodplain connectivity, and create habitat complexity and hydraulic diversity. Evaluate alternatives to improve the upper Beaver Creek Road crossing and abandoned crossing downstream to increase floodplain connectivity. Construct perennial side channel/alcoves for juvenile rearing. Possible excavation and large wood installation to reconnect relic side channels.	14	
Reach 6		Project Area 15 – RM 9.2 to 9.8	- Recreation Management - Road grading and drainage improvements - Install LWD structures (whole trees, jams, etc.) - Remove and/or relocate floodplain infrastructure - Groundwater fed off-channel habitat enhancement - Pool creation/enhancement - Evaluate fish passage at diversions	Single thread channel in confined valley, with little available floodplain, and undersized culvert at NF-4225 crossing. Install large wood habitat structures to create habitat complexity and hydraulic diversity Replace or repair culvert at NF-4225 crossing to improve the passage of flow, sediment, and woody debris to reduce the risk of catastrophic failure. Evaluate alternatives for recreation management to reduce impacts.	18	

Geomorphic Reach	Project Opportunity Location	Name	Potential Restoration Actions	Description and Rationale	Rank	Photo/Imagery
Reach 6		Project Area 16 – RM 9.8 to 10.2	- Recreation Management - Road grading and drainage improvements - Install LWD structures (whole trees, jams, etc.) - Alcove creation/enhancement	Single thread channel in confined valley, with sparse floodplain availability and limited access. Install large wood habitat structures in lower portion of project area to create habitat complexity. Construct large perennial alcove at Volstead Creek confluence for juvenile rearing habitat. Hand-fell existing trees or helicopter place woody debris in upper portion of project area to increase habitat complexity. Evaluate alternatives for recreation management to reduce impacts. Improve NF-200 Road crossings on Volstead Creek to reduce chronic sediment inputs or relocate road.	19	
Reach 7		Project Area 17 – RM 10.2 to 11.0	- Recreation Management	Single thread channel in confined valley, with sparse floodplain availability and limited access. Evaluate alternatives for recreation management to reduce impacts.	21	

APPENDIX F

Project Geodatabase

(provided on DVD)

This appendix is provided separately.

APPENDIX G

Project Area Prioritization Matrix

(provided on DVD)

This appendix is provided separately.