Buffalo Flats Project

Hydraulic Modeling: Basis of Design Report-30% Design

Little Creek, Union County, Oregon

Columbia Pacific Northwest Region

Little Creek existing channel, looking upstream, August 2020.

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1 Hydraulic Analysis Overview

Inter-Fluve conducted the hydraulic analysis described in this document as part of developing the 30% percent design for the Buffalo Flats Fish Habitat Enhancement Project (Project). The analyses described in this document are focused on modeled hydraulic conditions on Little Creek, which flows through the Project property and through the City of Union. The primary purpose of the analysis was to assess changes in floodplain inundation patterns and timing associated with the proposed Project under various hydrologic conditions. Additional analyses were conducted to assess the potential impacts of the proposed Project on flooding conditions within the Project area and on adjacent properties within the community, particularly near the downstream boundary of the Project. The hydraulic analyses described in this document are preliminary in nature, and are anticipated to be refined as the design progresses. This document is intended to serve as an appendix to the 30% Basis of Design Report. Additional Project background and design information is available in the Buffalo Flats 30% Basis of Design Report (Prepared by Inter-Fluve for Reclamation, December 2022).

2 Hydrology

Peak flow hydrology data were derived from a variety of sources, including gage scaling conducted by United States Bureau of Reclamation (Reclamation) as part of the Catherine Creek Tributary Assessment (Reclamation, 2012), USGS Regional regression equations, and 100-year flows published in the Union County FIS (HUD FIA, 1978). Seasonal flow estimates were similarly derived using previous gage scaling analyses performed by Reclamation. Flow rates used in the modeling for the 30% design are summarized in Table 1.

Table 1. Summary of peak flow estimates.

Buffalo Flats:

Summary of Peak Flow Estimates at Upstream end of Project Area[1]

Recurrence Interval	Little Creek (40 sq mi)		
	FEMA	USGS Regression Eq.[2]	Gage Analysis[3,4]
1.1-year	N/A	N/A	185
2-year	N/A	329	218
5-year	N/A	537	299
10-year	653	689	351
25-year	N/A	890	417
50-year	816	1,040	466
100-year	882	1,200	514

[1]All Flows in cfs

[2]Queried from StreamStats online (Streamstats.usgs.gov/ss/; Queried October 2020)

[3]Scaled from StreamStats Estimates at the gage location using drainage area ratio (Streamstats.usgs.gov/ss/; Queried October 2020)

[4]Estimated from Catherine Creek Tributary Assessment (Reclamation, 2012)

Low flow hydrologic statistics were derived from previous gage-scaling analyses conducted by reclamation. A synthetic record of average daily flows is provided in Figure 1. The design effort emphasized floodplain inundation and raising the water table available to plants within the Project area during much of the year. The figure highlights 30 cfs which is a flow typically exceeded during the spring (March -June).

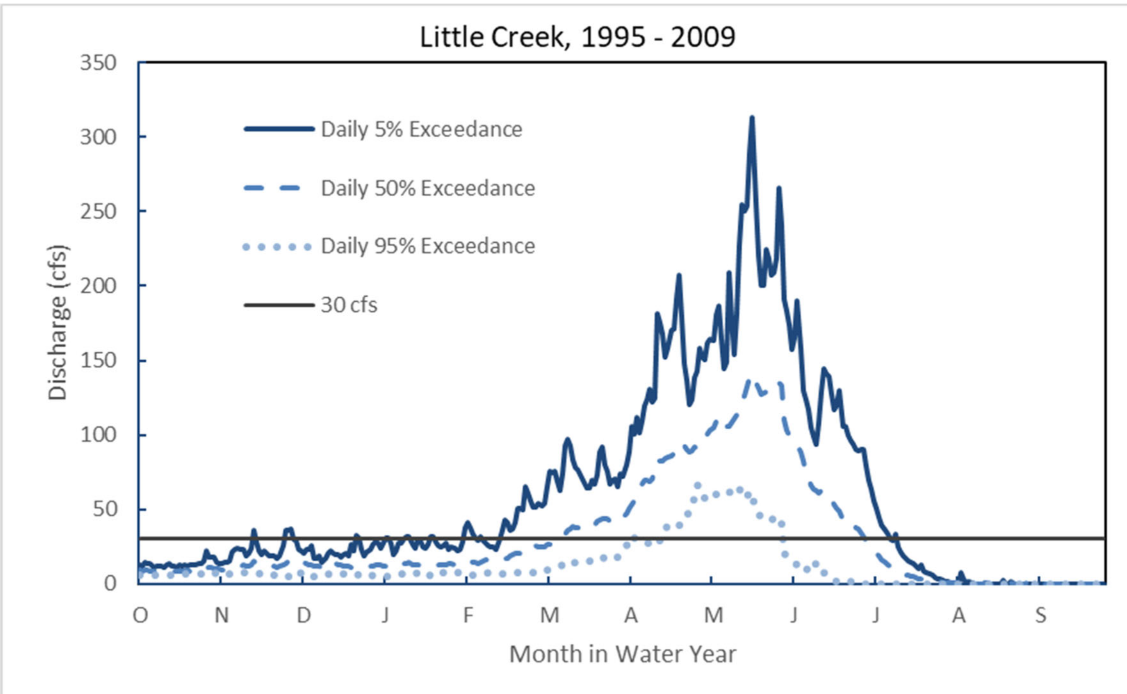

Figure 1 - Synthetic annual hydrograph for Little Creek at the Project Site.

Water level loggers have been in place to collect hourly stage data in Little Creek at the upstream and downstream ends of the Buffalo Flats property at the Kofford Road bridge and at the north entrance to the Eastern Oregon Livestock Show grounds (Figure 2). Flows are periodically measured by Union Soil and Water Conservation District (USWCD) at these locations, and rating curves were used to correlate continuous stage data with discharge estimates. These rating relationships were previously developed by Reclamation.

As of early 2021, additional data collection efforts have been implemented to better understand the hydrology of Little Creek, particularly at the Project site. These additional data will be used in future analyses where feasible, to refine the gage scaling relationship for peak flow estimates and will ideally help understand seasonal flow variations at the Project site. Information obtained through these data collection efforts will be synthesized in future design phases, as more data are collected and hydrology data are refined. Additional discussion of hydrology data that have been collected at the site previously is available in the Existing Conditions Modeling Report (Reclamation, 2020).

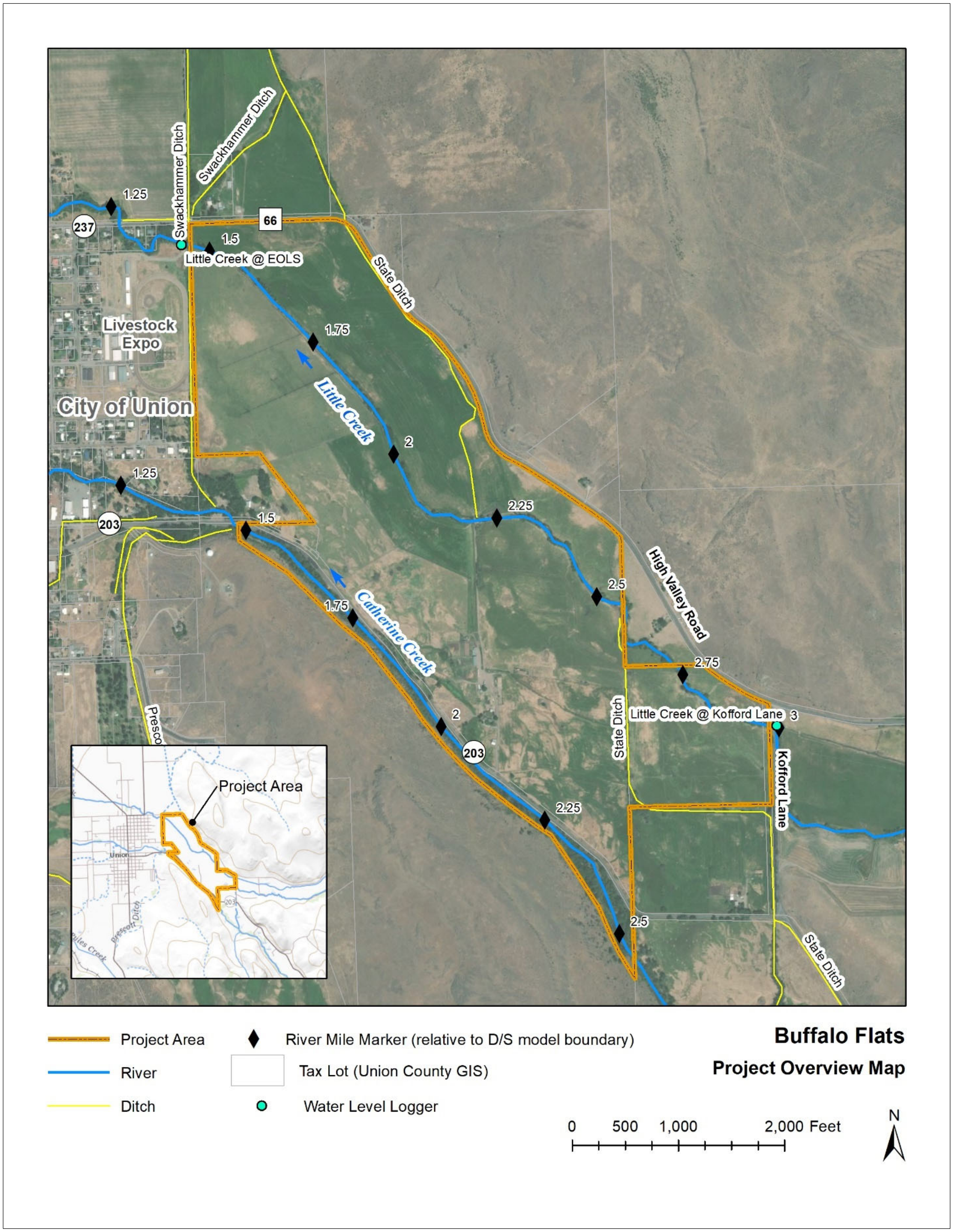

Figure 2. Overview of the Project area and prominent landmarks in the surrounding area.

The FEMA 100-year flood estimate of 882 cfs for Little Creek was originally developed using gage data from similar watersheds throughout eastern Oregon (HUD FIA, 1978). However, 882 cfs is substantially higher than the more recent 100-year flood estimate of 514 cfs that was developed for Little Creek as part of the Catherine Creek Tributary Assessment (Reclamation, 2012). This discrepancy is likely due the inclusion of more than 30 years of additional data in the more recent estimate, which also inherently reflects any potential changes that have occurred in hydrologic patterns throughout eastern Oregon. The FEMA 100-year flood is currently established as the regulatory base flood for Little Creek in the Project area. However, more recent hydrologic analyses demonstrate that 882 cfs may be closer to a 760-year flood[1], which suggests that the FEMA base flood may be overly conservative. As such, 514 cfs is used as the 100-year flood in evaluating pre- and post-project conditions, and the regulatory base flood will be re-evaluated through coordination with FEMA during the map revision process that is anticipated as the Project progresses.

During 2020, high flow events occurred at the Project site on Feb 6-7 and May 20-21. The estimated peaks in Little Creek at Kofford Road for these dates were 234 cfs and 300 cfs, respectively. These discharges were estimated from the rating relationships described above and fall within the range of the estimated 2- to 5-year flood described in Table 1. The estimated hydrograph from the May 2020 event is displayed in Figure 3. These high flow events were used for calibration of the preliminary existing conditions model (Reclamation, 2020).

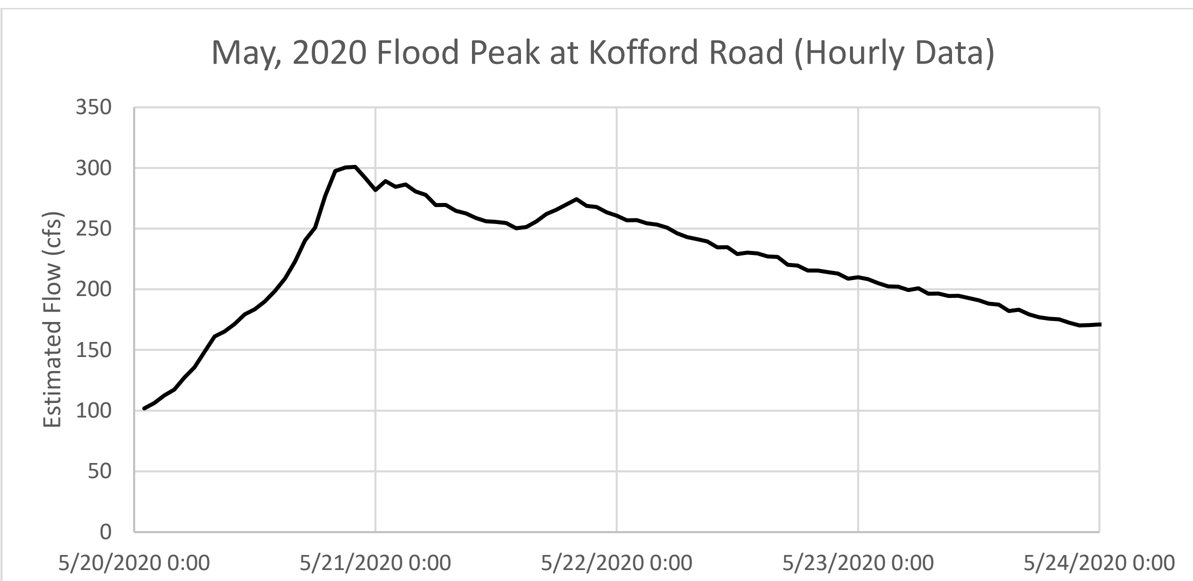

Figure 3. Flood peak estimated from water level logger data collected at the Kofford Road gaging site, which is monitored by USWCD.

[1] The 760-year recurrence interval was estimated by extrapolation from the flood frequency curve points displayed in Table 1, and does not represent an actual point on the flood frequency curve developed as part of the Little Creek flood frequency analysis.

3 Hydraulic Model Setup

Hydraulic models for the Project site were developed using HEC-RAS software Version 6.3.1 (USACE, 2022). The preliminary existing conditions model (Reclamation, 2020) was used as a starting point for this analysis, although some changes were made to the original model. These changes consisted of refinements to the computational mesh to better reflect the utility of the model as a tool to assess the Project design at a wide range of flows, as well as changes to input where updated computational methodologies in HEC-RAS and improved LiDAR data became available. These updates are described in greater detail in the following Sections.

3.1 Terrain Data

Topographic/bathymetric terrain data for the Project area and City of Union were acquired from multiple sources and used to develop a composite digital terrain model (DTM) representing pre-project conditions. Various data sources and approximate collection dates are summarized in Table 2. These data were compiled in AutoCAD Civil3D and GIS software, and merged into a composite DTM within the RASMapper interface (USACE, 2022). The DTM was updated from the original pre-project model to include topo-bathymetric LiDAR collected in August 2020 (NV5 Geospatial, 2021). Topo-bathymetric LiDAR data in Little Creek superseded bathymetric survey data collected by Anderson Perry & Associates, Inc. (AP), as the resolution of LiDAR data is far superior to what can be collected via ground survey. Spot checks were performed to verify that the LiDAR data were representative of the bathymetric surface in Little Creek. Future modeling iterations may require incorporation of additional survey data. These data are described in greater detail throughout this document and in Section 5.

Proposed conditions surfaces (channels and fill areas) were developed in AutoCAD Civil3D software and incorporated into the DTM for the 30% proposed conditions model runs.

Table 2. Survey data sources used to construct the digital terrain model for hydraulic modeling purposes.

Buffalo Flats Pre-Project Conditions Topographic/Bathymetric Terrain Model data sources		
Source	**Collected by**	**Collection date**
Ground and Bathymetric Survey- Little Creek: Spot Checks and coarse Infrastructure Survey	Inter-Fluve	2020
Topo-Bathymetric LiDAR Data- Little Creek Channel and Floodplain	Quantum Spatial, Received 2021	2020
Infrastructure Survey- Little Creek	Anderson Perry Associates	2019
Light Detection and Ranging (LiDAR)	Watershed Sciences, Received from Reclamation in 2020	2007-2009
Note: Survey Data listed in order of precedence from top to bottom		

3.2 Computational Domain

The 2D model domain was adjusted from the original existing conditions model (Reclamation, 2020), and 1D cross sections on both Little and Catherine Creeks downstream of the 2D domain were removed. The model domain encompasses both Catherine and Little Creeks, extending from valley wall to valley wall. The upstream extent of the model domain is Kofford Road and the downstream extent is N. 1st Street on Little Creek and approximately 800 feet downstream of the Swackhammer diversion dam on Catherine Creek. Preliminary model results demonstrated that under existing conditions, flood flows on Little Creek result in widespread inundation along the northeastern side of the valley, and therefore the model domain extends north along Cove Highway to approximately 0.75 miles north of Bryan Street. An overview of the complete model domain is displayed in Figure 4.

The 2D model domain contains computational cells with nominal spacing ranging from 10-50 feet in existing conditions, with smaller cell sizes used along main conveyance pathways (e.g., Little Creek channels), where higher resolution results were desired. Cell sizes ranging between 30 and 50 feet were primarily applied to relatively uniform floodplain areas with minimal topographic or vegetative variation. The proposed channels are substantially smaller than the existing Little Creek channel, and therefore computational cells with a nominal spacing of 4 feet were used in the proposed conditions model. Breaklines were used to align cell faces along prominent high ground features such as roads and berms, to prevent flow from artificially "leaking" between cells. In large, relatively flat floodplains, especially those developed from LiDAR data, some disconnected inundated areas are to be expected, as small depressions are filled with water from adjacent cells. However, the relative volume transferred between these areas is small, and the effects on the overall hydraulic patterns of the system are considered negligible. Breaklines were also used along channel alignments to orient computational cells perpendicular to flow.

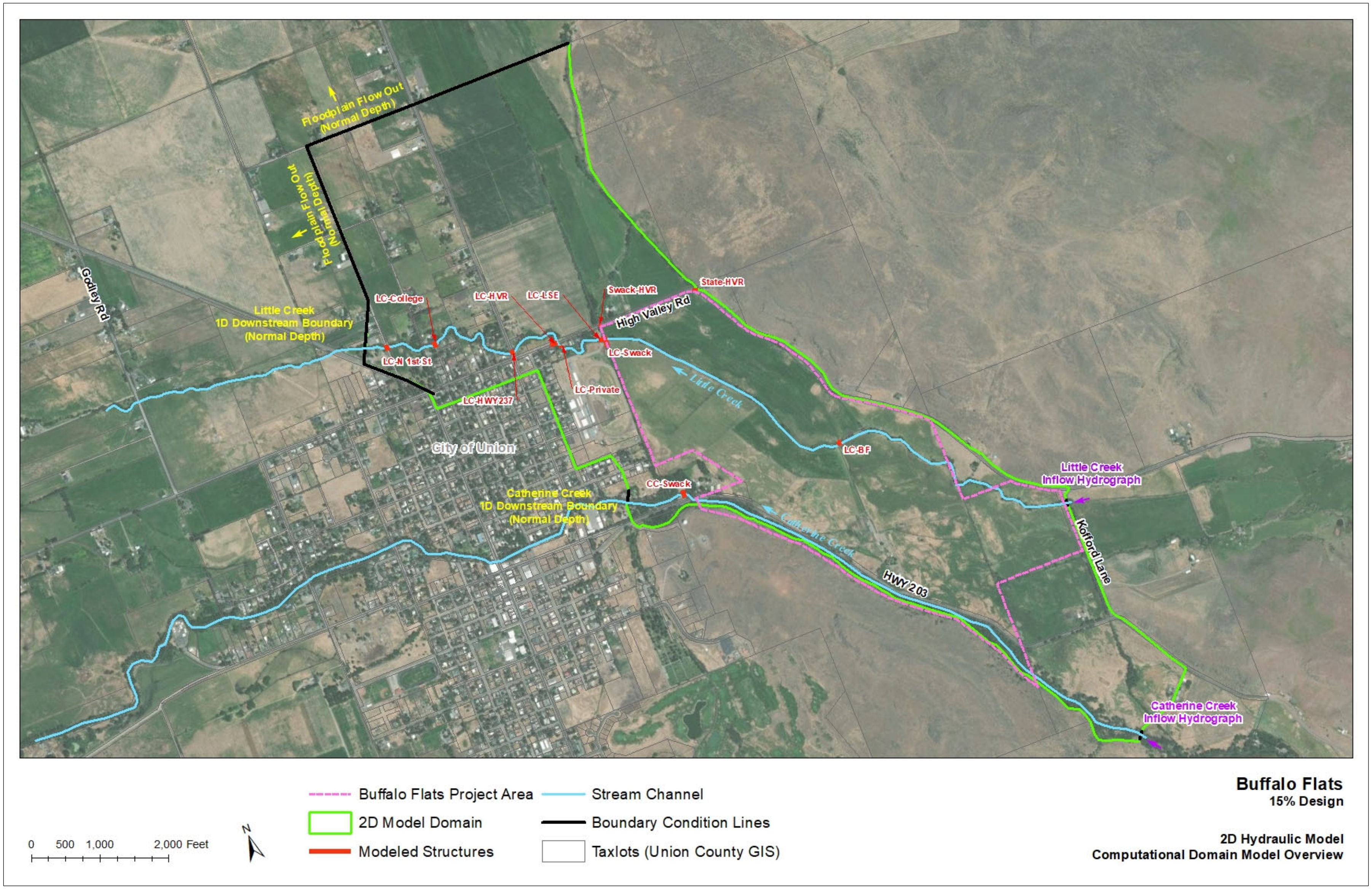

Figure 4. Overview of the computational domain used for the combined 2D model.

3.3 Infrastructure

Numerous bridge crossings, culverts, and diversion structures are present on both Catherine and Little Creeks throughout the model domain. Many of these structures were surveyed in detail by AP, and hydraulically important structures are explicitly represented in the model where appropriate. Given that the primary purpose of this modeling effort is to assess the proposed Project during seasonal high flows and flood events, many of the smaller diversion dams and culverts are not included as their influence on hydraulics during these flood events is expected to be low.

Where appropriate, major bridge crossings were incorporated into the 2D model domain using the internal 2D bridge routine functionality in HEC-RAS. Hydraulically important culverts were also directly included in the 2D domain using the culvert computations available in HEC-RAS. A majority of the bridge input data were obtained from various AP survey data, and supplemented with coarse survey data collected by Inter-Fluve in 2020.

Some data gaps with respect to certain culverts and bridges do exist. In cases where the culvert was critical in transferring flow through a high flow barrier (e.g., State Ditch crossing under High Valley Road), invert elevations and culvert configurations were approximated. Survey of these critical data gaps was conducted in 2022, and will be incorporated into the modeling during future design phases. A summary of the major road crossings, culverts, and diversion dams depicted on Figure 4, along with their respective representation in the current model, is provided in Table 3.

Table 3. Summary of major infrastructure in the modeled reaches. Note that names referenced in this table correspond with those displayed in Figure 4.

Buffalo Flats-Summary of Major Infrastructure Included in 2D Model Domain		
Name	*Infrastrcuture Description*	*Notes and Assumptions*
Little Creek-Main Channel		
LC-BF	Box culvert under Dirt Road on BF Property	Box Culvert with grade control sill represented as depth blocked
LC-Swack	Swackhammer Ditch- Parabolic Pipe over Little Creek	Box Culvert with top elevation at bottom of parabolic pipe and width approximates openings between abutments
LC-LSE	Livestock Expo North Entrance Road-Full Span Bridge	Internal 2D Bridge
LC-Private	Private Driveway-Full Span Bridge	Internal 2D Bridge
LC-HVR	High Valley Rd Street Bridge-Full Span Bridge	Internal 2D Bridge
LC-HWY 237	N. Cove Street-HWY 237	Internal 2D Bridge- Approximated Opening Terrain Geometry
LC -College	N. College Street	Box Culvert with top elevation at approximate low chord and span set to approximate width
LC- N 1st St	N. First St and Diversion Dam	Box Culvert with top elevation at approximate low chord and span set to approximate width
Little Creek-Floodplain		
State-HVR	State Ditch under High Valley Rd	Approximated Culvert configuration
Swack-HVR	Swackhammer under High Valley Rd	Approximated Culvert configuration
Catherine Creek-Main Channel		
CC-HWY 203	HWY 203	Not represented in current model due to low flow condition simulated in Catherine Creek
CC-Swack	Swackhammer Diversion Dam	Diversion dam elevation included in Catherine Creek channel as internal 2D connection
Notes:		
1. Assumes effects of diversion dams are insignificant at high flow.		
2. Infrastructure is listed from upstream to downstream for Catherine Creek and Little Creek		

3.4 Boundary conditions

Boundary conditions consist of inflow hydrographs at the upstream end, normal depth at the downstream end of the model domain on Catherine Creek and Little Creek, and normal depth boundaries at floodplain outlets of the 2D domain. Normal depth boundaries are based on the approximate slope of the channel or floodplain at the respective boundary locations. Boundary conditions were placed as far as possible from the area of interest, which includes the Project area and the City of Union immediately downstream of the Project area, to dampen any potential uncertainties associated with boundary condition assumptions.

Inflow hydrographs primarily consist of quasi-steady state hydrographs, which are synthetic hydrographs that gradually ramp up to a discharge of interest (e.g., 2-year flood) and remain constant for a period of time long enough to allow the model to reach a steady-state condition. This approach generally provides conservative results with respect to floodplain inundation by underrepresenting floodplain storage. During a typical flood hydrograph, flood peak attenuation can be reduced by allowing floodplain storage to fill enough to reach a quasi-steady state condition. Additional simulations were performed using the estimated hydrograph from the May 2020 flood event (approximate 5-year flood), to assess the potential effects of the Project on floodplain storage.

3.5 Hydraulic Roughness (Manning’s n)

Existing Conditions

Existing conditions roughness within the 2D domain was unchanged from the original model. Landcover classifications and associated Manning’s n values for existing conditions are provided in Table 4 for reference. It’s important to note that 2D and 1D roughness values, particularly those in stream channels, can have appreciable variation for the same landcover classification or substrate type, as many of the additional losses accounted for in 1D roughness values are directly computed in the 2D equations (Robinson et al., 2019).

Proposed Conditions

At the current design stage, treatments within the proposed channels, existing channel, and floodplain grading nodes are generalized. As such, proposed conditions were represented using roughness values as a proxy for multiple design elements such as local channel fill in the existing channel, large wood, post assisted brush treatments, vegetation treatments. Proposed channel roughness values were assumed to equal 0.075 in new channels, and 0.5 in existing channels where channel spanning wood structures are expected to be key components of the design. Channel fill areas that were built in to the DTM with mounded microtopography were assigned a roughness value of 0.07, to represent a range of vegetative conditions post-construction. Roughness values for floodplain grading nodes and shallow swales were unchanged from existing conditions. Further refinement of proposed conditions roughness values will be incorporated into model development for future design phases as appropriate.

Table 4. Assumed hydraulic roughness (Manning's n) coefficients used in the hydraulic model

Buffalo Flats Hydraulic Model Roughness Assumptions	
Landcover Description	**Manning's n Value**
Little Creek Channel Corridor	0.075-0.1
Little Creek Channel	0.04-0.045
Catherine Creek Channel	0.039
Riparian (Varying Densities)	0.08-0.15
Pasture (shallow depths)	0.07
Trees (Varying Densities)	0.065-0.15
Ditches	0.055-0.08
Relic Channel	0.08
Hillslope Trees	0.06
Road Embankment	0.06
Open Space	0.025
Landscaped	0.055
Residential (Light Density)	0.065
Residential (Med Density)	0.075
Residential (High Density)	0.09
Buildings	10
Gravel Road	0.03
Paved Road	0.02
Proposed Channel (New)	0.075
Proposed Treatment to Existing Channel (Spanning Large wood)	0.5
Proposed Existing Channel Fill (Built into terrain)	0.07

3.5.1 Calibration

The original existing conditions model was calibrated to water level logger data, photos and video taken during high flow events, high water marks, and anecdotal observations made by local residents. This calibration process is described in detail in the Existing Conditions Modeling Report (Reclamation, 2020). As described previously, new topo-bathymetric LiDAR data were incorporated into the existing conditions model described in this document (Section 3.1). The existing conditions model may be re-calibrated in future design phases if additional data become available and warrant revising the model calibration.

4 Proposed Conditions Analysis

4.1 Overview

Proposed conditions models were used to analyze and iteratively refine grading to effectively meet the primary design objectives of: a) increasing frequent floodplain inundation on the Project property; and b) maintaining downstream flooding conditions that are consistent with, or improved upon existing conditions during large flood events. Development of the proposed grading and design features is described in the 30% Basis of Design Report.

A detailed Alternatives Analysis was conducted as part of the 15% Design phase in 2021 (Reclamation, 2021). Much of the analysis focused on adjusting channel dimensions and planform to evenly distribute flood flows throughout the floodplain. Further design changes have occurred during the 30% design iteration to meet objectives of landowners and funders.

4.2 Floodplain Inundation

Grading plans and design features for the 30% design were iteratively adjusted until model results demonstrated that an acceptable level of floodplain inundation could be achieved at the target flow rates of 30 cfs (estimated annual average) and the 1.1-year flood event (185 cfs). Grading adjustments primarily consisted of alterations to channel geometry and elevations, with some adjustments to channel planform and locations of channel fill areas where necessary. Representative sections for each sub-reach are displayed in Figure 5-Figure 8. Under existing conditions, the floodplain is substantially perched and disconnected from the Little Creek channel in many locations throughout the Project reach. Therefore, the primary goal of this initial analysis was to increase water surface elevations from existing conditions, while also maintaining relatively even wetting across the channel and floodplain.

The current proposed design for Subreaches 2 and 3 contains little to no grading of the channel, and therefore the channel cross section appears largely unchanged at the representative cross section (Figure 5). However, the addition of channel-spanning wood, post assisted brush mounds, vegetation, and select local fill was represented using roughness in the 2D model, which results in an increased water surface elevation under proposed conditions. Further refinement of the design and associated modeling approach in Subreaches 2 and 3 is anticipated to increase the frequency of inundation even further.

A comparison of modeled depths between existing and proposed conditions at select moderate to large floods provided in Figure 9-Figure 11. Modeled inundation depths at 10 cfs, 30 cfs, as well as the 2-, 5-, and 100-year floods for the final iteration of the 30% design are displayed in Figure 12 - Figure 16.

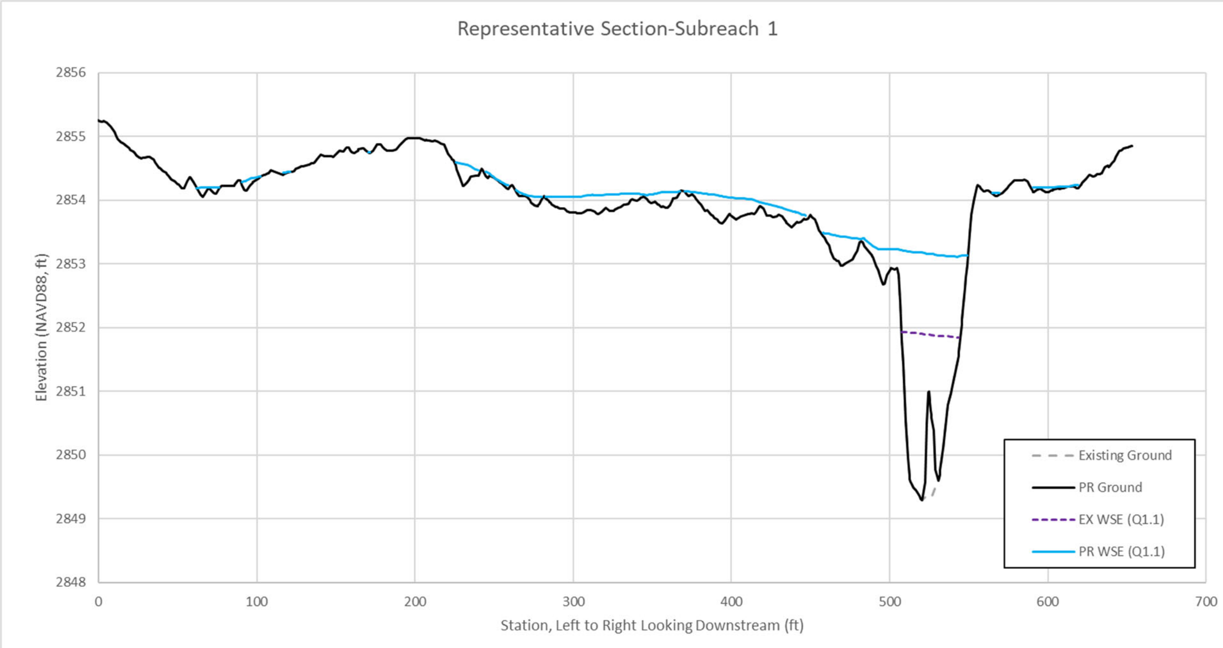

Figure 5. Representative section in Sub-Reach 1.

Note: 2D modeling results in varied water surface elevations across the length of a cross section, as opposed to 1D modeling, which results in a single, average water surface elevation.

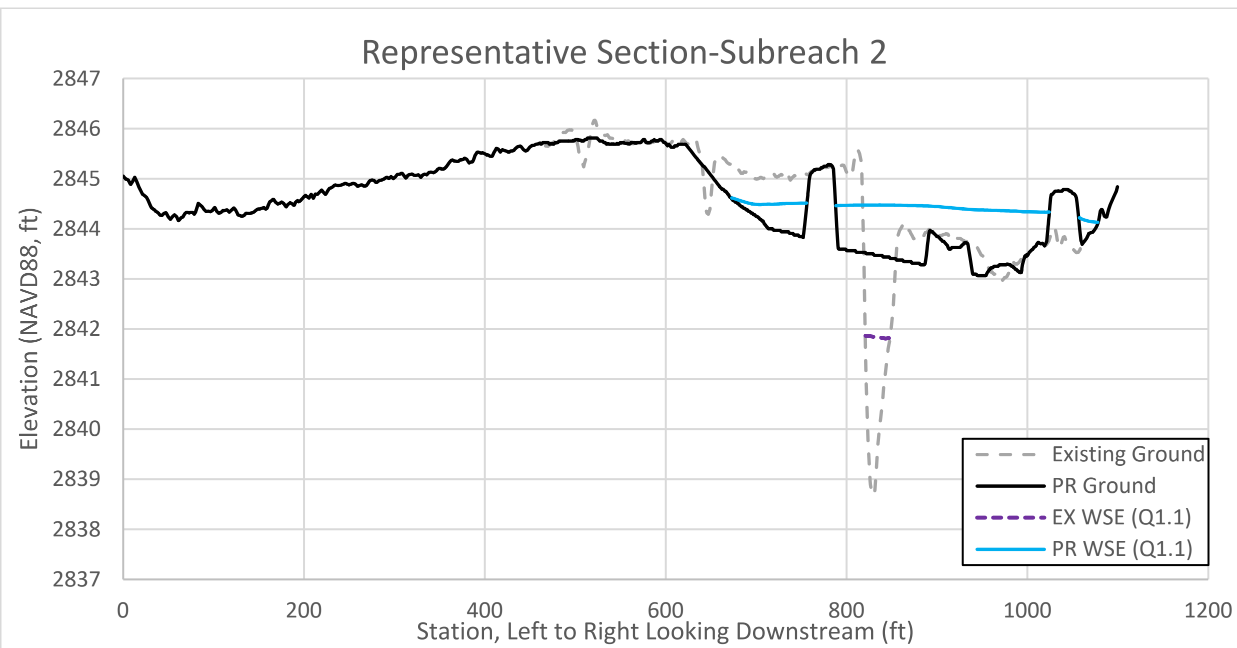

Figure 6. Representative section in Sub-Reach 2.

Note: 2D modeling results in varied water surface elevations across the length of a cross section, as opposed to 1D modeling, which results in a single, average water surface elevation.

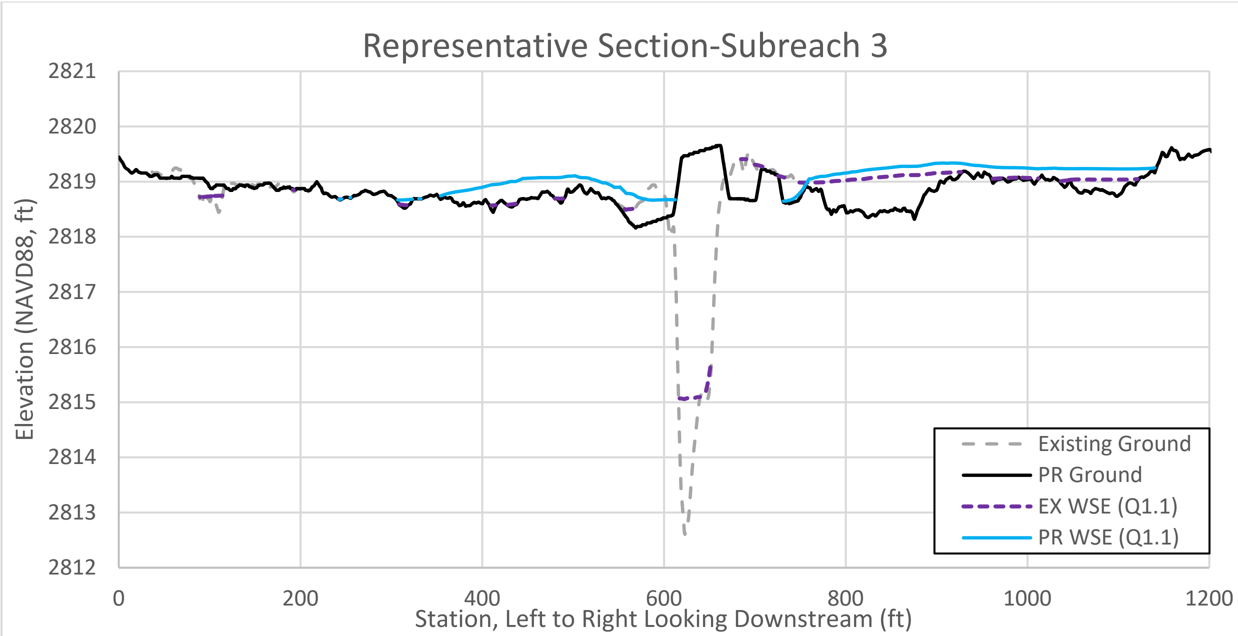

Figure 7. Representative section in Sub-Reach 3.

Note: 2D modeling results in varied water surface elevations across the length of a cross section, as opposed to 1D modeling, which results in a single, average water surface elevation.

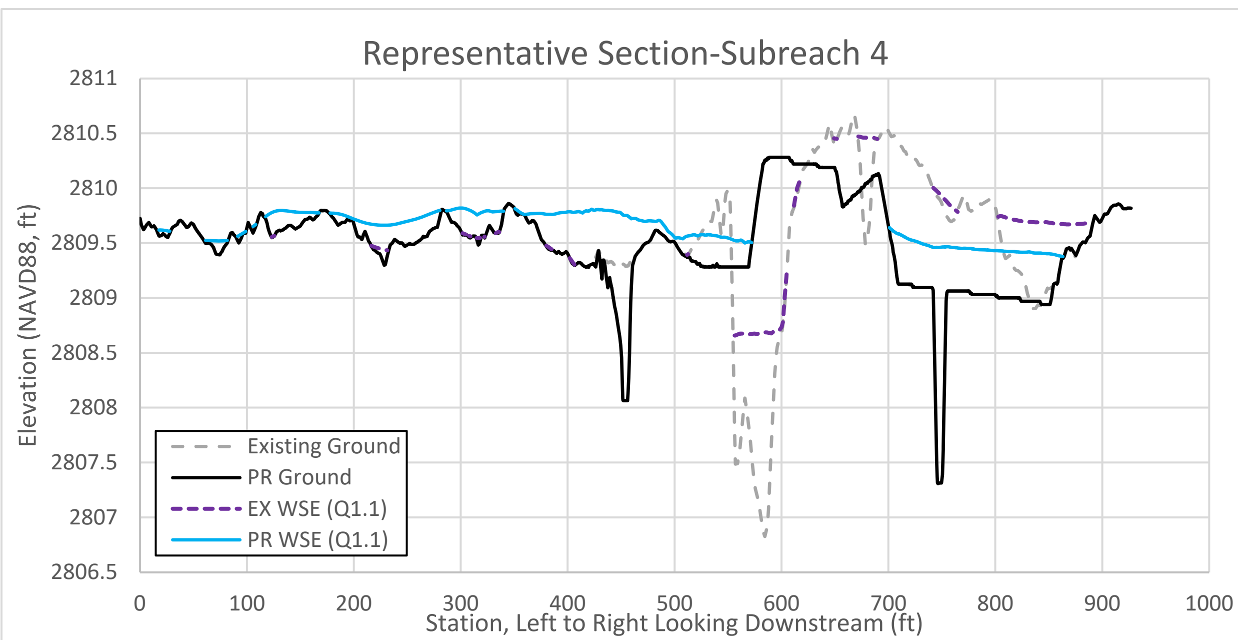

Figure 8. Representative section in Sub-Reach 4.

Note: 2D modeling results in varied water surface elevations across the length of a cross section, as opposed to 1D modeling, which results in a single, average water surface elevation.

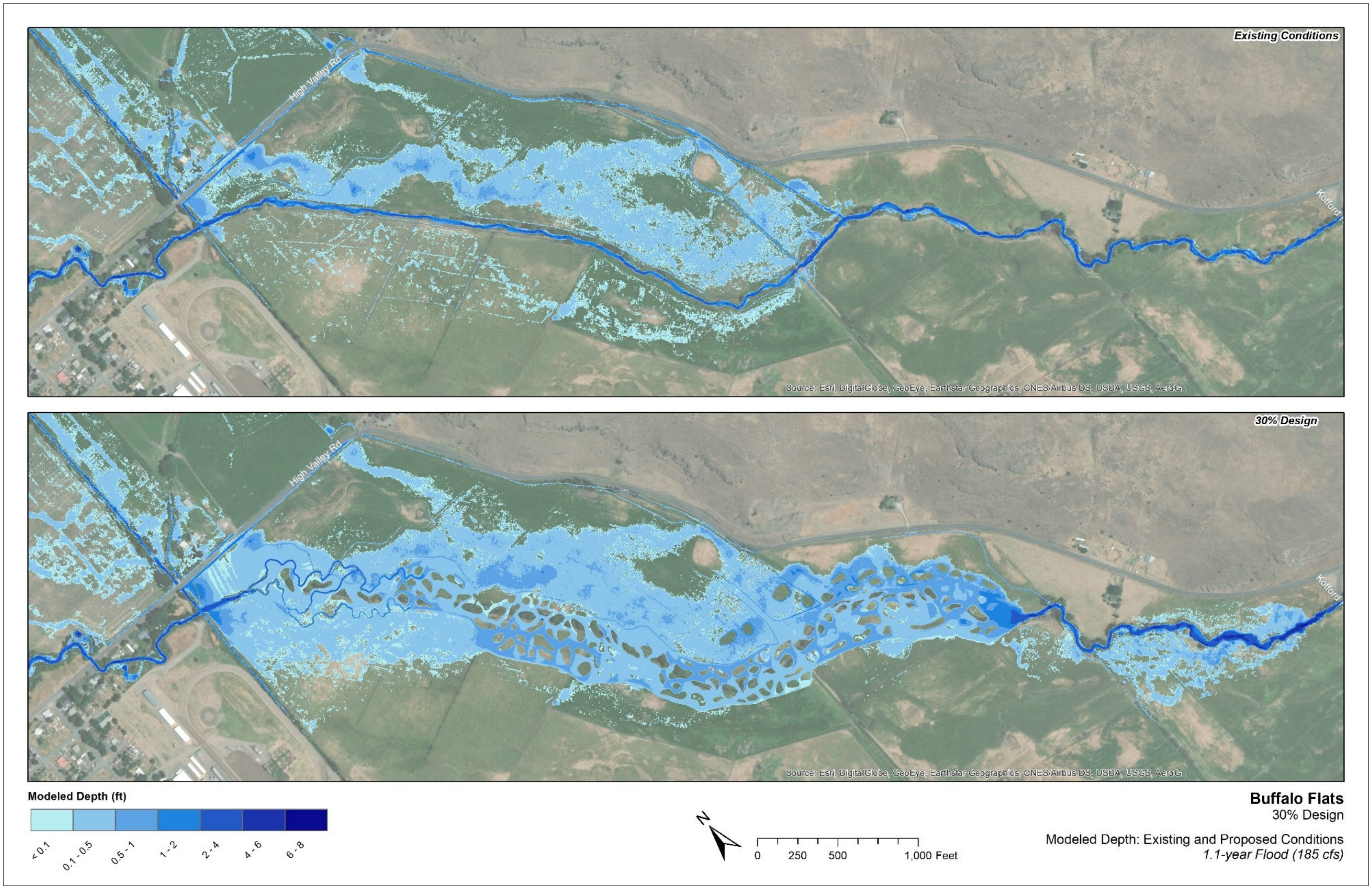

Figure 9. Modeled Inundation depths for the 1.1-year flood.

Existing Conditions are shown in the upper panel and 30% Design Conditions in the lower panel.

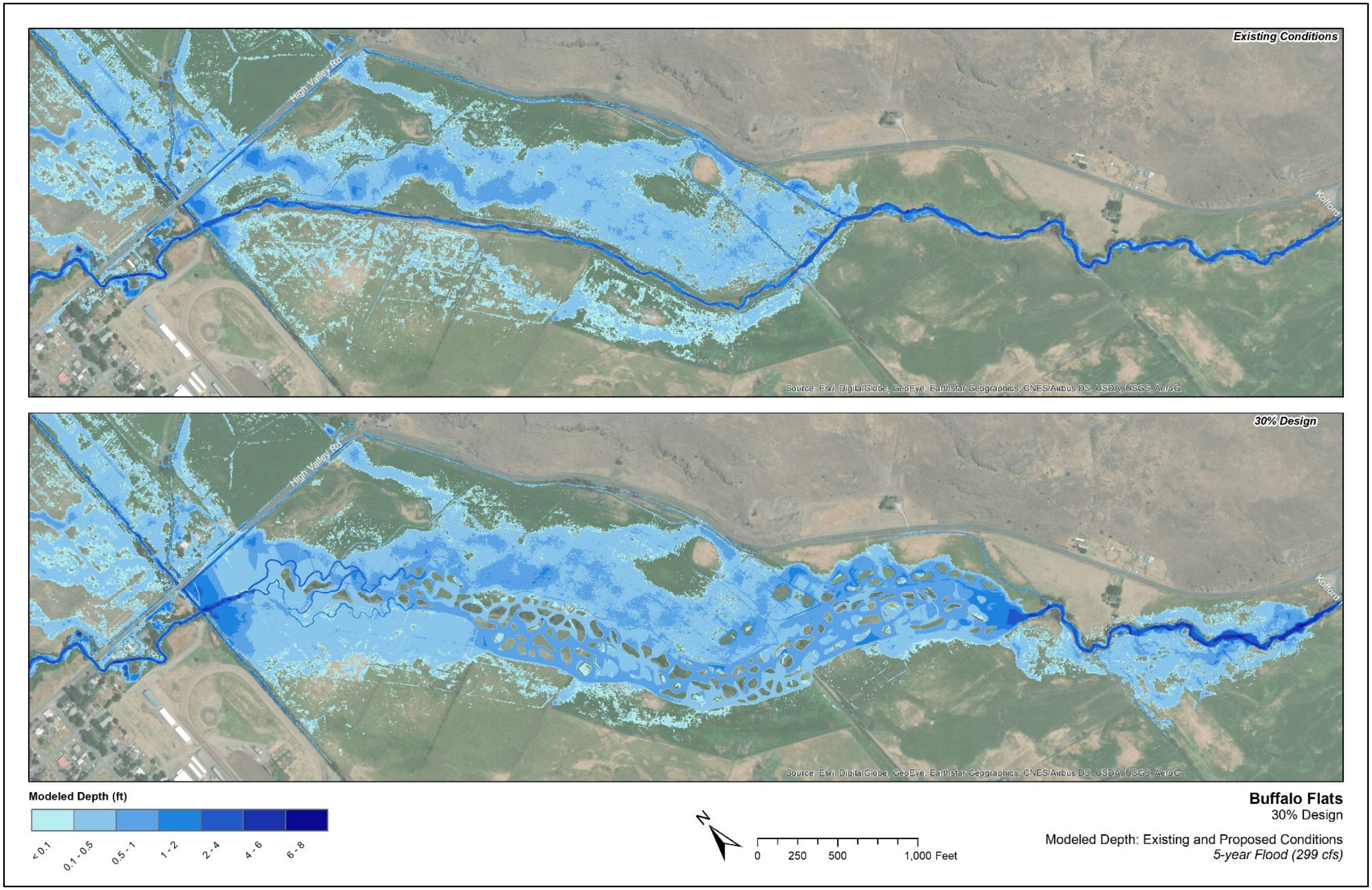

Figure 10. Modeled Inundation depths for the 5-year flood.

Existing Conditions are shown in the upper panel and 30% Design Conditions in the lower panel.

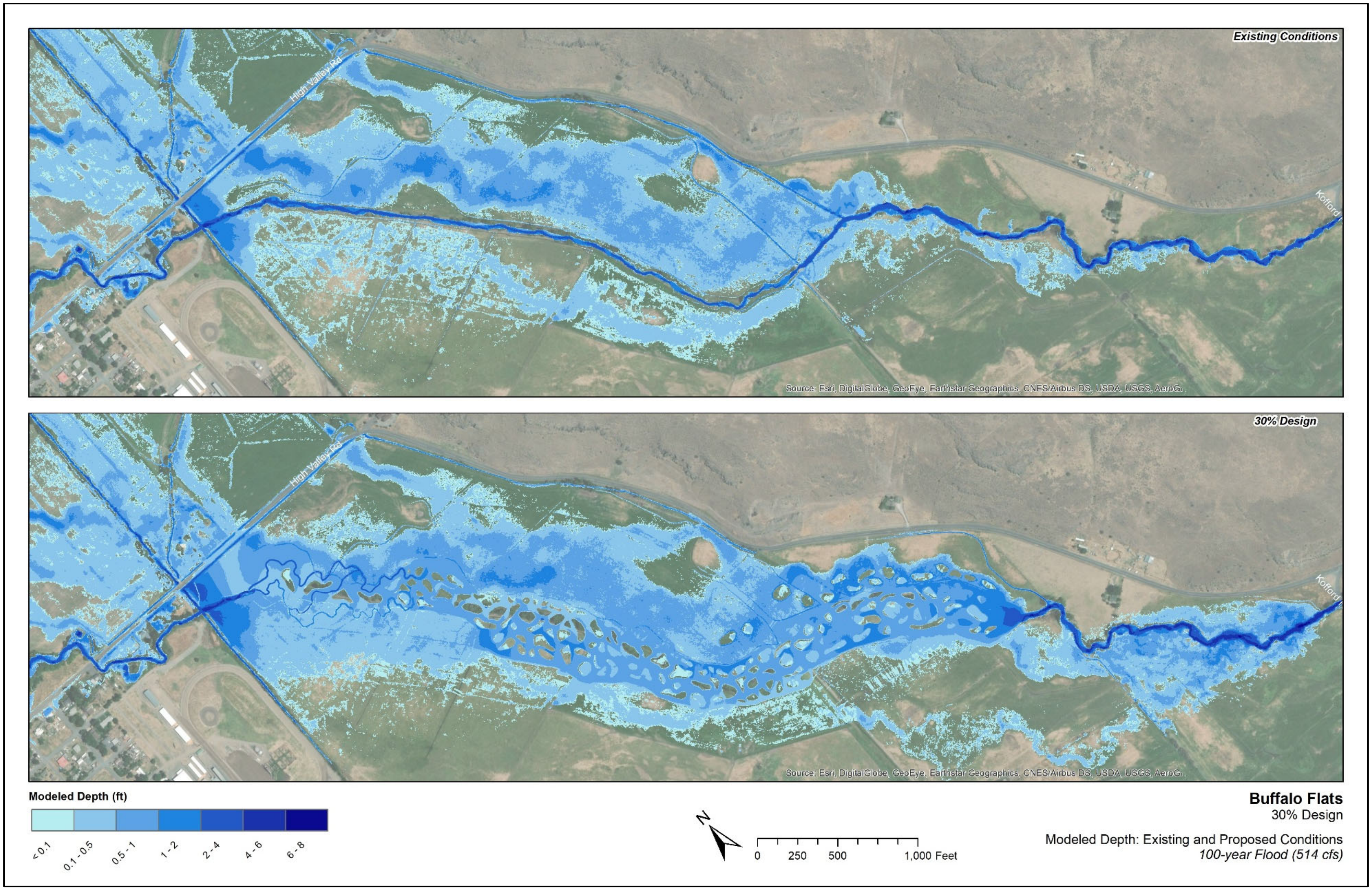

Figure 11. Modeled Inundation depths for the 100-year flood.

Existing Conditions are shown in the upper panel and 30% Design Conditions in the lower panel.

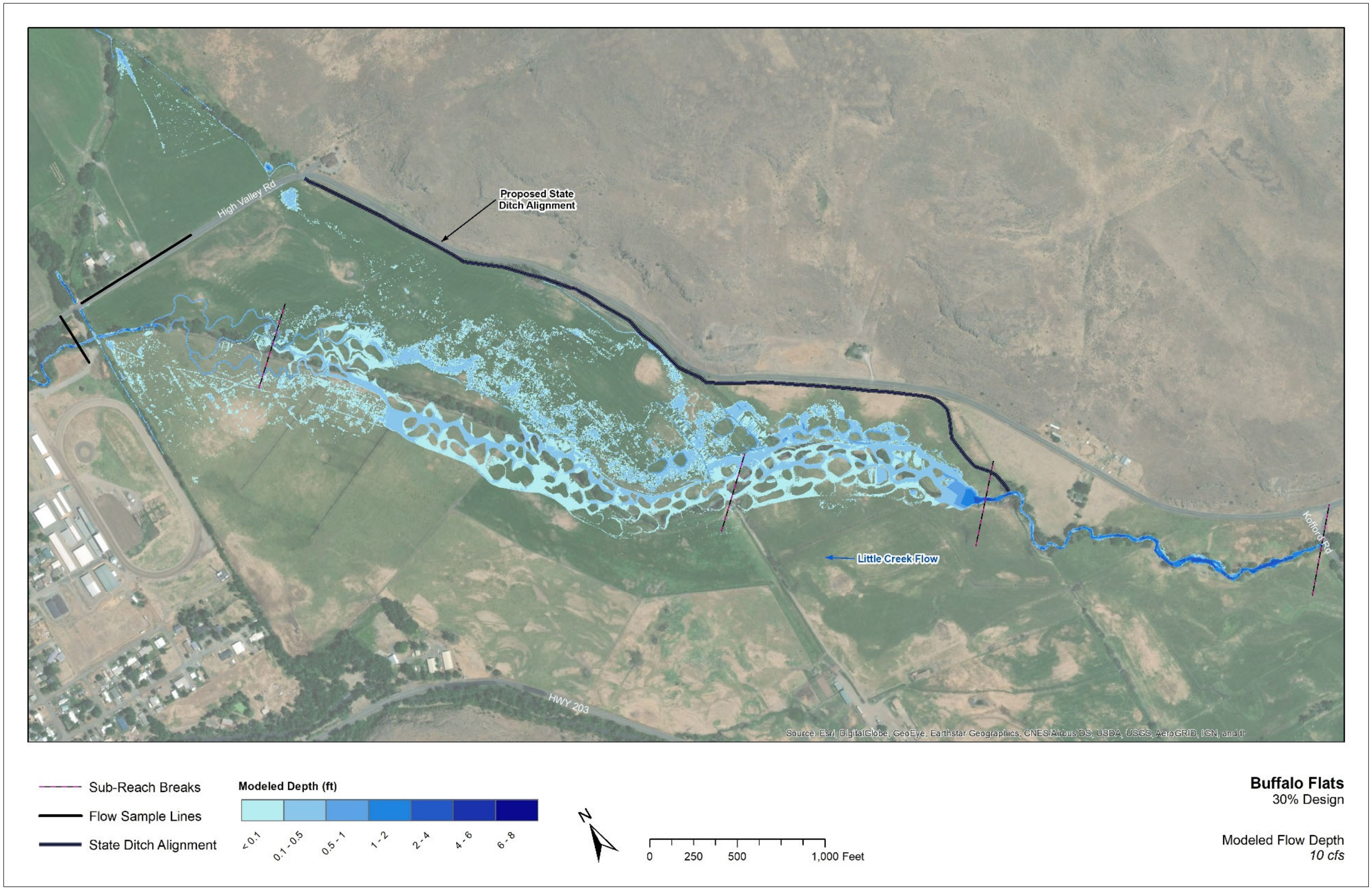

Figure 12. Modeled Inundation depths for 10cfs which represents an average winter flow (November-February) (Proposed Conditions).

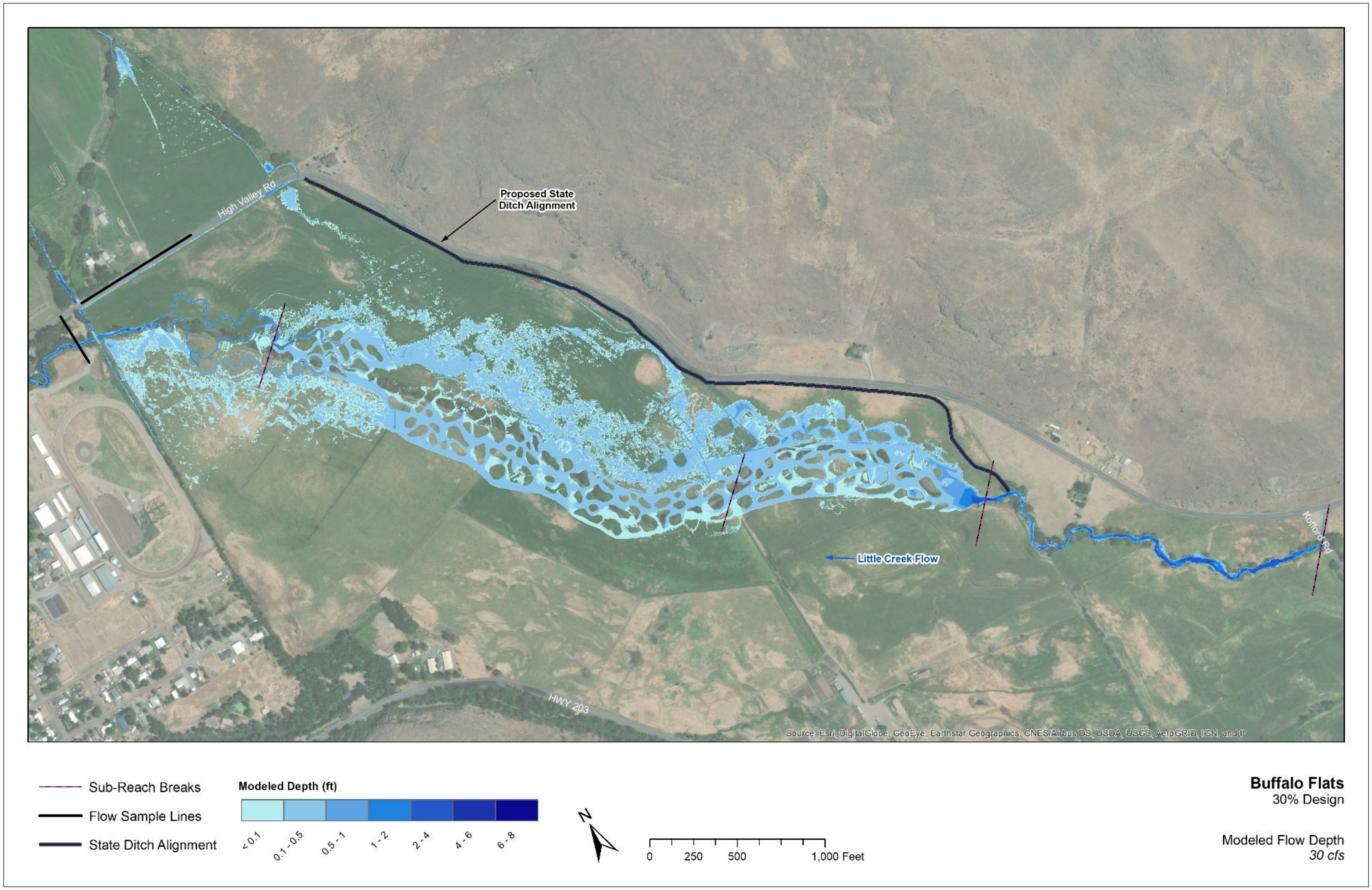

Figure 13. Modeled Inundation depths for 30cfs which represents an average spring (March-June) exceedance flow (Proposed Conditions).

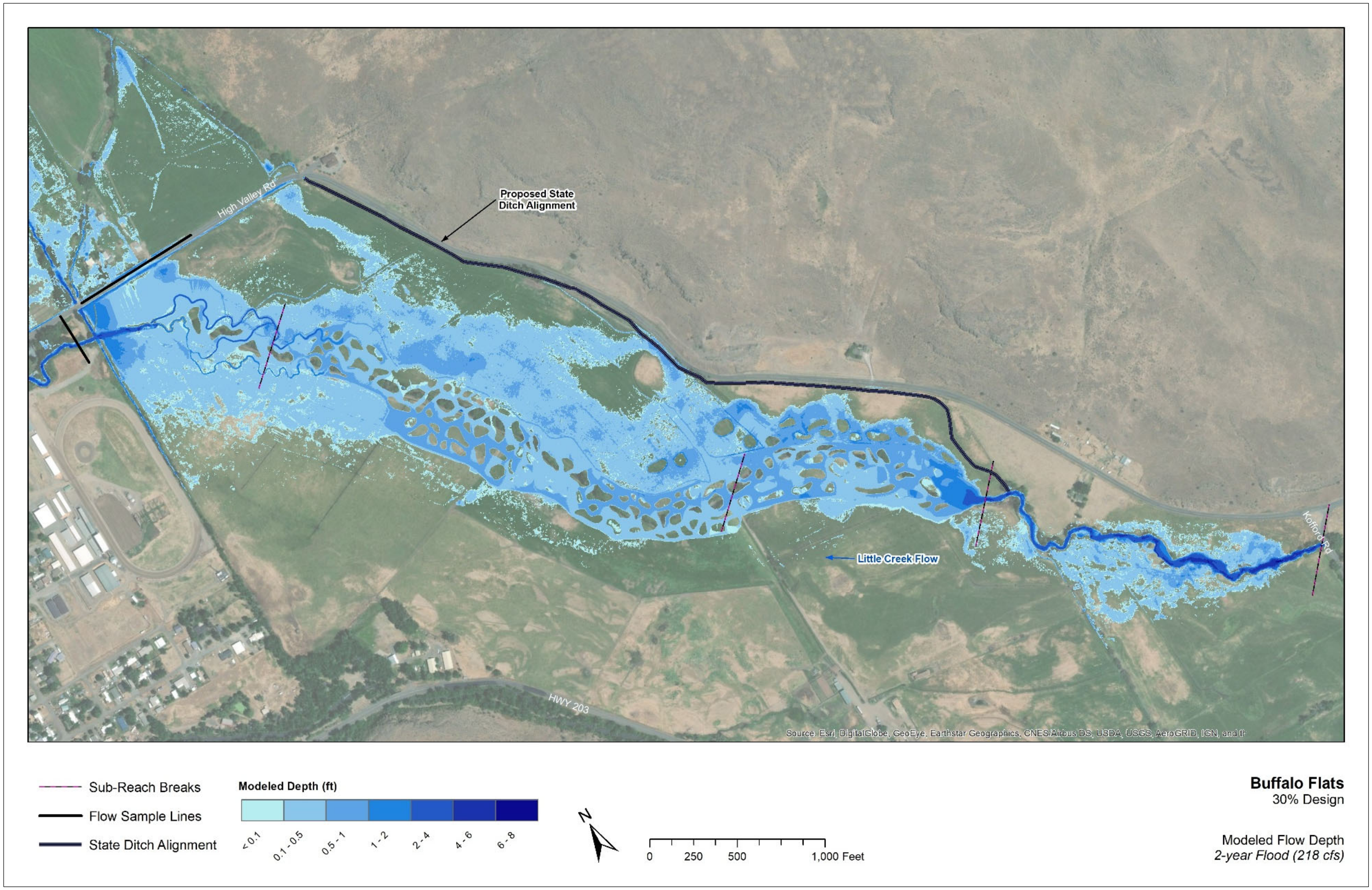

Figure 14. Modeled Inundation depths for the 2-year flood (Proposed Conditions).

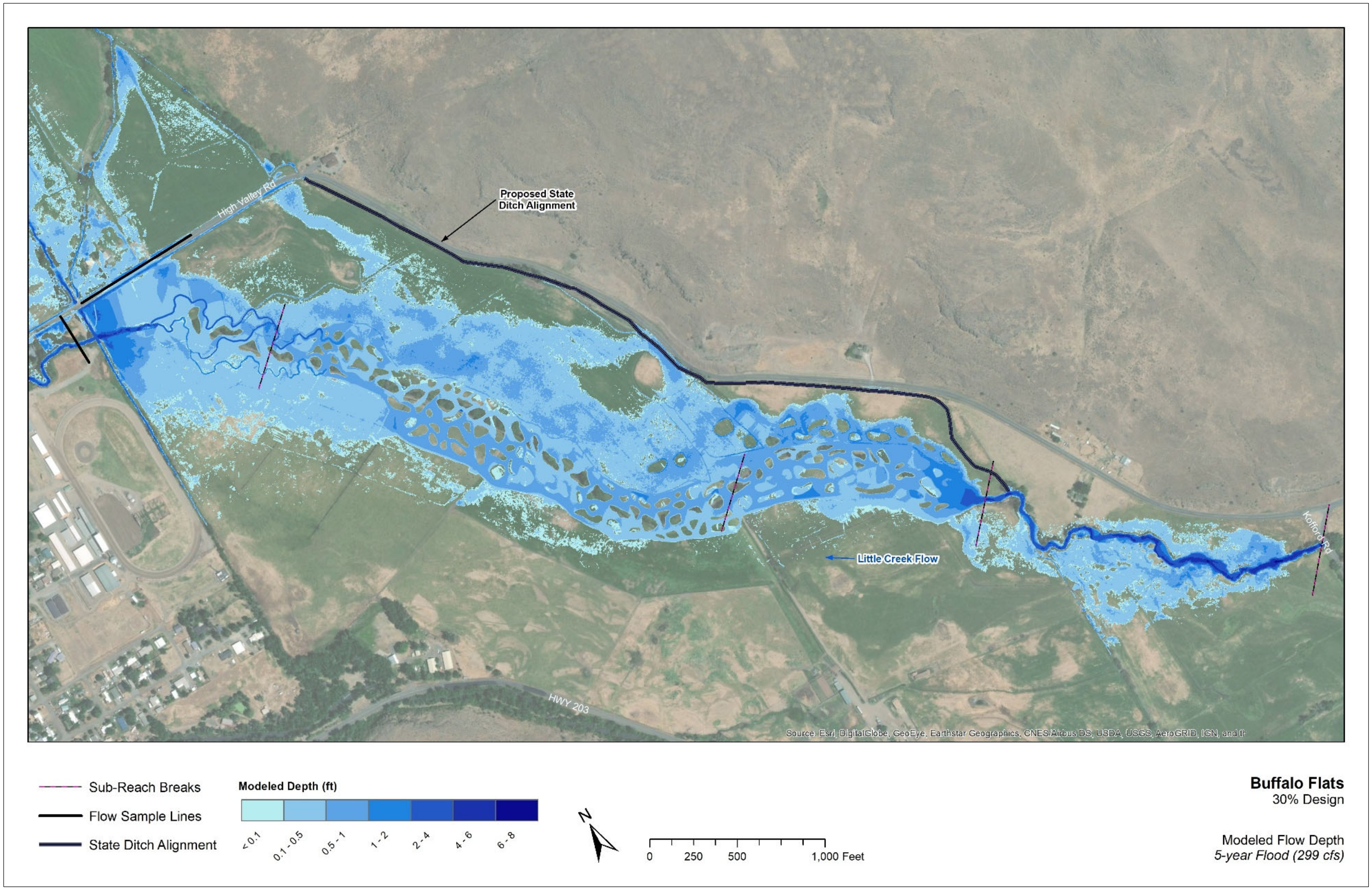

Figure 15. Modeled Inundation depths for the 5-year flood (Proposed Conditions).

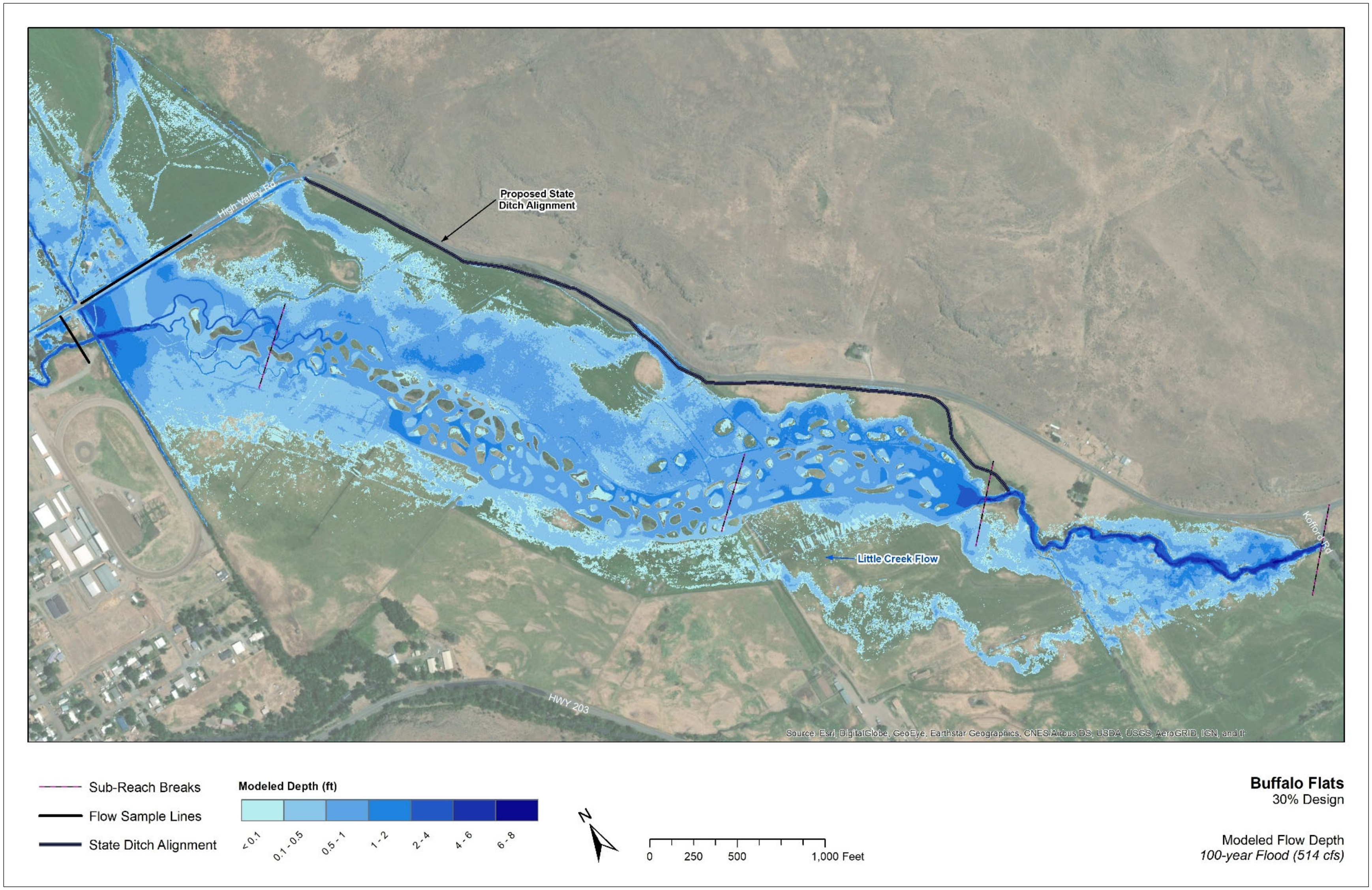

Figure 16. Modeled Inundation depths for the 100-year flood (Proposed Conditions)

4.1 Downstream Areas

Existing condition models show flooding downstream of the Project area currently. A key project objective is to maintain downstream flooding conditions that are consistent with, or improved upon existing conditions during large flood events. The potential effect of the proposed project on downstream flooding were assessed by comparing discharge leaving the project site adjacent to 2 main outlet points: through Little Creek under Swackhammer Ditch, and over High Valley Road (Figure 17). Sampling discharge from the model results at these locations demonstrates that there is a slight reduction in flow leaving the property under proposed conditions, at both locations (Figure 18 and Figure 19). However, it is worth noting that the magnitude of flow is very similar under existing and proposed conditions, and the difference is within the tolerance of the model and therefore considered negligible.

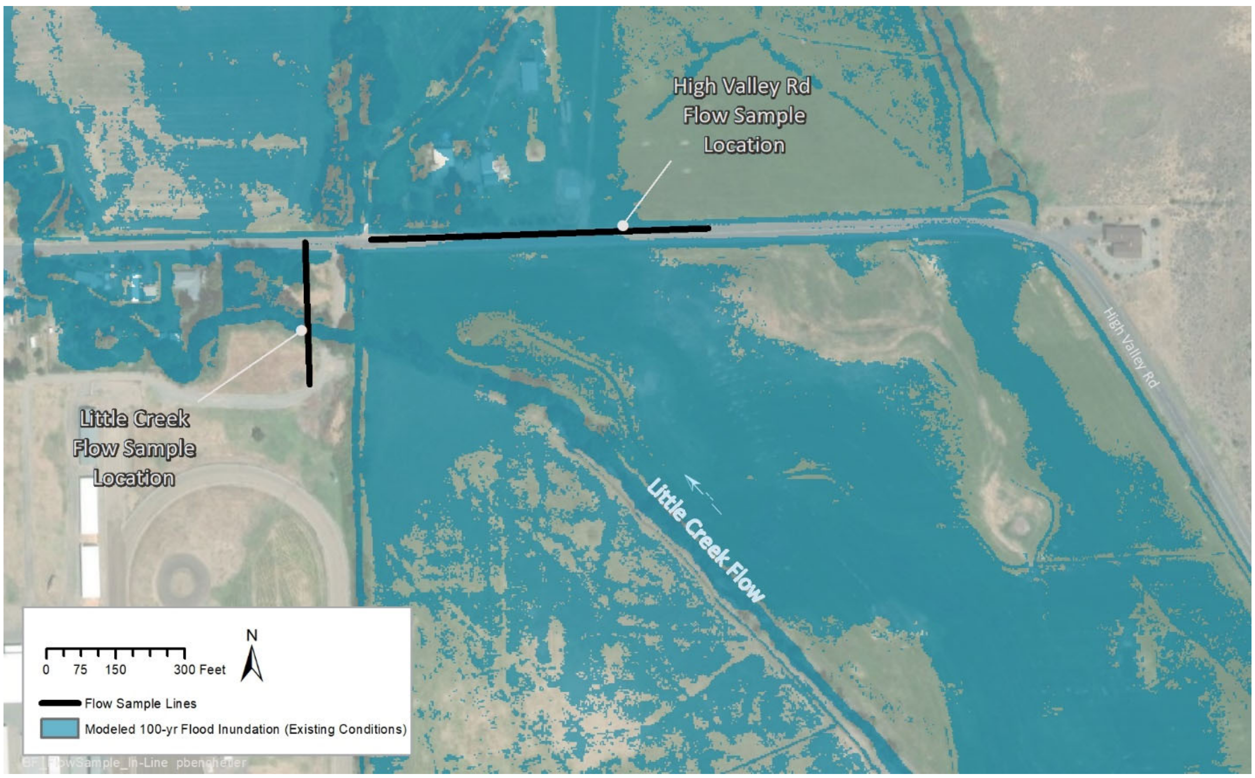

Figure 17. Flow Sample locations at the downstream end of the Project property (Existing flood conditions shown).

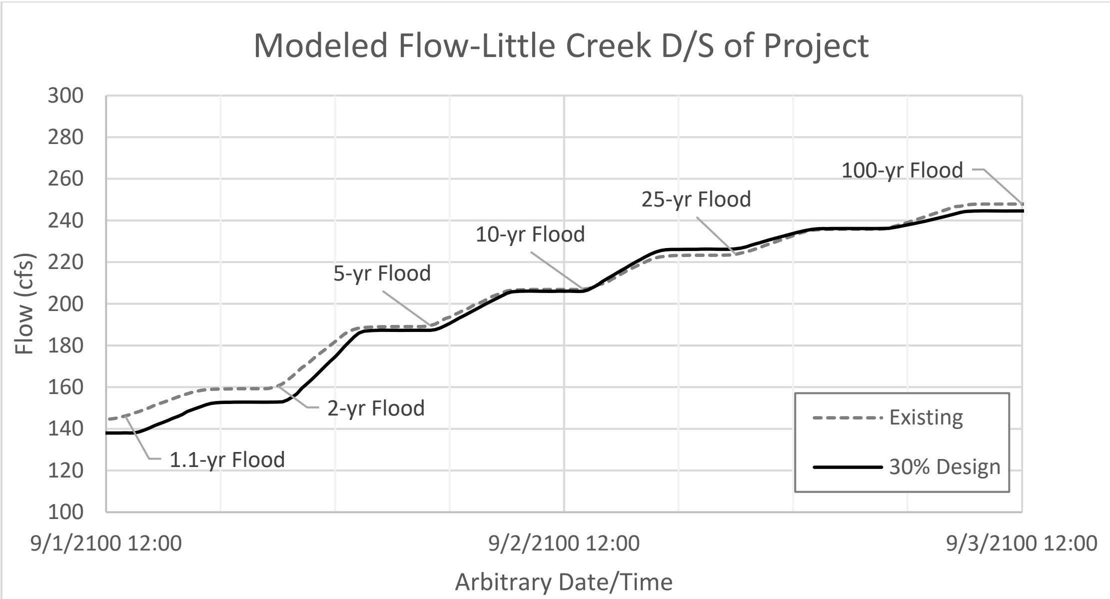

Figure 18. Modeled quasi-steady state hydrographs for existing and proposed conditions downstream of the Project site on Little Creek.

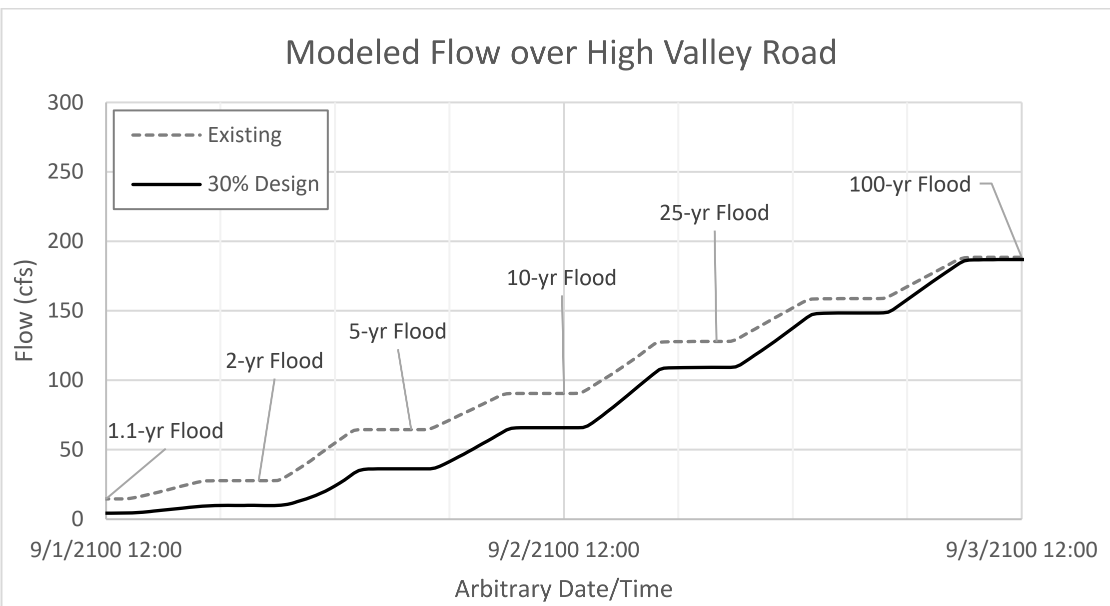

Figure 19. Modeled quasi-steady state hydrographs for existing and proposed conditions flowing over High Valley Road.

5 Model Limitations and Data Gaps

In addition to computational limitations typically associated with 2D hydraulic models, project-specific limitations with respect to data gaps and assumptions are described throughout this document. A summary of key limitations, assumptions, and known data gaps is provided below:

Infiltration

The current version of HEC-RAS does not compute infiltration losses associated with surface water flow, or any other subsurface water flow. As the modeled flood peak recedes, the computational cells in the model are dried by volume transfer of surface flow only, as this model is not intended to be a groundwater model. However, infiltration is not expected to have a meaningful impact on the hydraulic model results, as antecedent moisture conditions and soil saturation during flood events are expected to result in minimal, if any, subsurface infiltration capacity.

Bridge Infrastructure

Given the increased computational capabilities of the recent version of HEC-RAS and the inclusion of bridge routines within 2D areas, additional review of the bridge input data may be warranted. Although the data included in the current model are sufficient for relative comparisons between existing and proposed conditions, more detailed discrete analyses may require revisions to the bridge input data.

Irrigation infrastructure

Many irrigation ditches, culverts, and other minor infrastructure were not explicitly defined in the model domain and assumed to have a negligible impact on high flow events. Although larger ditches such as Swackhammer, State, and Prescott are represented in the digital terrain model, their diversion dams and inlet works were not defined and therefore the distribution of flow to these ditches may not be entirely representative of actual conditions. Future modeling iterations may warrant additional consideration of this infrastructure.

Incorporate 2022 survey data for Swackhammer Ditch and associated infrastructure

Elevations in the model along the Swackhammer Ditch alignment are currently based on LiDAR data. Survey data collected along Swackhammer Ditch in late 2022 will be compared against LiDAR data and incorporated into the DTM as necessary during future design iterations.

Incorporate 2022 survey data for State Ditch Culvert under High Valley Road

Invert elevations for the State Ditch culvert crossing under High Velley Road were surveyed in late 2022. The modeling described in this document includes approximated culvert information in both existing and proposed conditions, which will be updated in future design phases.

State Ditch Diversion-Proposed Conditions

The current State Ditch diversion point is situated in Sub-Reach 2, in the upper half of the Project Reach. The 30% design proposes that the diversion point is re-located to a point upstream. Detailed design of the diversion point and associated re-alignment of the State Ditch is currently underway and will be incorporated into future modeling iterations in subsequent design phases.

Little Creek Crossing- Proposed Conditions

The Project outlet at the Swackhammer Ditch crossing on Little Creek will need to be designed in greater detail during future design phases. The design for the downstream end of the Project may include increasing the channel grade in Little Creek, altering the opening size and configuration of the Swackhammer Ditch crossing on Little Creek, or some combination of design elements that meet the Project objectives.

Ice Modeling

Both Catherine Creek and Little Creek are subject to ice impacts during winter floods. The current modeling efforts do not include any simulations with ice effects. As the Project design progresses, simulations that include ice effects may be warranted

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