FINAL FLOOD REDUCTION INVESTIGATION FOR LAKE MCMURRAY, HULL DRIVE & HULL ROAD

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1. INTRODUCTION AND BACKGROUND

Watershed Science and Engineering (WSE) was retained by Skagit County Public Works (County) to determine if enlarging culverts under Hull Drive, Hull Road, and an abandoned railroad berm will reduce flooding along both roads and on multiple private properties along the shore of Lake McMurray and west of the abandoned railroad berm. The project area is located along the west shore of Lake McMurray near the intersection of State Route (SR) 9 and Hull Drive, approximately 5 miles east of Conway, Washington (Figure 1).

Flooding within the project area is generated by three primary water sources -- Lake Creek, an unnamed creek which flows into Lake Creek, and Lake McMurray. Lake Creek is classified as fish bearing in its entirety according to the Statewide Washington Integrated Fish Distribution (SWIFD) dataset. The unnamed tributary to Lake Creek is classified as fish bearing for a section of the stream from its confluence with Lake Creek to Hull Drive. However, there is no barrier to prevent fish utilizing the reach between Hull Drive to SR9. Lake Creek and the unnamed creek enter the project area from the west-northwest and west-southwest respectively and join just upstream of an abandoned railroad earthen berm (Figure 1). The abandoned railroad berm runs parallel to Hull Road from the Hull Drive intersection north to the north end of Hull Road. The berm unintentionally helps reduce flooding along both Hull Road and multiple lake front properties, but worsens flooding on property west of the berm because it captures and retains water from Lake Creek and the unnamed creek. The water stored upstream of the abandoned railroad berm is directed to a pair of culverts which carry it under the berm to a culvert under Hull Road. The Hull Road culvert connects to an open channel that transports the water to Lake McMurray. This open channel does not have the capacity to convey large flows; therefore, both private properties that border the channel flood. Water exiting the Hull Road culvert also enters and overwhelms the roadside ditch along the east side of Hull Road, flooding several additional lake front properties.

Flooding along the unnamed creek occurs where it enters a culvert to pass under Hull Drive. The culvert is too small to pass floods so water overtops to the right (east) bank and flows down Hull Drive to flood several lake front properties. This water also enters the roadside ditch along the east side of Hull Road and flows north contributing to the ditch related flooding mentioned above.

WSE has completed a detailed hydrologic and hydraulic investigation to determine why the flooding in the vicinity of Hull Road and Hull Drive is occurring and to identify and evaluate alternatives to reduce this flooding. The results of the investigation are presented in the main body of this report.

In addition to the flooding described above, flooding is also caused by rising lake levels in Lake McMurray during heavy winter rain storms. According to landowners, the elevated lake levels are due to obstructions in the lake outlet channel, possibly beaver dams. At the request of the County, WSE conducted a field investigation of the lake outlet channel between February and March 2020. A memorandum summarizing WSE's observations is included as Appendix A. Following the field investigation, WSE completed a second investigation which included developing a hydraulic model of the outlet channel to examine how various observed obstructions impact the channel's ability to drain the lake. A memorandum summarizing the hydraulic investigation is included as Appendix B.

Special Note:

The original report submitted June 2020 has been revised to correct the size of the existing Hull Road culvert. The earlier version of the report used a culvert diameter of 36 inches, but it was later discovered that the culvert has a reducer inside of it that makes the effective diameter 30 inches. The culvert diameter was corrected in the model and all simulations were re-run. The figures in this report have been updated to show the revised results. The correction produced only minor changes to the modeling results and did not change the investigation conclusions.

1.1 Other Relevant Studies

Washington State Department of Transportation (WSDOT) is in the process of designing a replacement for the existing culvert on Lake Creek at SR9. This existing crossing is located approximately 750 feet upstream of the abandoned railroad berm. A preliminary hydraulic design report for the SR9 culvert replacement project was obtained from WSDOT (WSDOT, 2019). WSDOT proposes to replace the existing 36-inch reinforced concrete pipe (RCP) culvert on Lake Creek at SR9 because it poses a barrier to fish passage. According to the preliminary hydraulic design report, the existing culvert causes backwatering at events as small as the 2-year storm event. Ponding of water upstream of the culvert also causes overtopping of SR9 in the 50-year event. The proposed replacement of the existing culvert will be a 26-foot span structure which will eliminate the backwater effect up to the 100-year event (WSDOT, 2019).

WSE's hydraulic model of the Hull Road project area begins downstream of the SR9 culvert on Lake Creek. Therefore, the effects of the SR9 culvert were not analyzed. WSE's model assumed that all run off generated upstream of the model boundary would reach the model unattenuated (or without ponding upstream of SR9). Therefore, the ponding effects of the SR9 culvert, which currently causes flows to be delayed and reduced in magnitude before reaching the abandoned railroad berm, are not represented in the existing conditions modeling.

Figure 1. Project Area and Key Project Features.

2. HYDROLOGY

To assess current flooding issues and evaluate proposed flood reduction alternatives WSE first needed to estimate the magnitude of flood peaks for broad range of flood events. For each flood event the flood peak is defined as the maximum volumetric rate of water (referred to as flow or discharge) passing through a given cross-sectional area during the flood event. Discharge and flow are used interchangeably in this report and are reported in units of cubic feet per second (cfs). WSE estimated the magnitude of the 2-, 10-, 25- and 100-year flood peaks occurring on Lake Creek and the unnamed creek. These floods corresponded to the likelihood that they could occur within any given year; a 2-year flood has a 1 in 2 (50%) chance of occurring in any year whereas a 100-year event has a 1 in 100 (1%) chance of occurring. The larger the “year event” the larger the flood. These events were selected because they provide a broad range of floods, small to large, to evaluate. WSE estimated the flows using an on-line web application tool known as Streamstats (USGS, 2019). StreamStats was developed by the United States Geological Survey (USGS) and uses a series of regional regression equations to estimate the average annual instantaneous peak flood discharge at a specific location within a watershed and is commonly used to estimate peak flows (Mastin et al, 2016). Discharges were computed at the confluence of Lake Creek and the unnamed creek just upstream from the abandoned railroad berm. The contributing drainage basins for both streams are 563 acres and 93 acres respectively, and are illustrated in Figure 2. The computed peak discharges for each event are listed in Table 1.

Storage of flood water along the upstream side of the abandoned railroad berm attenuates (reduces and spreads out through time the peak of the) downstream flows and needed to be accounted for in the hydraulic modeling described in the next section. This required WSE to construct hydrographs for each flood event, a task that was accomplished using a software tool known as the Western Washington Hydrology Model 2012 (WWHM). The model requires the input of precipitation data, soil type, land slope, and landcover type for the contributing drainage basin. Precipitation data were obtained from the Burlington airport which is the nearest precipitation gage with a relatively long period of record. Soil and land slope data were obtained from the USDA’s Gridded Soil Survey Geographic (gSSURGO) Database (USDA-NRCS, 2016) and land cover types were identified from 2017 NAIP imagery (USDA-FSA, 2017). WSE ran the WWHM model to produce a continuous synthetic record of flows for the period October 1, 1948 to September 30, 2009, the period for which precipitation data are available. The resulting flows produced a continuous series of flood hydrographs which were examined by WSE. WSE then selected pattern hydrographs for both Lake Creek and the unnamed tributary which appear to represent common extreme flood events on both streams. The hydrographs for Lake Creek and the unnamed creek were then scaled up (adding water) or down (removing water) until the peak discharge in the hydrograph matched the 2-, 10-, 25-, and 100-year instantaneous flood peaks from StreamStats. The pattern hydrographs are shown in Figure 3.

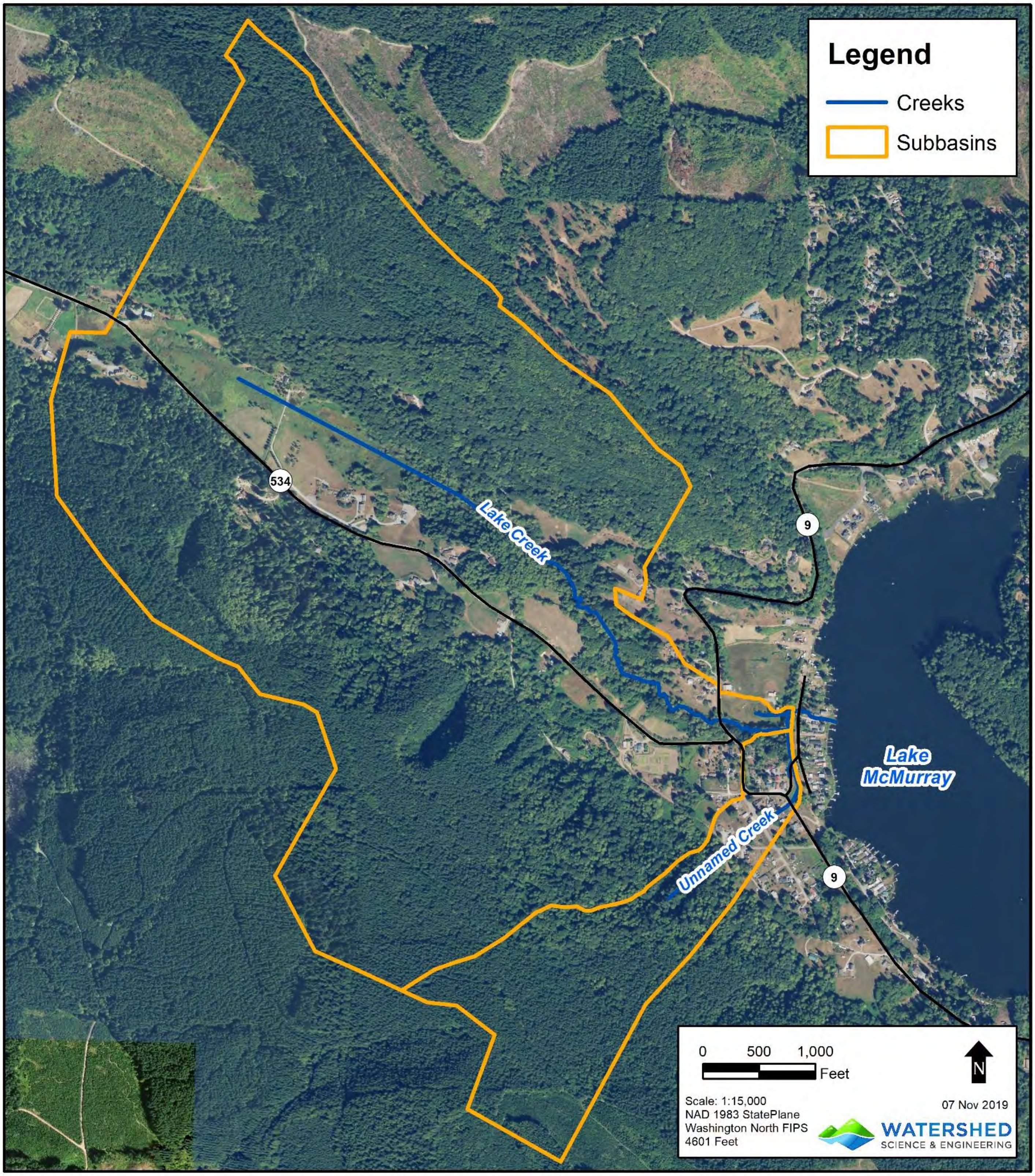

Figure 2. Contributing drainage basin map for Lake Creek and the unnamed creek.

Table 1. Annual Instantaneous Peak Flows Computed by StreamStats.

Return Interval (Years)	Lake Creek Peak Discharge (cubic feet per second)	Unnamed Creek Peak Discharge (cubic feet per second)
2	31	6
10	61	11
25	76	14
100	100	18

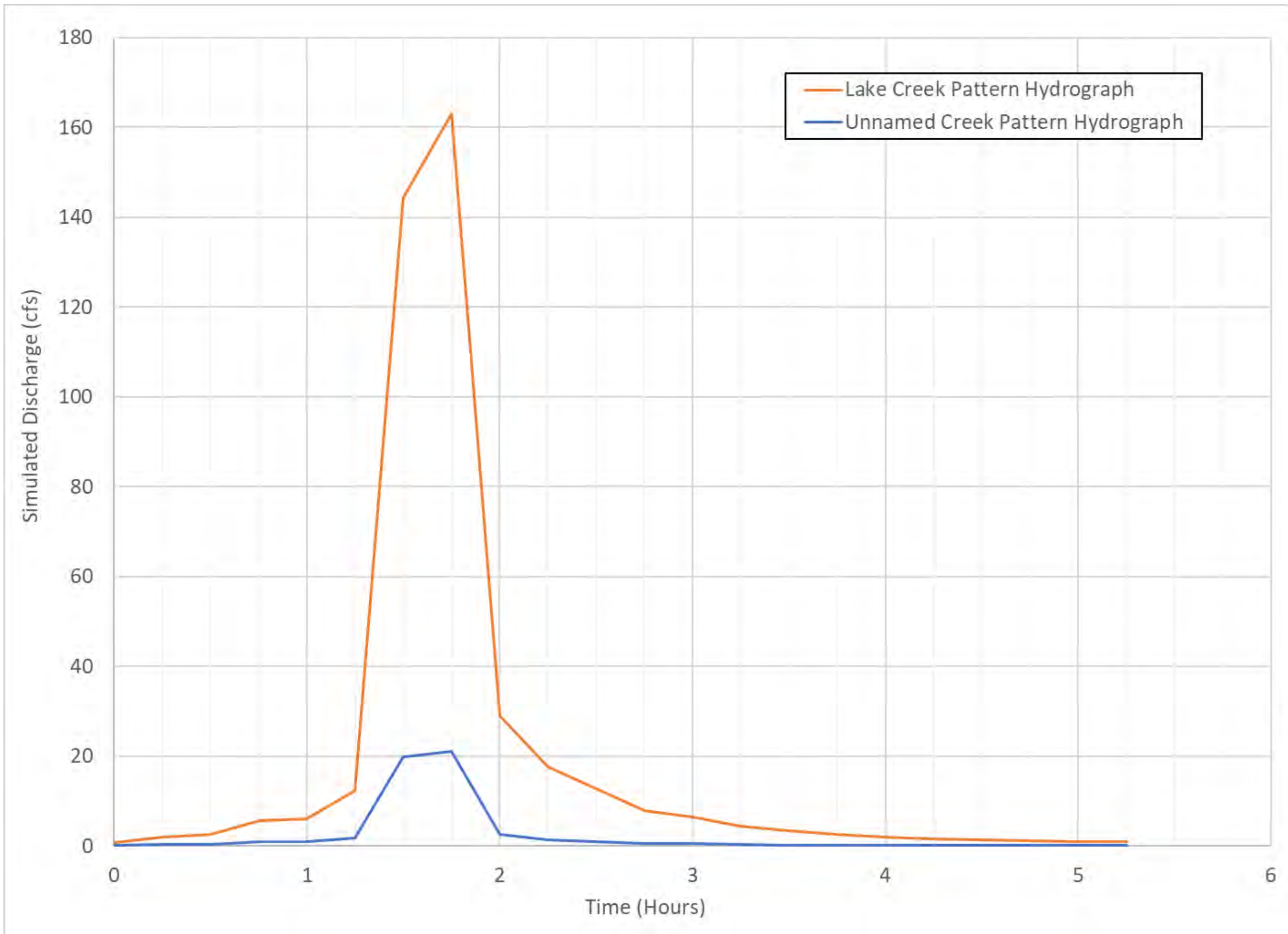

Figure 3. Flood Hydrographs for Lake Creek and the Unnamed Creek.

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3. FLOOD MODELING

3.1 Hydraulic Model Development

Flood patterns within the project area are complex because water follows multiple routes to the lake. To simulate these patterns WSE used a relatively complex 2D unsteady hydraulic model known as HEC-RAS 2D which was created by the US ARMY Corps of Engineers (USACE-HEC, 2019).

In addition to the flood hydrographs described in the preceding section, ground topography is a key data set that must be incorporated into the model as it determines where the water travels and to what depths it ponds when it is no longer within the channel. WSE developed the required topography by combining 2017 North Puget LiDAR data (Quantum Spatial, 2017) with survey data collected in July 2019 by the County specifically for this project. The County survey included culvert inverts and dimensions at Hull Drive, Hull Road, the abandoned railroad berm, and at each driveway culvert in the Hull Road roadside ditch. It included the unnamed creek between SR9 and Hull Drive and the channel that extends from Hull Road to the lake. Once the topography was input into the model, a computational gridded mesh was created to represent the topography in a form that the model requires to complete hydraulic calculations. The mesh cells have an average size of 5 feet by 5 feet square and cover the area within the black outline in Figure 4.

All known culverts are included in the model and are identified in Figure 4. All are assumed to be clear of sediment and debris except the two under the abandoned railroad berm. During a site visit WSE observed that the two 36-inch diameter concrete pipe culverts are partially plugged with sediment. The right (south) culvert is blocked approximately 75% and the left (north) 25%, for a total blockage of approximately 50%. To represent the blockage in the existing condition model, only one 36-inch culvert was modeled.

The model requires the user to input what are referred to as model boundary conditions which are used by the model at the start of a model simulation. This required WSE to provide an elevation for Lake McMurray and inflow hydrographs for Lake Creek and the unnamed tributary. The locations of where these data were input into the model are identified by the thick red lines in Figure 4. The inflow hydrograph developed for Lake Creek did not take into account the ponding effects of the SR9 culvert. All runoff generated in the Lake Creek watershed was assumed to inflow into the model domain unattenuated. To simulate existing flooding, the elevation of Lake McMurray was set to a high winter flood lake level estimated from flood photos provided by landowners (see Photos 1 – 3 presented later in this document).

The model also requires the user to input land cover type in the form of Manning's n coefficients. Manning's n values represent flow roughness which the model uses to calculate energy losses as the flow moves through or over each land cover type. WSE used engineering judgement and experience to estimate appropriate Manning's n values based upon field observations and review of the 2017 NAIP aerial imagery. The selected Manning's n values are identified in Figure 5. Often Manning's n values are refined through a process known as model calibration; however, calibration can only take place if observed highwater marks and stream discharges are available. No such data exist for the project area; therefore, WSE could not calibrate the model. Instead WSE completed a series of sensitivity model runs to validate that it produces results that appear reasonable when compared to flood photos (Photos 1-3) provided by several landowners. Additionally, hydraulic modeling used in the WSDOT SR9 culvert replacement design used similar Manning's n values, 0.06 for the Lake Creek channel and 0.08 for the overbank areas downstream of SR9 (WSDOT, 2019).

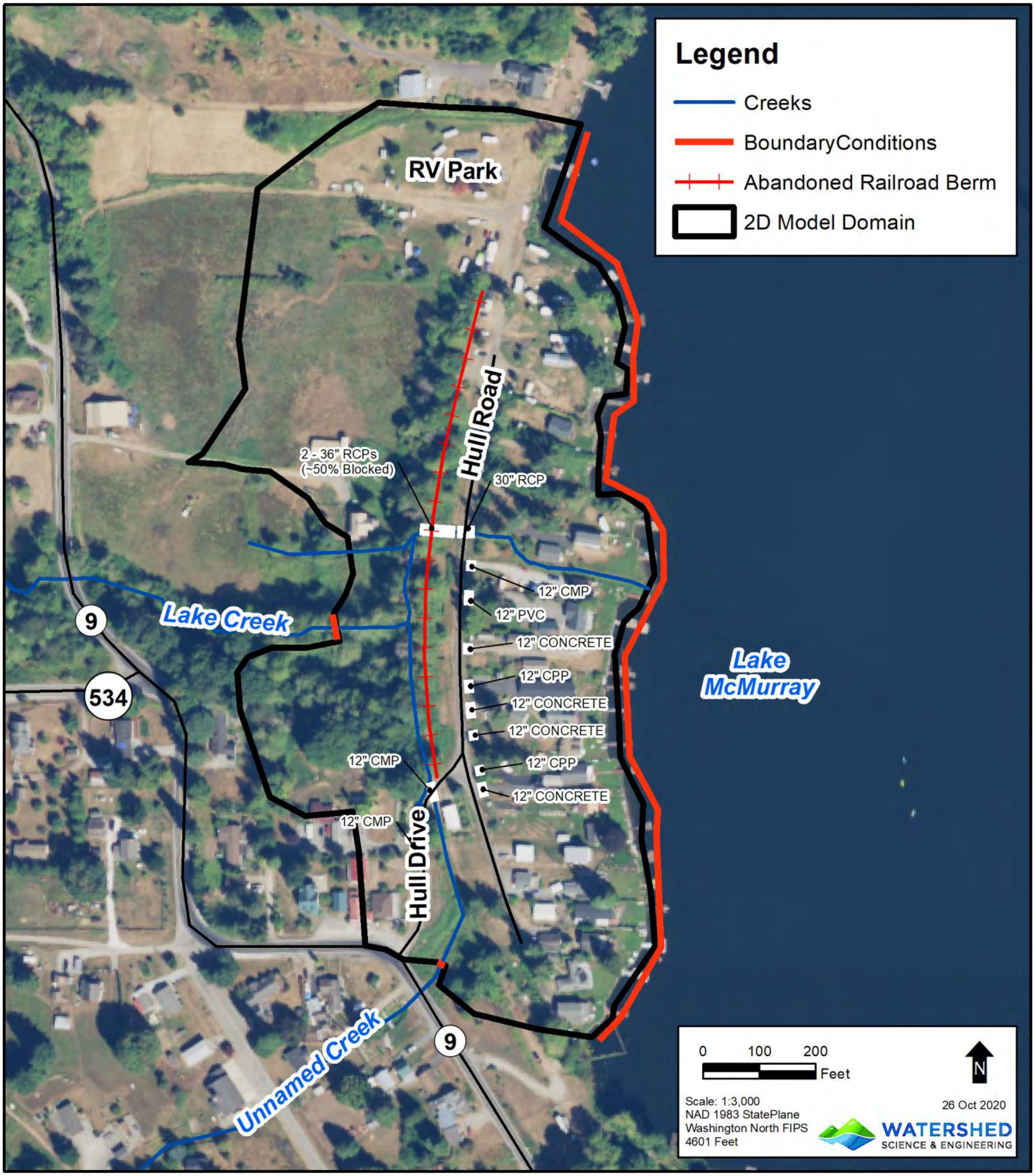

Figure 4. HEC-RAS 2D Hydraulic Model Domain, Boundary Condition Locations, and Culvert Dimensions.

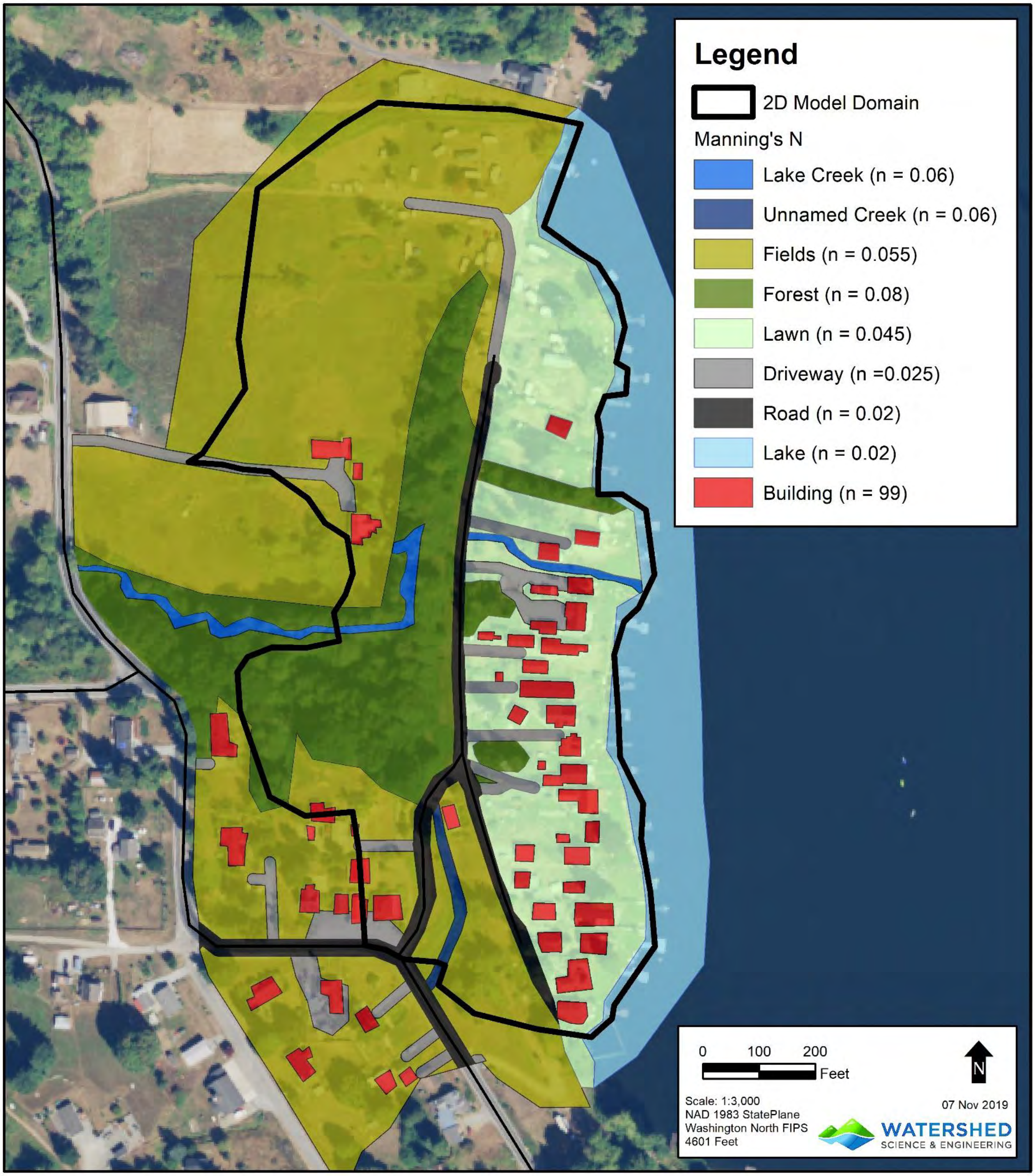

Figure 5. HEC-RAS 2D Manning's N Values.

3.2 Flood Characteristics for Existing Conditions

The HEC-RAS 2D hydraulic model was used to estimate flood depths and inundation limits for existing conditions for the four flood events, 2-, 10-, 25-, and 100-year floods. Model results, illustrated in Figures 6 to 9, combined with personal observations from landowners, reveal that there are six distinct flood problems within the project area:

1. Numerous lake front properties flood in the winter by high lake levels.
2. Four lake front properties flood by water that spills from the unnamed creek at the inlet to the Hull Drive culvert.
3. A large area that includes one home floods by water that ponds along the upstream (western) side of the abandoned railroad berm.
4. The RV park at the north end of Hull Road floods by the water that flows north from the ponded area upstream of the abandoned railroad berm.
5. At least three lake front properties flood by water that spills out of the road side ditch along Hull Road.
6. Two properties flood that border the stream between Hull Road and Lake McMurray.

Each of these are discussed below:

1. Flooding of Lake Front Properties by Lake McMurray

During major winter rain events the level of Lake McMurray rises significantly and floods the yards of most lake front properties along Hull Road. Photos 1 to 3 show examples of the lake flooding that occurred in 2015 and 2018. WSE estimated that the lake elevation rose to approximately 232.8 ft during these floods by comparing the flood extents in these photographs to available topographic contours. Anchor (2010) reported that the lake rose to elevation 234.3 feet during a major storm in 2009, the highest level reached in recent memory. Figures 6 to 9, presented later in this report, show the extent of the flooding along the entire shoreline for an elevated lake level of 232.8 ft. Lake front property owners have reported to the County that the lake level has increased significantly in recent years which they believe is due to obstructions in the lake outlet channel, possibly beaver dams. Between February and November 2020, WSE investigated the cause of elevated lake levels. WSE first conducted a field investigation which involved making observations while walking from the lake outlet to approximately 3,800 feet downstream and collecting aerial imagery and videography using a drone. The 2017 LiDAR topography of the lake outlet was also examined. The results of the field investigation are summarized in a separate memorandum which is attached to this report as Appendix A. WSE then completed a hydraulic investigation which involved creating a hydraulic model of the outlet channel to examine the relative impact various obstructions are having on the channel, and to test several alternatives to reduce the impact of the obstructions. The results of the hydraulic modeling investigation are presented in Appendix B.

Both investigations revealed that multiple features are working together to limit / reduce the capacity of the lake outlet channel including vegetation, logs, abandoned beaver dams and a sediment delta created by the unnamed tributary that enters Lake Creek 300-feet downstream from McMurray Shore Drive. Solutions considered included clearing an unobstructed flow path through the existing vegetation, abandoned beaver dams, and logs, removing all or a portion of the sediment delta, and implementing an effective beaver management program to include dam removal and beaver relocation or extermination. WSE note that although these may be logical solutions, they may be difficult if not impossible to implement due to access and environmental permit restrictions.

Photo 1. High lake levels during winter flood. Photo is immediately north of where Lake Creek empties into the Lake McMurray. (Photo provided to County by landowner, photo taken 11-15-2015).

Photo 2. High lake levels during winter flood. Photo is immediately north of where Lake Creek empties into the Lake McMurray. (Photo provided to County by landowner, photo taken 11-15-2015).

Photo 3. High lake levels during winter flood. Photo is looking north from approximately 300 feet south of where Lake Creek empties into the Lake McMurray. (Photo provided to County by landowner, photo taken 2-5-2018).

2. Flooding of Lake Front Properties by Flow Spilling out of the Unnamed Creek at Hull Drive

Model results reveal that the existing 12-inch corrugated metal pipe (CMP) culvert that carries the unnamed creek under Hull Drive is too small to pass floods, causing water to spill over the right (east) bank and flow down Hull Drive. The water crosses Hull Road and floods portions of lake front properties (illustrated in Figures 6 to 9). Water also enters the roadside ditch along Hull Road, which contributes to the flooding of additional properties further north along the ditch.

Following a flood in 2018, the section of the unnamed stream upstream from Hull Drive was dredged and the spoils used to build a small flood containment berm along the right bank (Photo 4). This was completed by one or more private property owners, not the County. The hydraulic model indicates that the berm and channel currently contain the 100-year flood except at the inlet to the Hull Drive culvert. The capacity of this dredged section is already decreasing due to sediment deposition and vegetation growth. Periodic maintenance dredging and vegetation removal will be required to preserve channel capacity to prevent overtopping of the earthen berm. If the berm overtops, erosion on the landward side of the berm could cause the berm to fail, sending focused flow toward Hull Road and multiple lake front properties.

Photo 4. Unnamed tributary channel leading to Hull Drive shortly after it was dredged and the spoils placed to form a small berm along the east bank. (Photo provided by County, October 15, 2018).

3. Ponding of Water Upstream (west) of the Abandoned Railroad Berm

Water from Lake Creek and the unnamed creek flood a large area of land along the upstream (west) side of the abandoned railroad berm (Figures 6 to 9). The water ponds because the existing culverts under the berm do not have the capacity to pass the flow in-part because they are 50% plugged with sediment (Photo 5) and they are too small even if they were free of sediment. Other factors contribute to the ponding as well including the flatness of Lake Creek and the unnamed creek, thick vegetation leading to the culverts, and the near 90-degree right-hand turn the channel must make to enter the culverts. The ponding impacts one home located just upstream (west) of the culverts and contributes to the flooding described in item 4.

Photo 5. Viewing downstream (east) to the inlets of the culverts under the abandoned railroad berm. The culverts are partially plugged with sediment (May 30, 2019).

4. Flooding of the RV Park at the North End of Hull Road

During the 10-year and larger floods, the water that ponds upstream (west) of the abandoned railroad berm begins to flow north to flood portions of the RV park and several adjacent parcels (Figures 7 to 9). It appears that there is another small stream that passes west to east along the northern edge of the RV park. It is not included in the hydraulic model; therefore, flooding is likely under-represented in the vicinity of the RV park in the figures. This small stream has a contributing drainage area of approximately 40 acres and does not contribute to the Lake Creek basin shown in Figure 2.

5. Flooding of Lake Front Properties by Water Spilling out of the Hull Road Ditch

The stream channel between Hull Road and the lake is choked with vegetation and sediment which has reduced its ability to convey water to the lake. This has elevated water levels at the outlet of the Hull Road culvert which in-turn forces a portion of the water exiting the culvert to enter and flow south in the road side ditch shown in Photo 6. The ditch does not have the capacity to contain the total flow and water spills through low spots along the east side of the ditch and floods several lake front properties (Figures 6 to 9).

Photo 6. Viewing upstream (south) along the Hull Road ditch. The culvert near the mail box is the culvert that carries the stream under Hull Road. The stream exits the left side of the photo (May 30, 2019).

6. Flooding of the Two Parcels that Border the Stream between Hull Road and Lake McMurray.

The channel between Hull Road and the lake was choked with grass and sediment (Photos 7 and 8). Fortunately, flooding along both properties has been limited due in part to the limited capacity of the Hull Road and abandoned railroad berm culverts (Photos 9 and 10). Flooding caused by the high lake level has been the primary problem for both properties (Figures 6 to 9). This channel segment will need to be cleaned periodically to maintain capacity to prevent flooding, regardless of whether the culverts under Hull Road or the abandoned railroad berm are enlarged.

Photo 7. Viewing downstream (east) from Hull Road along the stream channel that leads to Lake McMurray. The roadside ditch exits the right side of the photo (May 30, 2019).

Photo 8. Viewing downstream (east) along the channel between Hull Road and Lake McMurray. Channel is choked with grass (May 30, 2019).

Photo 9. Viewing upstream (west) to Hull Road culvert along the channel that leads to the lake. (Photo provided to County by landowner, November 15, 2015).

Photo 10. Viewing south across channel that leads to the lake. (Photo provided to County by landowner, November 15, 2015).

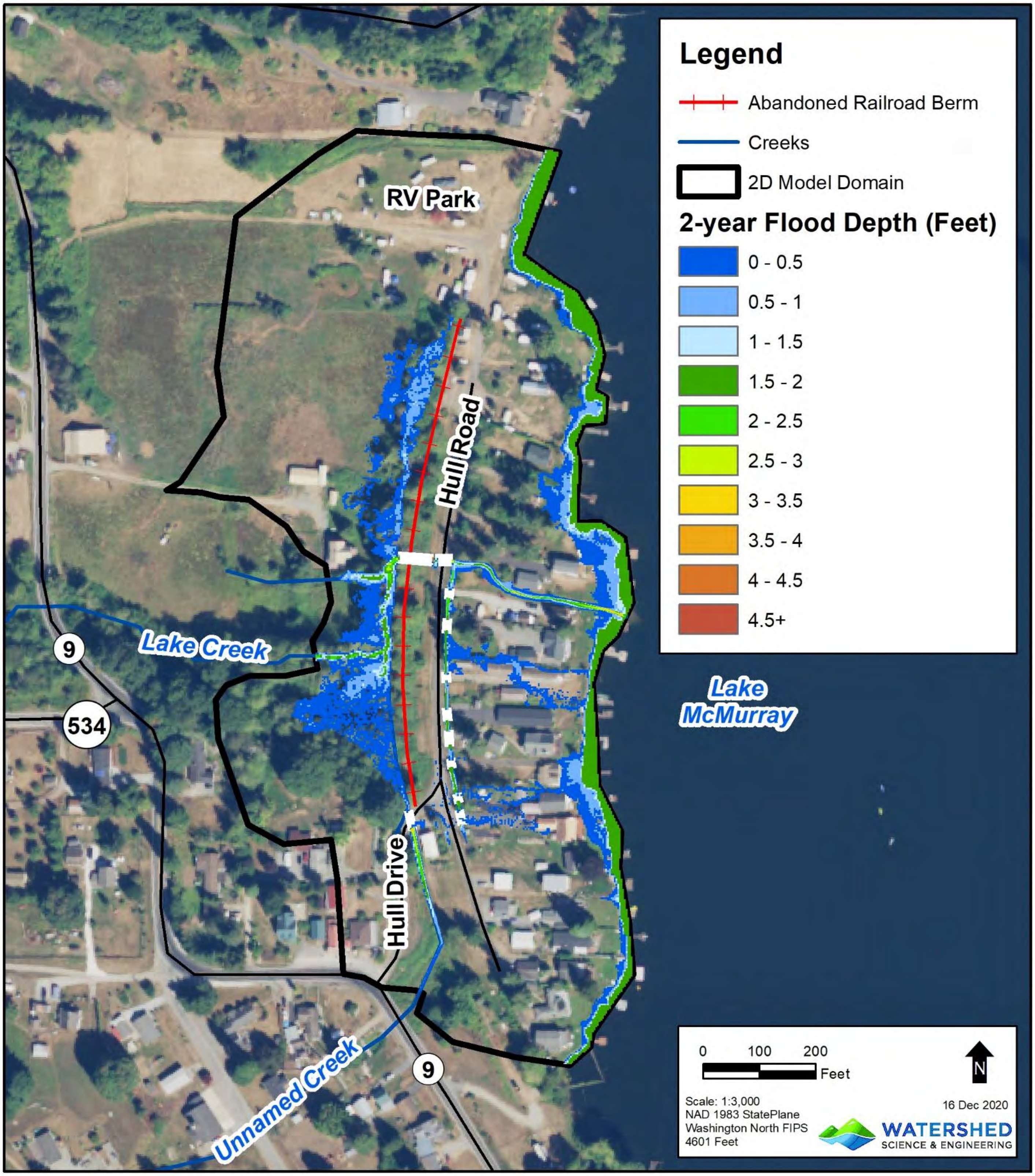

Figure 6. Existing Conditions 2-year Flood Depth with High Lake Level (Elevation 232.8 ft).

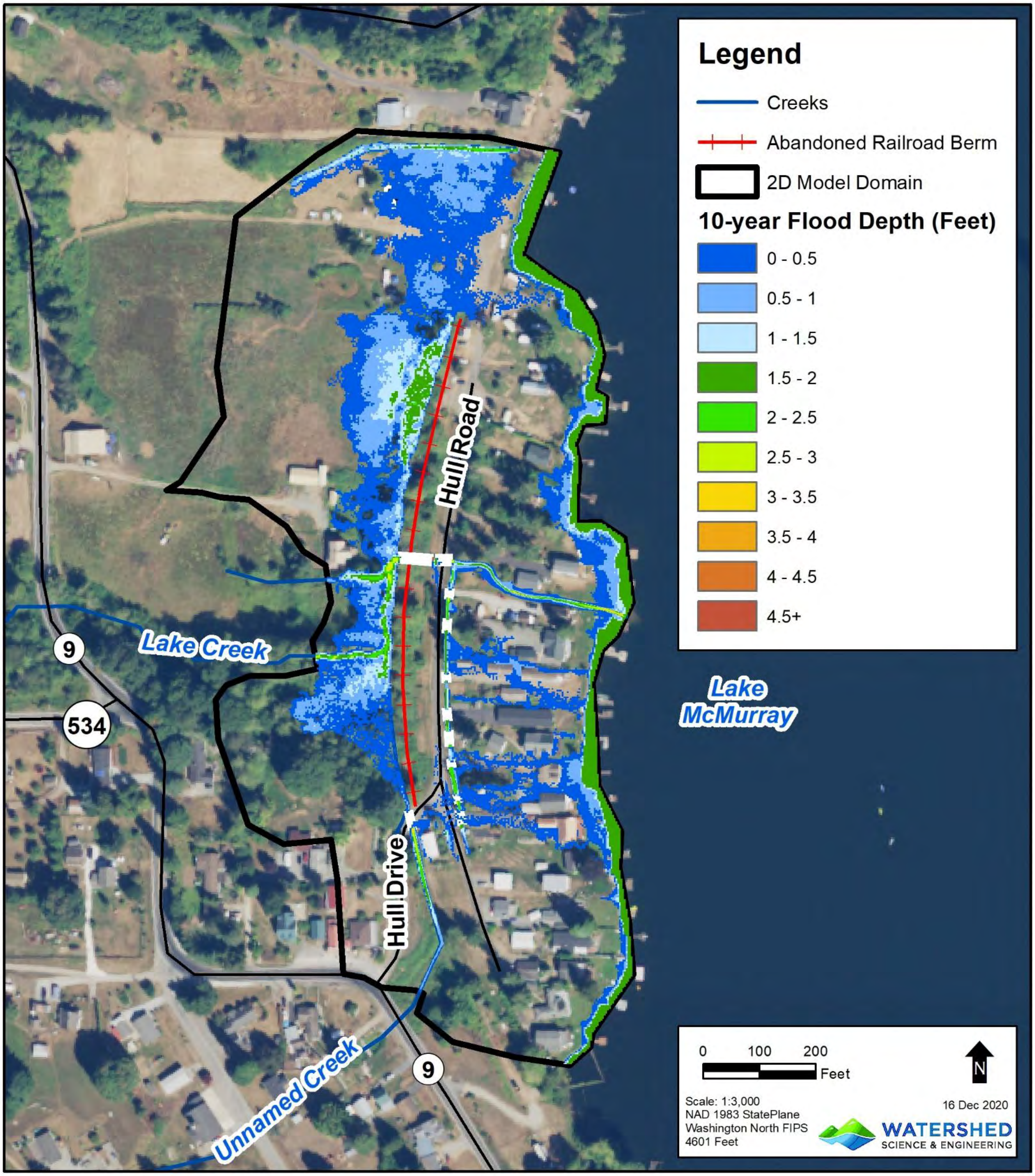

Figure 7. Existing Conditions 10-year Flood Depth with High Lake Level (Elevation 232.8 ft).

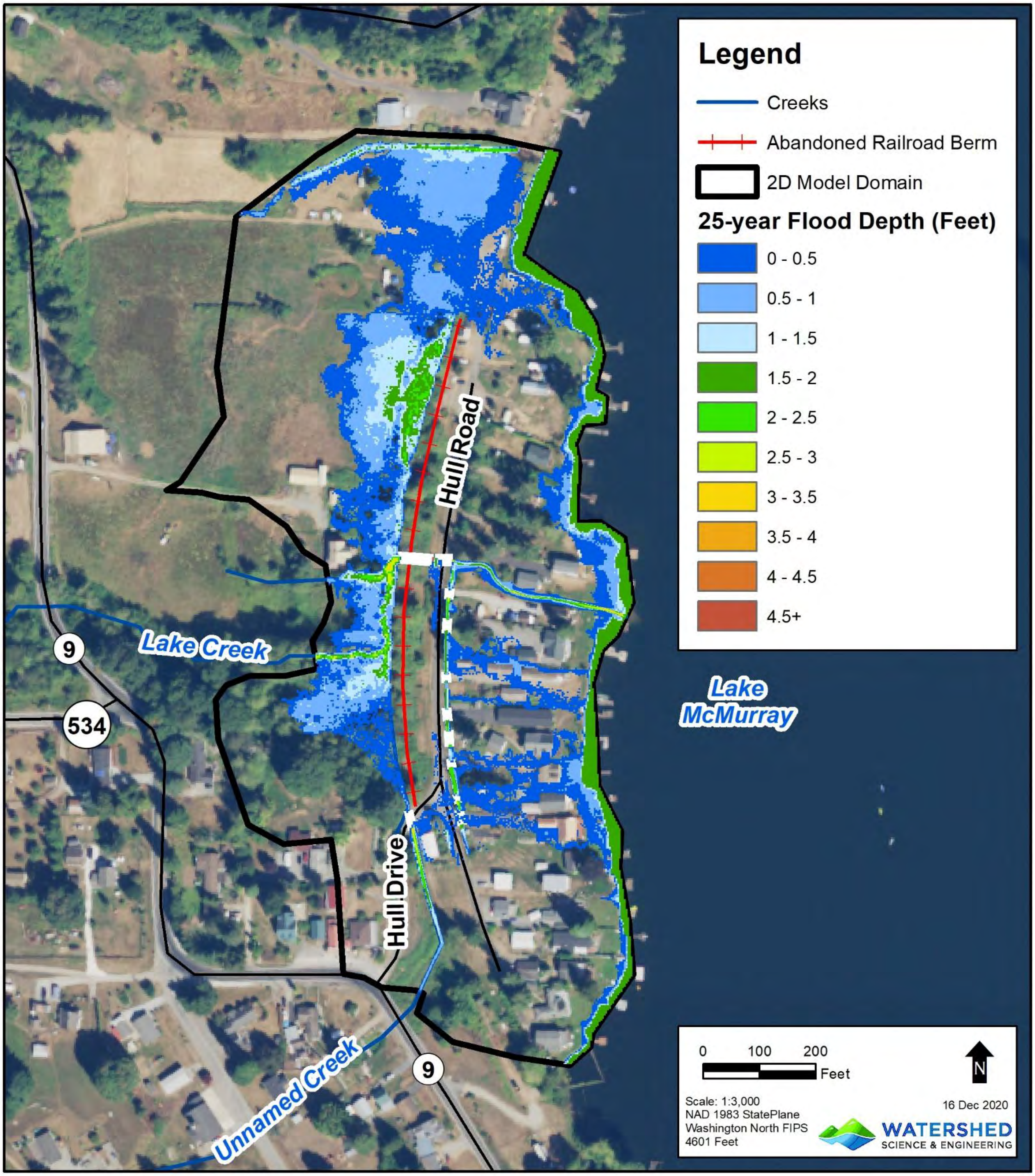

Figure 8. Existing Conditions 25-year Flood Depth with High Lake Level (Elevation 232.8 ft).

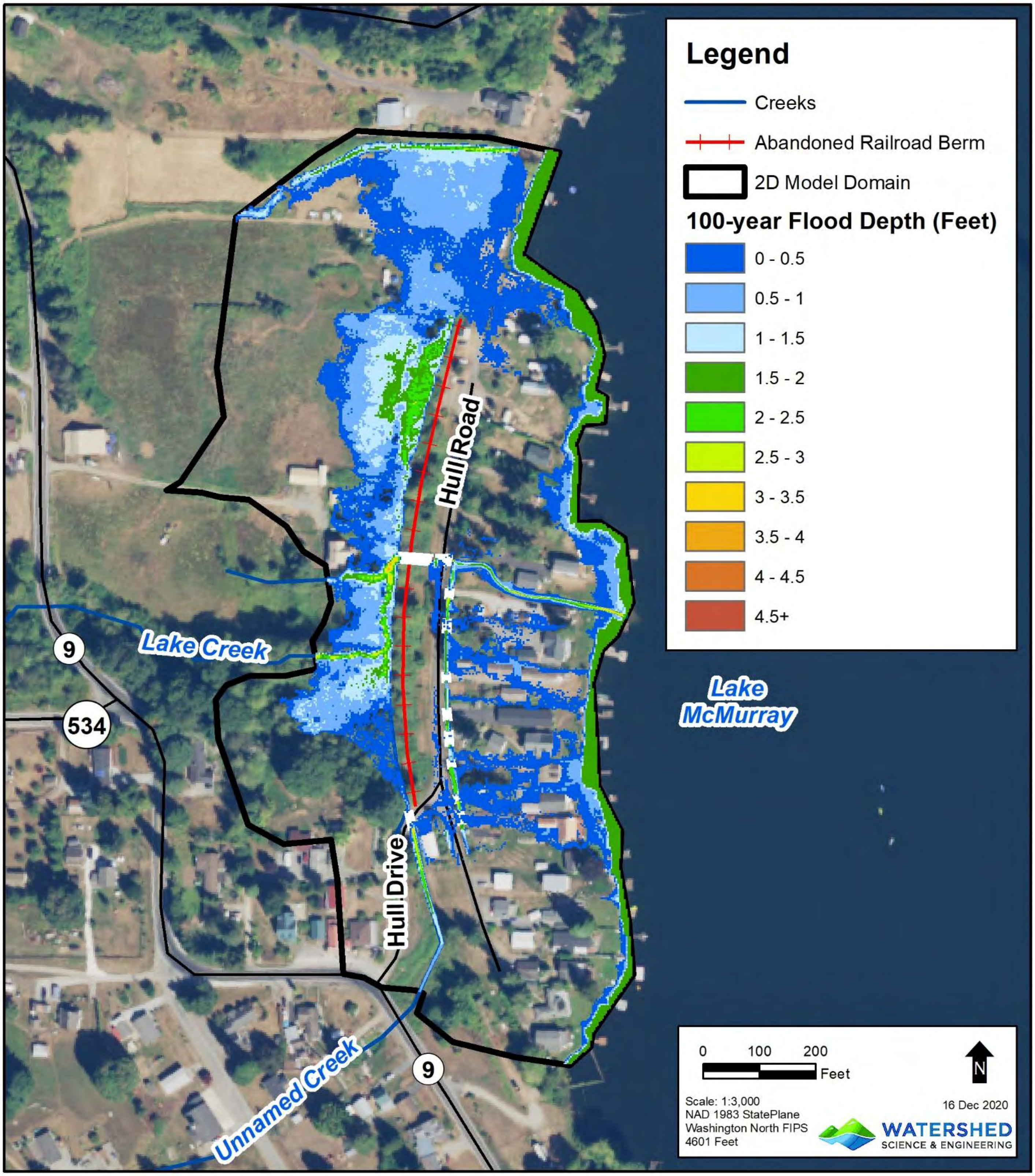

Figure 9. Existing Conditions 100-year Flood Depth with High Lake Level (Elevation 232.8 ft).

3.3 Flood Relief Alternatives and Expected Flood Reduction Benefits

The HEC-RAS model was used to test five flood reduction alternatives. They:

1. Increase the size of the culvert under Hull Drive.
2. Remove obstructions from the lake outlet channel.
3. Modify the culverts both under the abandoned railroad berm and Hull Road.
4. Remove the abandoned railroad berm.
5. Construct a new stream channel to the lake.

The potential benefits of each as revealed by the hydraulic model are described below.

Alternative 1 – Increase the Size of the Culvert under Hull Drive

Increasing the size of the culvert under Hull Drive from the existing 12-inch CMP to a 24-inch RCP (Reinforced Concrete Pipe) will stop most floods from overtopping the right bank at the culvert inlet and flowing down Hull Drive to flood multiple lake front properties. Figures 10, 11, and 12 compare the 2-, 10- and 100-year flood limits for Alternative 1 to those for existing conditions. The blue shading in the figures shows areas that the model predicts will no longer flood. The figures reveal that water no longer overtops the right (east) bank at the culvert inlet. Stopping the spill eliminates flooding of both Hull Drive and Hull Road as well as flooding on four lake front properties. The analysis assumes the culvert entrance remains open and does not clog with sediment or woody debris.

A larger culvert will increase flows to the ponded area upstream of the abandoned railroad berm. Figures 13, 14, and 15 show the change in maximum 2-, 10-, and 100-year water surface elevations, respectively, caused by increasing the size of the Hull Drive culvert and taking no other action, as predicted by the HEC-RAS model. The largest rise of 0.3 feet will occur at the outlet of the upsized Hull Drive culvert in the 10-year event and 0.5 feet in the 100-year event. The increase in water surface elevation in the 10- and 100-year events diminishes as water flows to the north. Maximum increases to water surface elevation near the home located just upstream of the abandoned railroad culverts is approximately 0.12 feet during the 10-year event and 0.13 feet during the 100-year event. During the 2-year event the largest increase of 0.11 feet will occur at the north end of the ponded section near the RV park. Near the house located west of the railroad berm the maximum increase in water surface elevation during the 2-year event will be approximately 0.04 feet.

If the new Hull Drive culvert needs to meet fish passage requirements it will need to be larger than a 24-inch RCP. A larger culvert will not change the model results described above.

Alternatives 2, 3, 4, and 5 described below assume that the Hull Drive culvert has been enlarged to a 24-inch RCP.

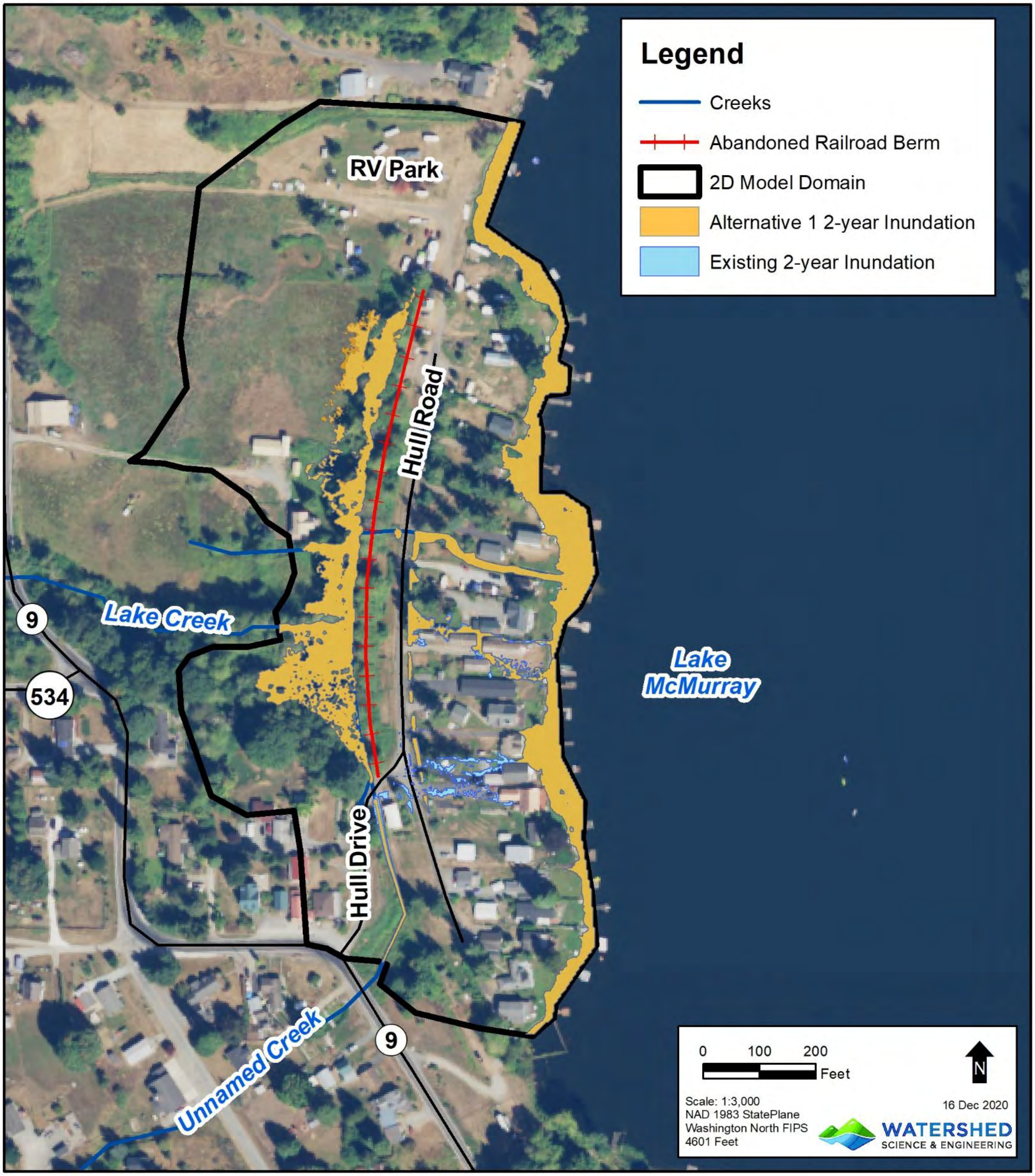

Figure 10. 2-year Flood Inundation Limits Alternative 1 vs. Existing Conditions (see Figure 13 for changes in water depth).

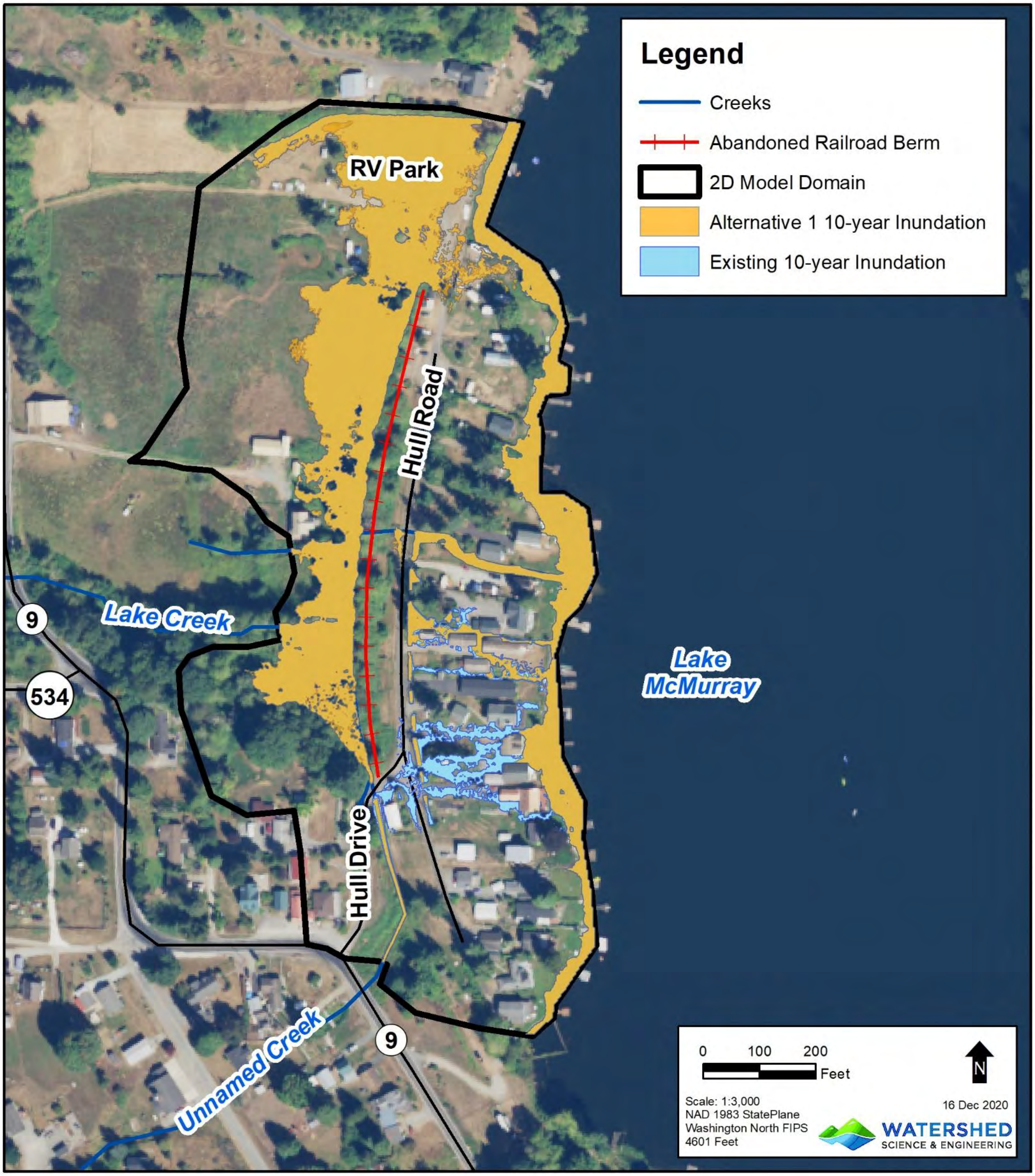

Figure 11. 10-year Flood Inundation Limits Alternative 1 vs. Existing Conditions (see Figure 14 for changes in water depth).

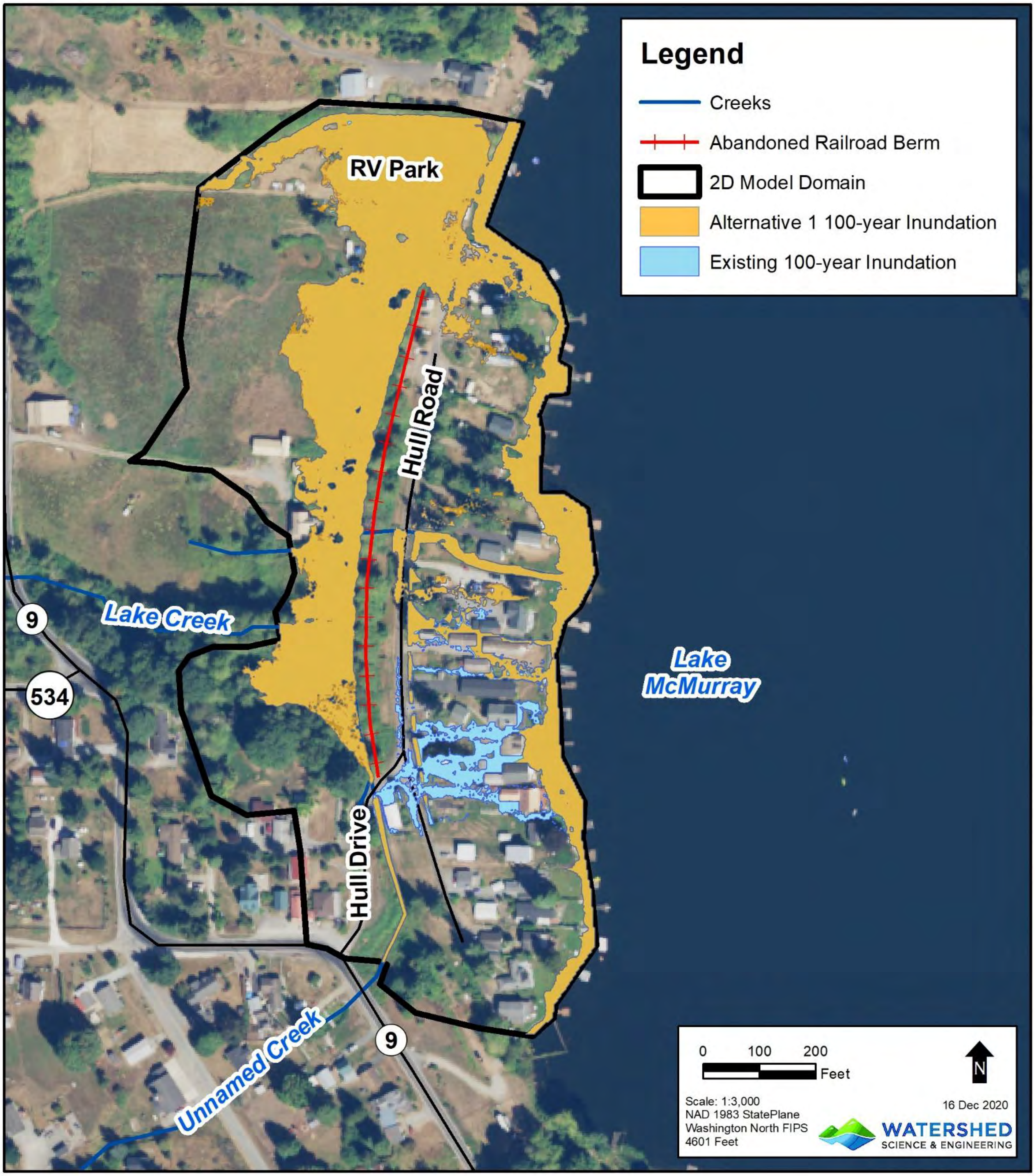

Figure 12. 100-year Flood Inundation Limits Alternative 1 vs. Existing Conditions (see Figure 15 for changes in water depth).

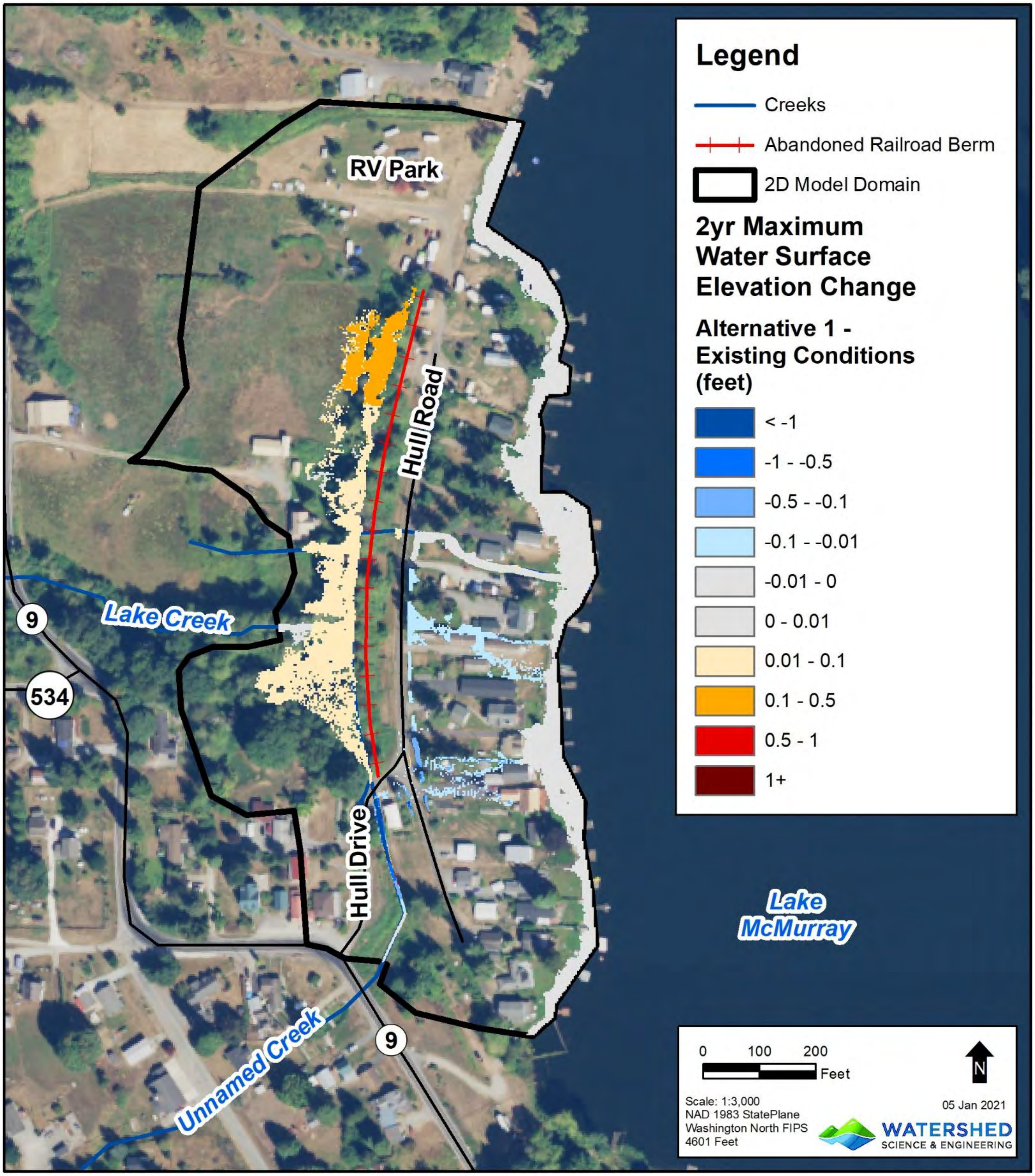

Figure 13. 2-year Flood Water Surface Elevation Change Alternative 1 vs. Existing Conditions.

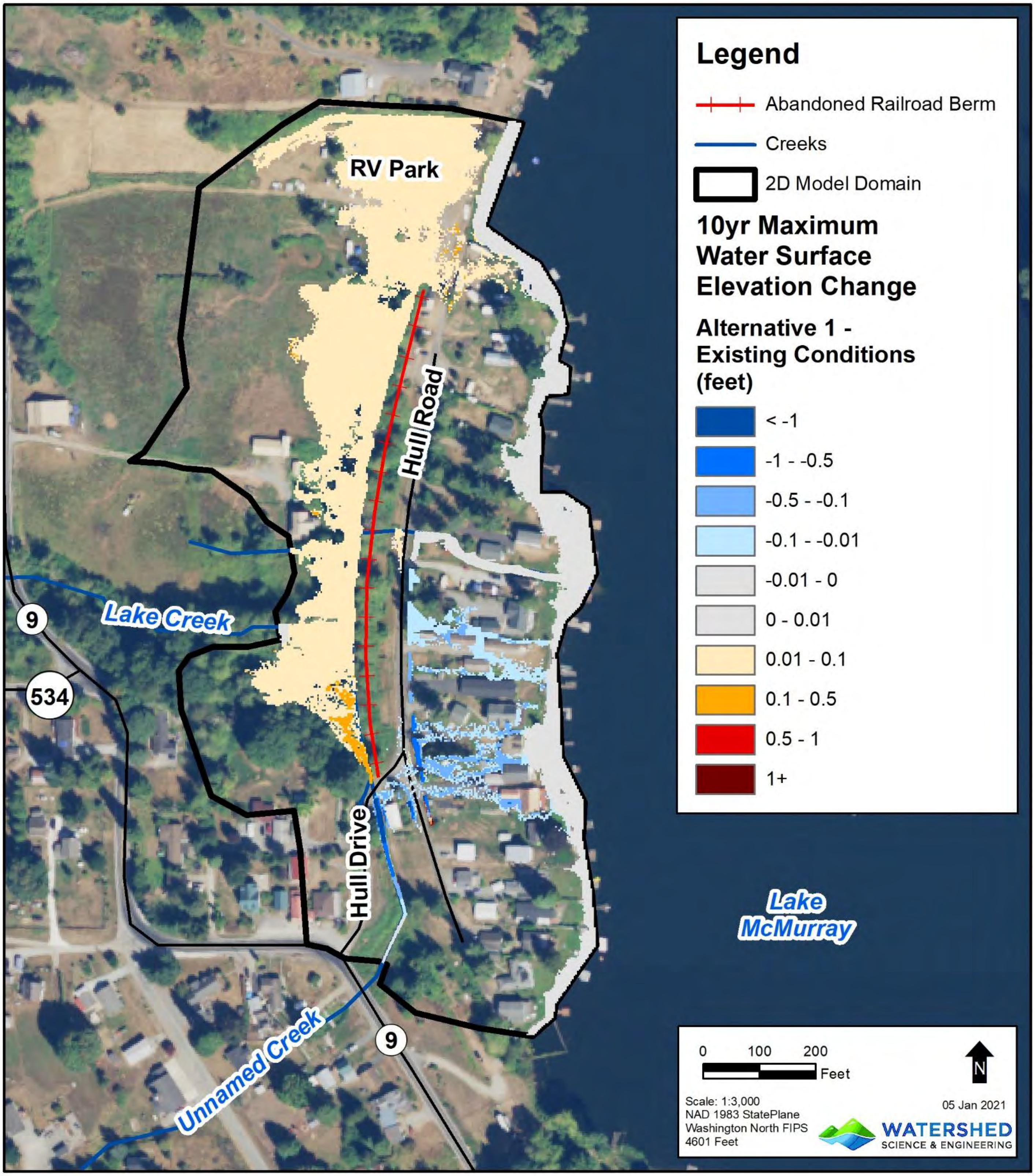

Figure 14. 10-year Flood Water Surface Elevation Change Alternative 1 vs. Existing Conditions.

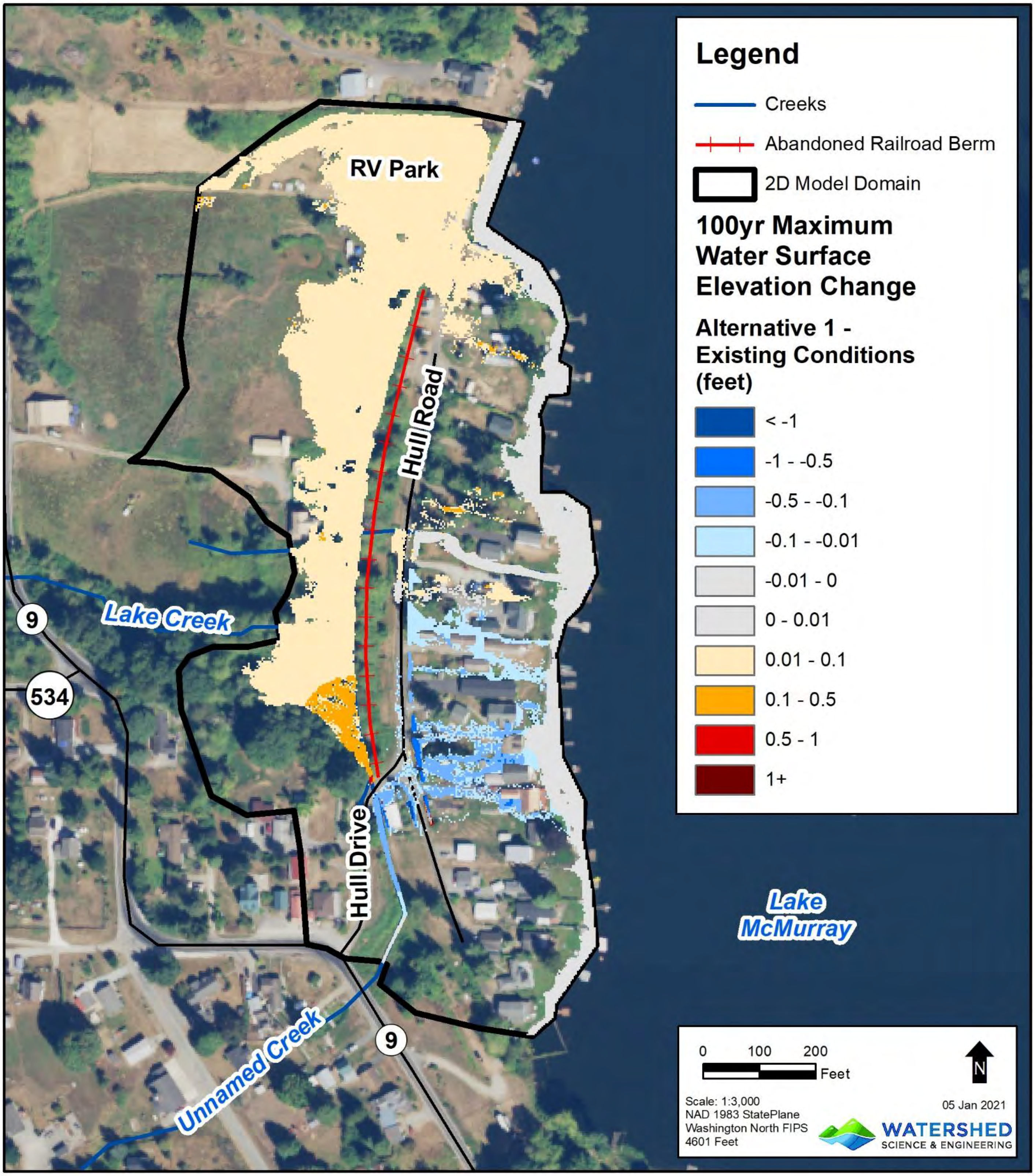

Figure 15. 100-year Flood Water Surface Elevation Change Alternative 1 vs. Existing Conditions.

Alternative 2 – Remove Obstructions from the Lake Outlet

This alternative assumes that there are obstructions in the lake outlet channel and that they can be removed to lower the winter lake level from 232.8 feet to 231 feet. According to property owners, 231 feet is a reasonable estimate of the typical non-flood winter lake elevation. Figure 16, 17, and 18 compare the 2-, 10-, and 100-year model results, respectively, for Alternative 2 to those for existing conditions. The blue shading in the figures show areas that the model predicts will no longer flood during these events.

Alternatives 3, 4, and 5 assume that the lake level has been lowered to 231 feet and the culvert under Hull Drive has been enlarged.

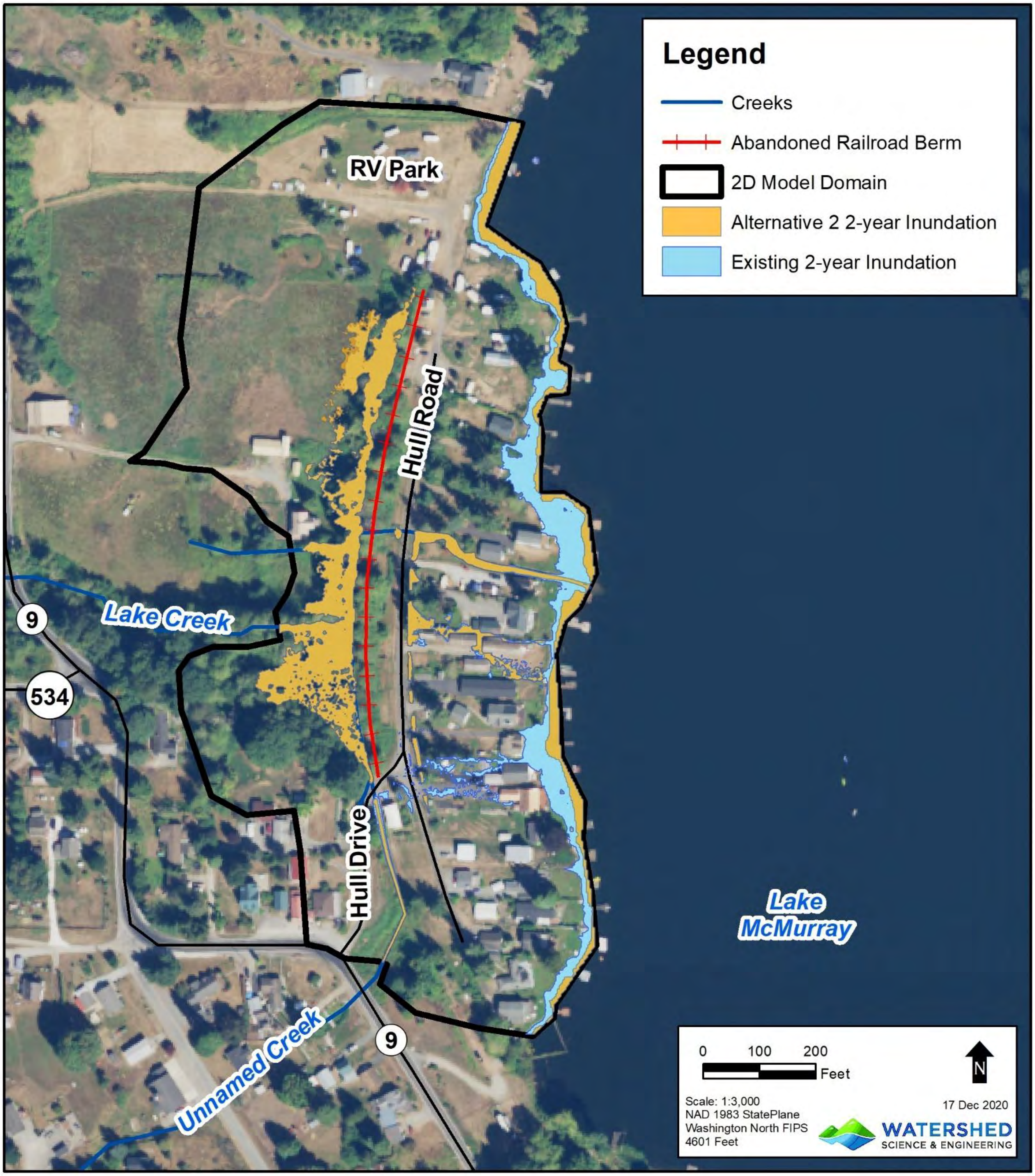

Figure 16. 2-year Flood Inundation Limits Alternative 2 vs. Existing Conditions.

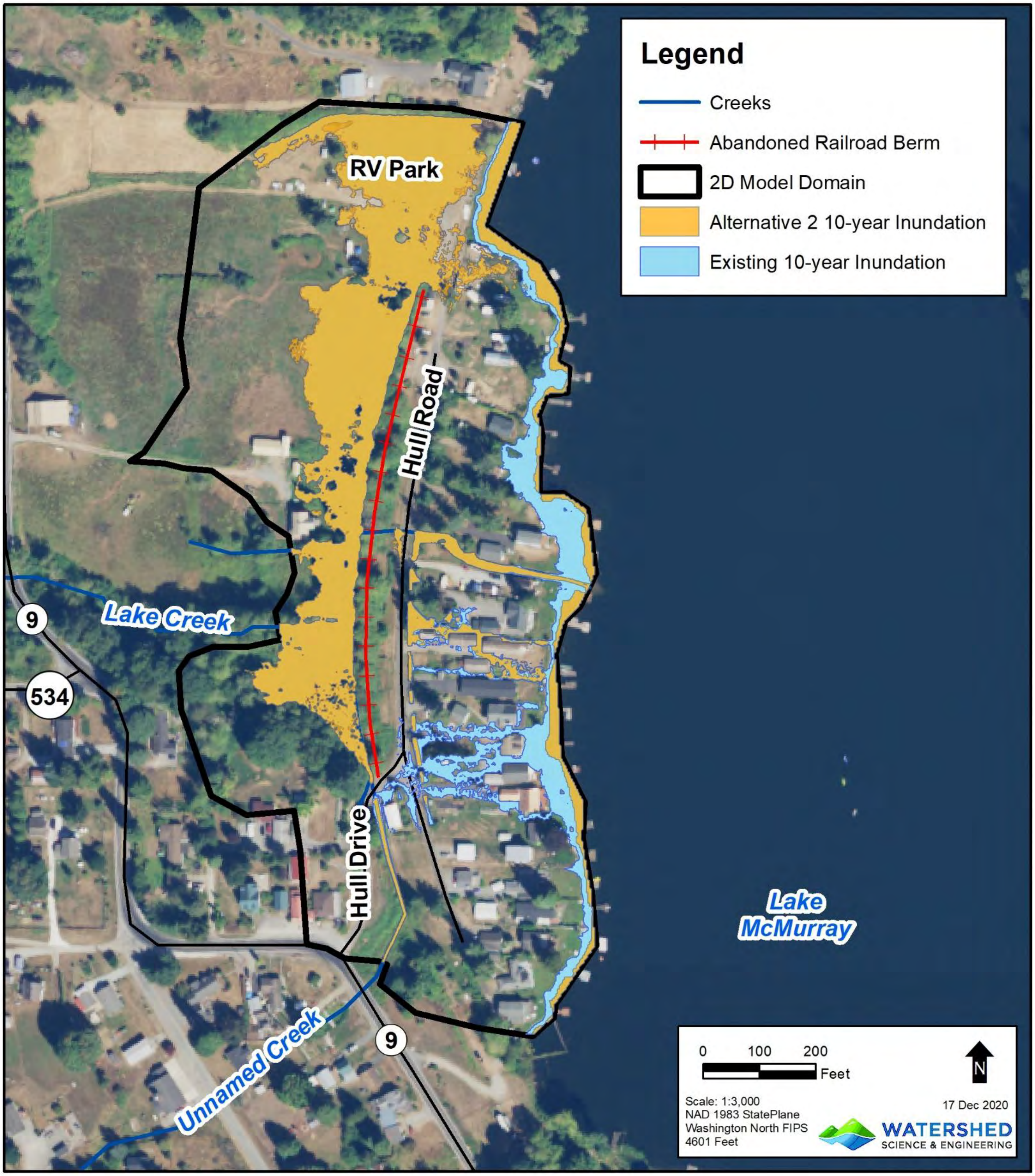

Figure 17. 10-year Flood Inundation Limits Alternative 2 vs. Existing Conditions.

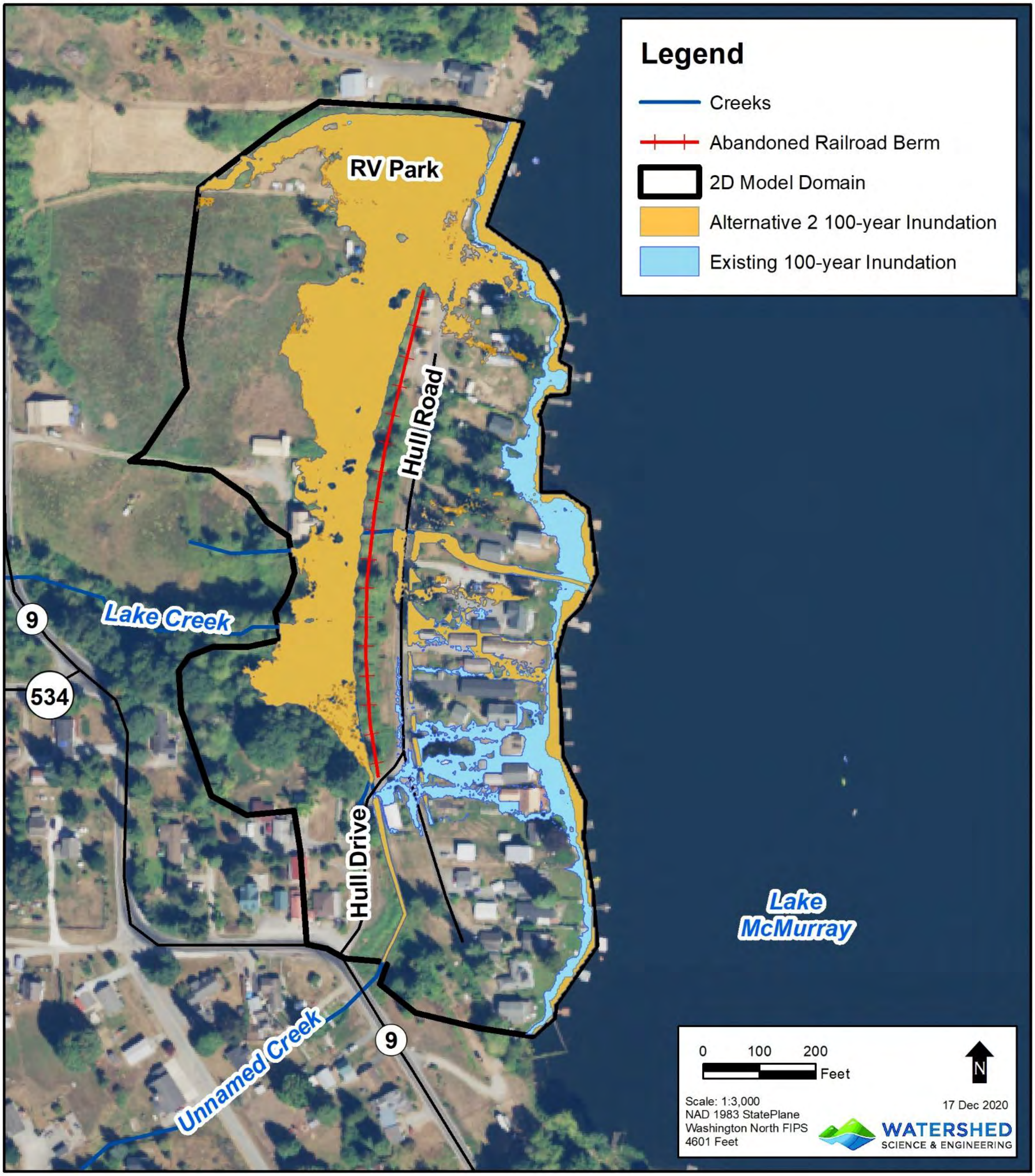

Figure 18. 100-year Flood Inundation Limits Alternative 2 vs. Existing Conditions.

Alternative 3 -- Modify the Culverts under the Abandoned Railroad Berm and Hull Road

The goal of the third alternative is to reduce flooding upstream (west) of the abandoned railroad berm without increasing flooding downstream. Three variations of Alternative 3 were examined and will be referred to as Alternatives 3A, 3B and 3C. All three include the following four actions:

- Replace the existing 30-inch Hull Road culvert with a fish passable crossing estimated to be 3-foot high by 12-foot-wide concrete box culvert in this study. (Note – the size of culvert required will need to be determined through a thorough analysis of stream characteristics which is beyond the scope of this investigation).
- Clean and increase the size of the channel between the outlet of the Hull Road culvert and the lake. The improved channel was assumed to have a bottom width of 8 feet, a top width of 10 feet and approximate depth of 1.5 feet.
- Lower the lake level to 231 feet as discussed in Alternative 2.
- Replace the culvert under Hull Drive with a 24-inch RCP.

The action that is different in each alternative is:

Alternative 3A

- The existing 36-inch concrete culverts under the abandoned railroad berm will be replaced with a fish passable 3-foot high by 12-foot-wide concrete box culvert.

Alternative 3B

- The culverts under the abandoned railroad berm will be replaced with an open cut. The open cut was modeled as a trapezoidal shaped opening through the existing railroad berm with an approximately 12-foot bottom width, 50-foot top width, and 2 horizontal feet to 1 vertical foot side slopes.

Alternative 3C

- The culverts under the abandoned railroad berm will remain in place and will be cleaned.

Model results showing the estimated benefits of alternatives 3A, 3B, and 3C are illustrated in Figures 19 through 27. Figures 19, 20, and 21 compare the 2-, 10-, and 100-year results for Alternative 3A to existing conditions. Figures 22, 23, and 24 compare the 2-, 10-, and 100-year results for Alternative 3B to existing conditions. Figures 25, 26, and 27 compare the 2-, 10-, and 100-year results for Alternative 3C to existing conditions.

The figures reveal that flooding can be reduced through a series of channel, culvert and lake lowering improvements. All three alternatives produce similar flood reductions, with Alternative 3C producing slightly less because the existing culverts under the railroad berm do not have the capacity to pass the 100-year flood downstream – even after they are cleaned. Alternatives 3A and 3B do.

For Alternatives 3A, 3B, and 3C, the Hull Road culvert will need to be replaced and the channel between Hull Road and Lake McMurray enlarged at the same time or prior to making the changes to the abandoned railroad berm culverts. Cleaning out the existing culverts or replacing them with a fish passable crossing or an open cut will send larger flows to Hull Road and the downstream channel, neither of which currently have the capacity to convey the flow to the lake.

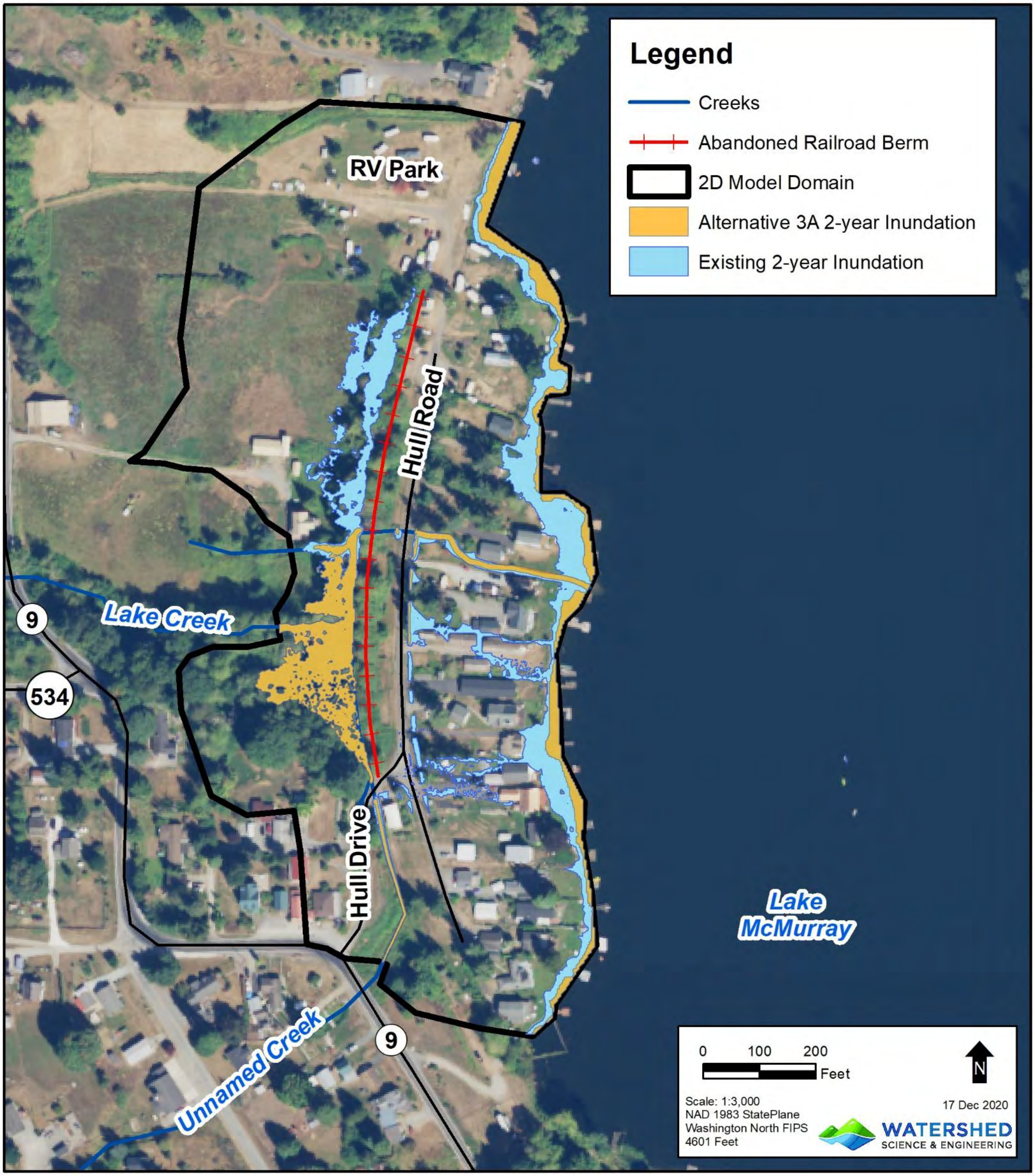

Figure 19. 2-year Flood Inundation Limits Alternative 3A vs. Existing Conditions.

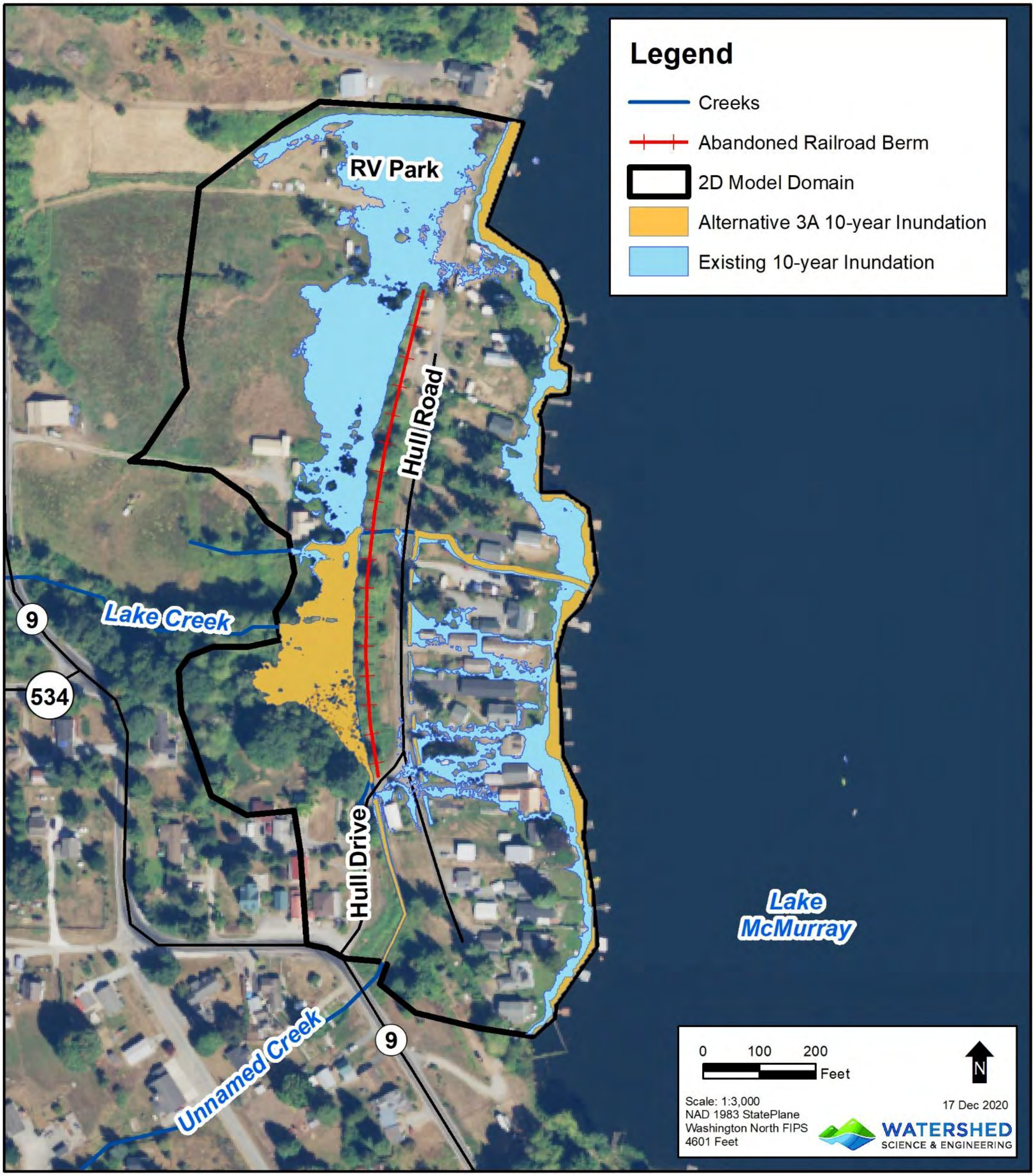

Figure 20. 10-year Flood Inundation Limits Alternative 3A vs. Existing Conditions.

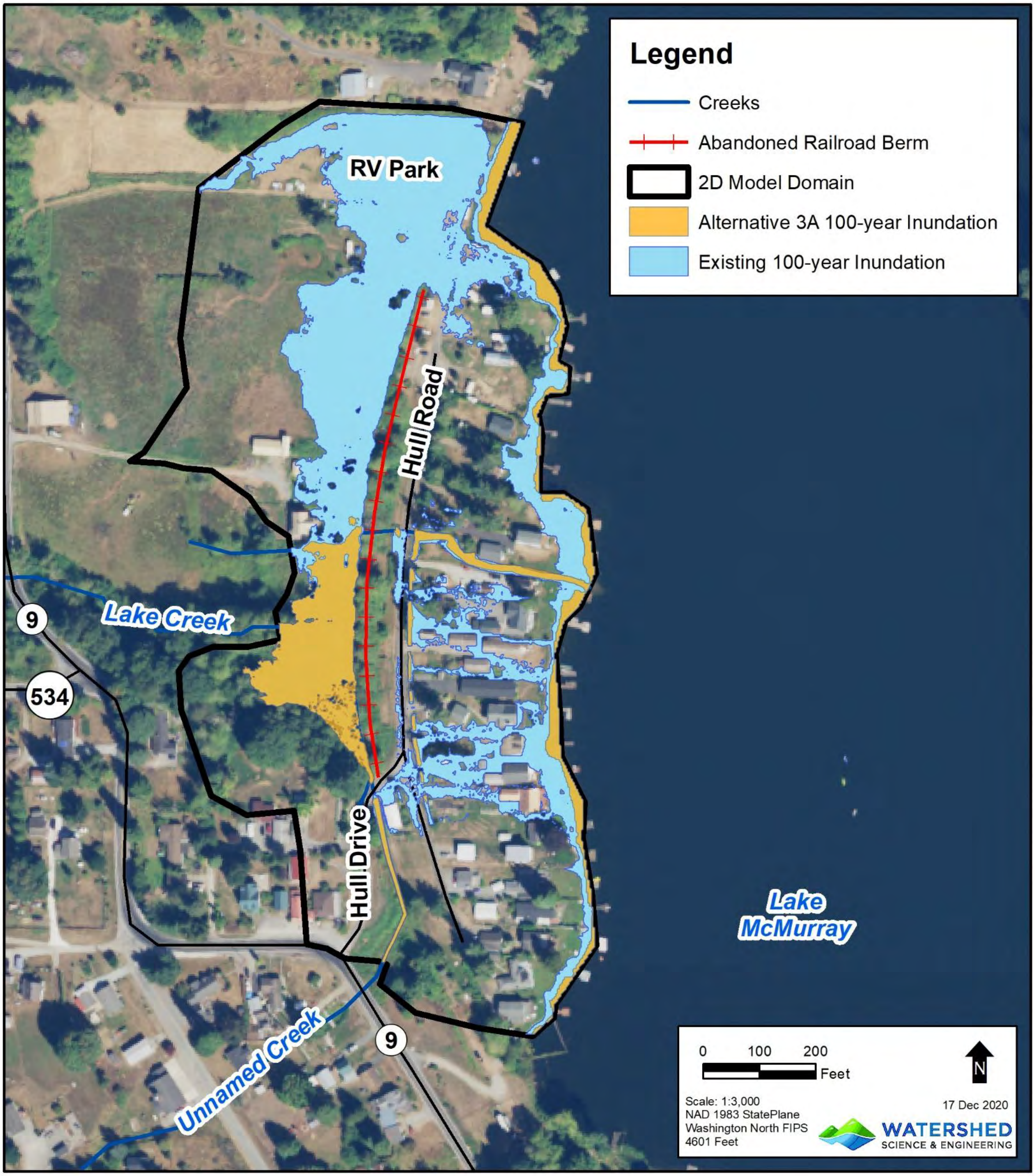

Figure 21. 100-year Flood Inundation Limits Alternative 3A vs. Existing Conditions.

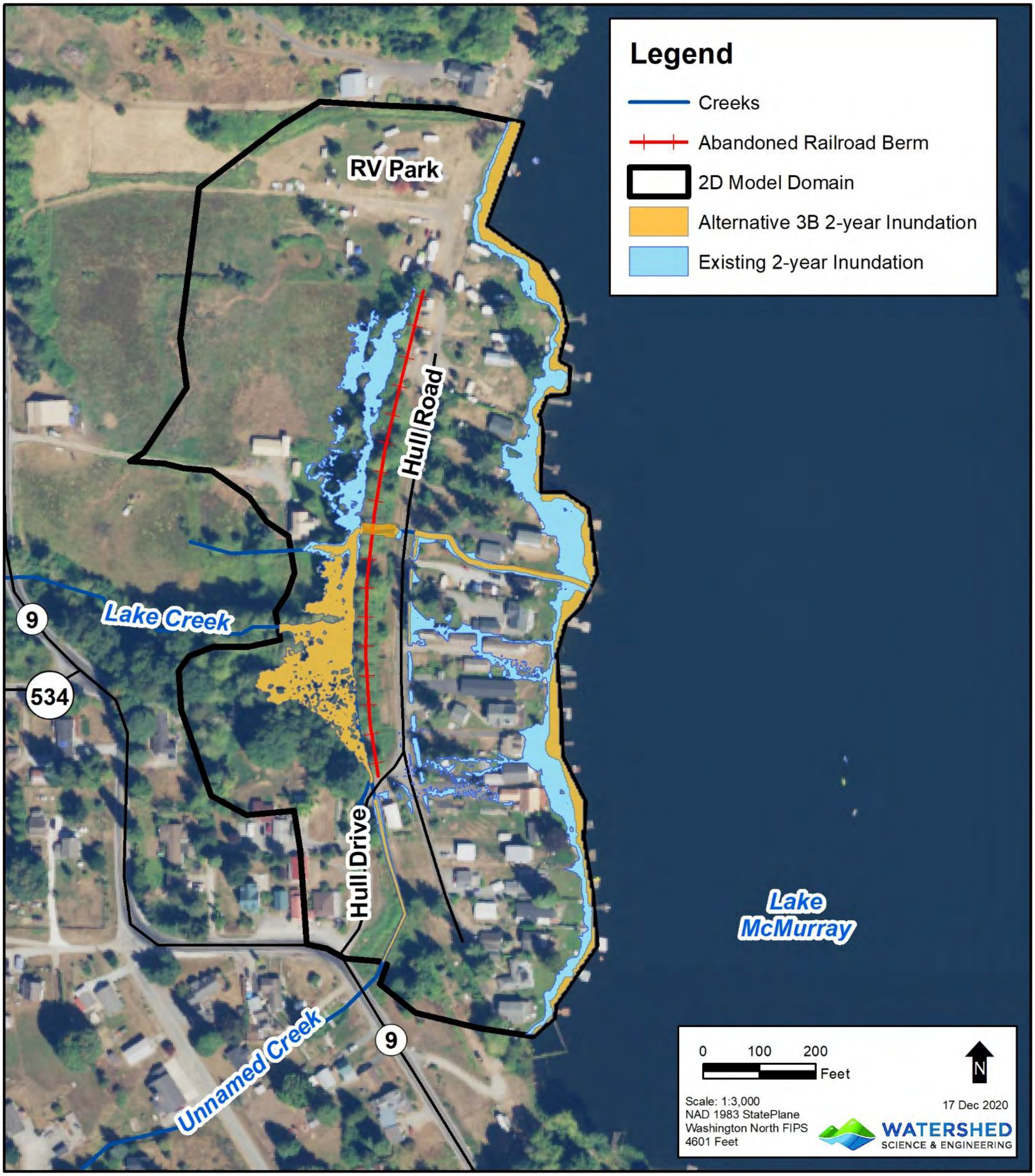

Figure 22. 2-year Flood Inundation Limits Alternative 3B vs. Existing Conditions.

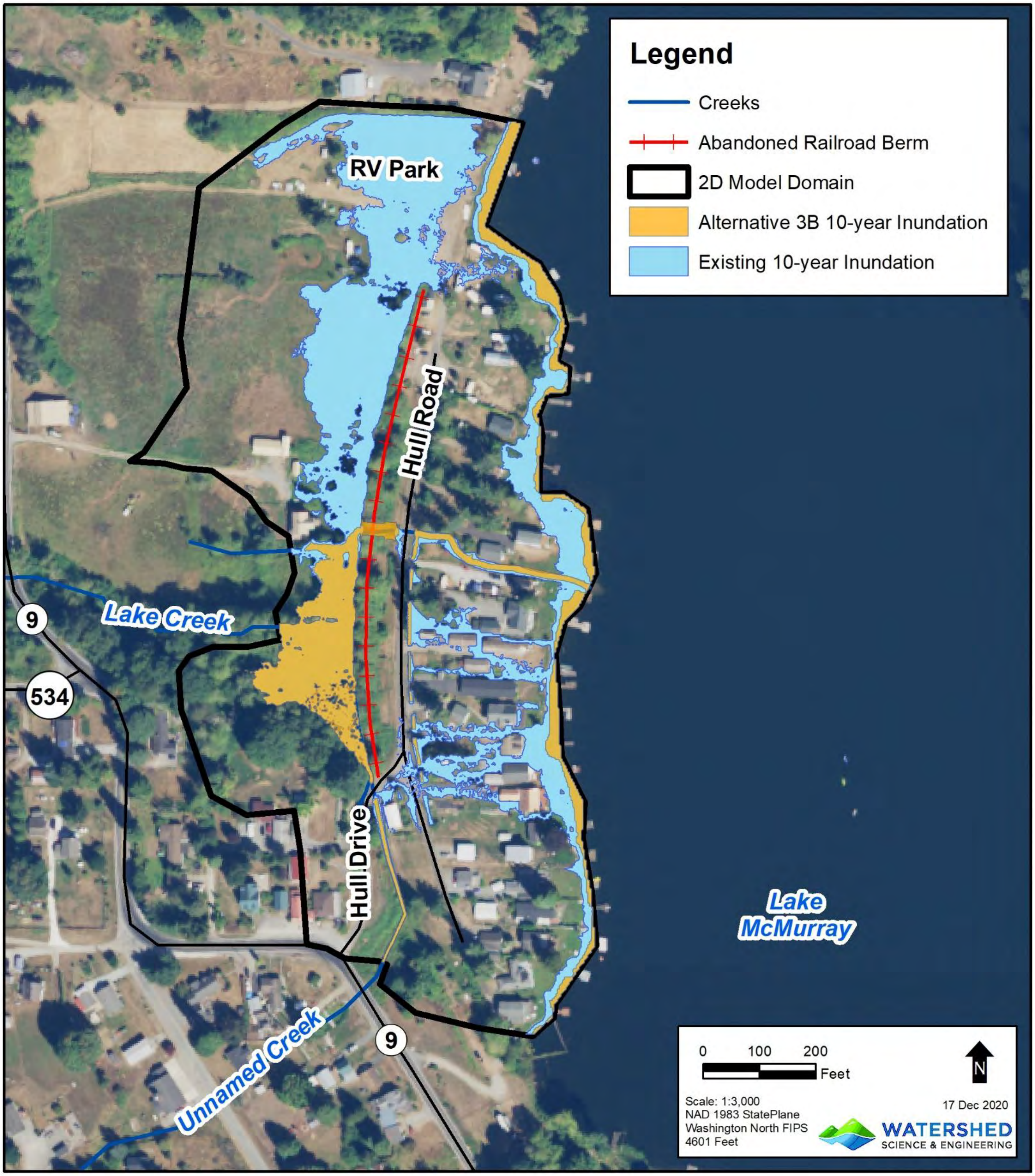

Figure 23. 10-year Flood Inundation Limits Alternative 3B vs. Existing Conditions.

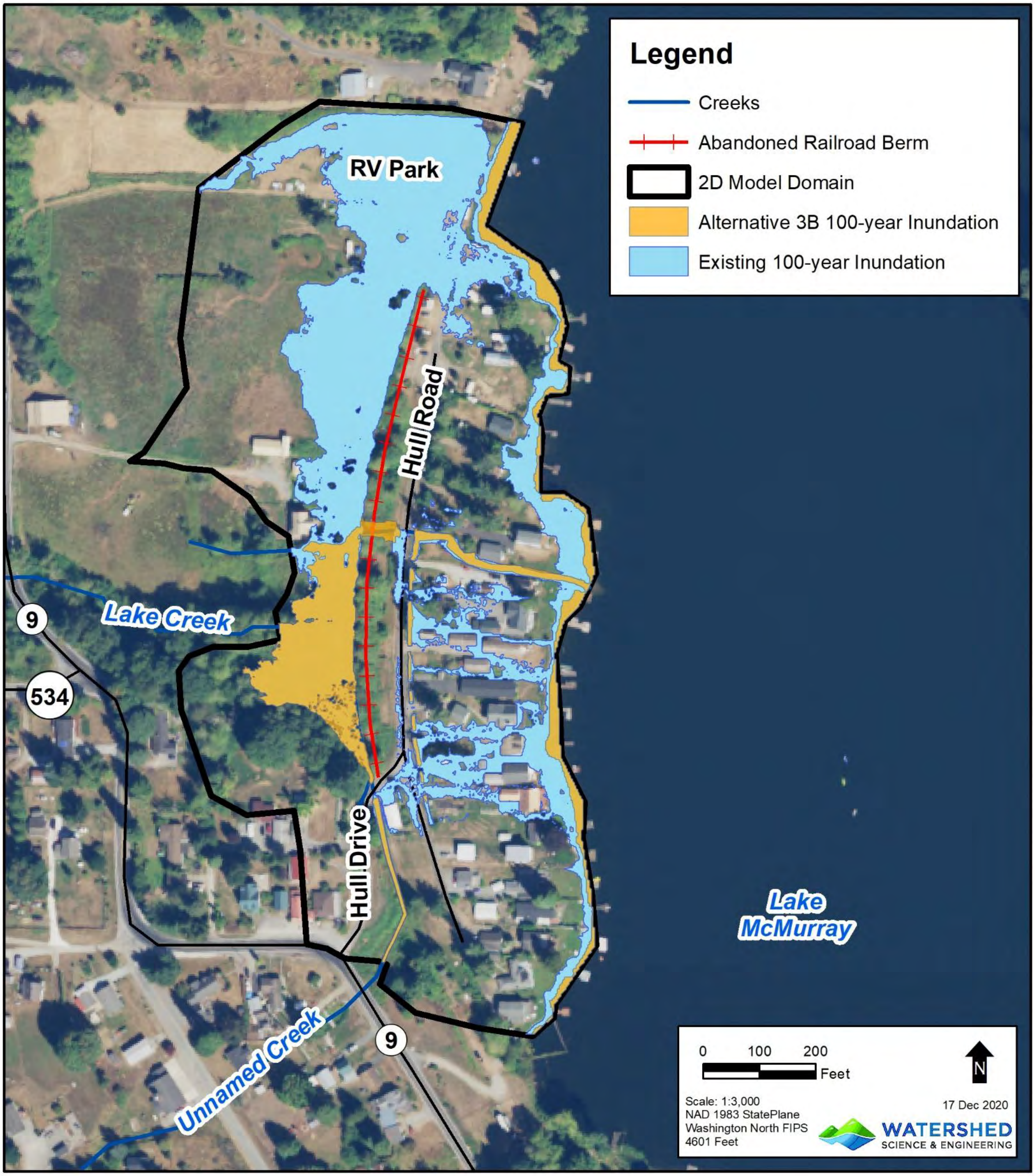

Figure 24. 100-year Flood Inundation Limits Alternative 3B vs. Existing Conditions.

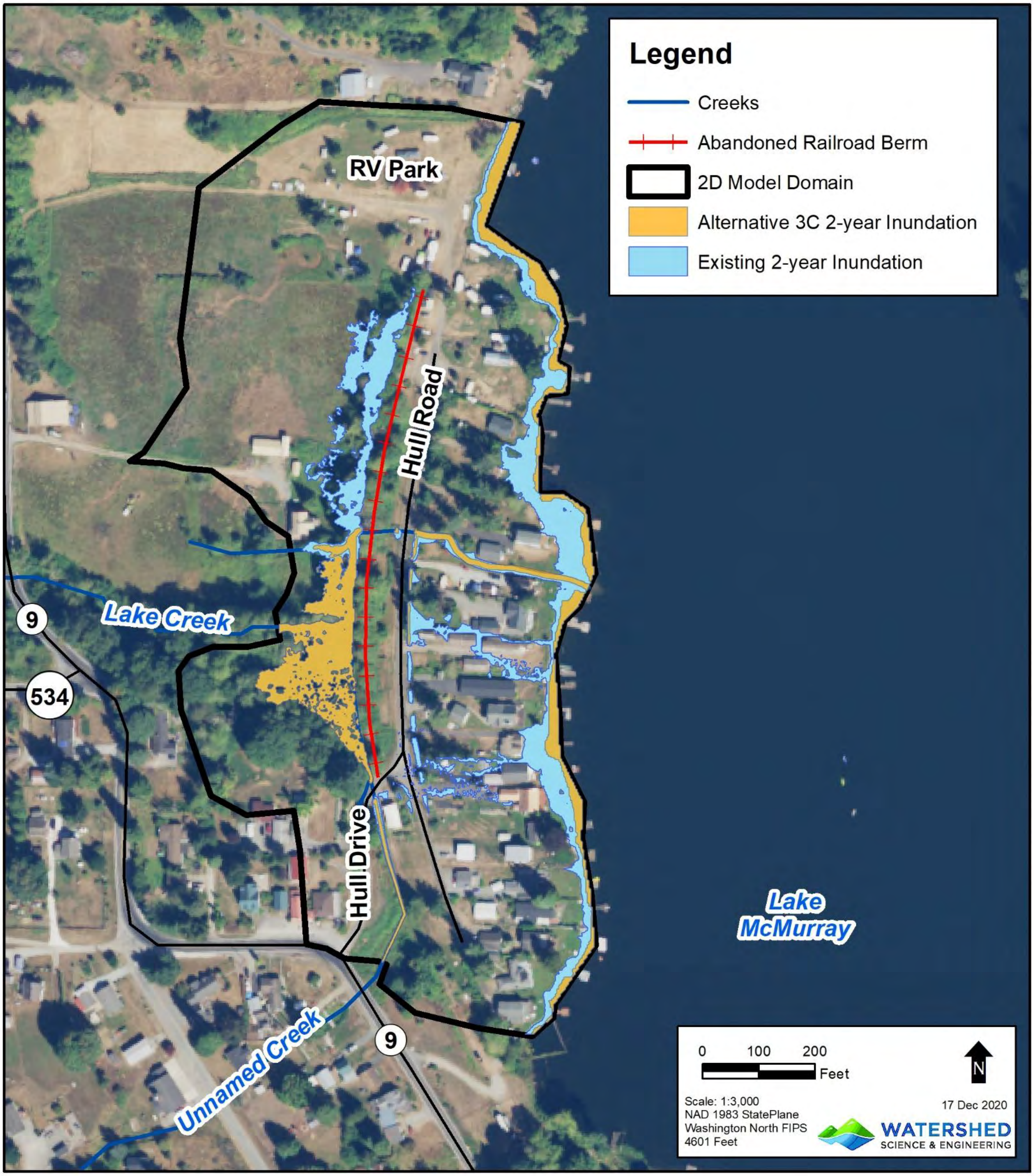

Figure 25. 2-year Flood Inundation Limits Alternative 3C vs. Existing Conditions.

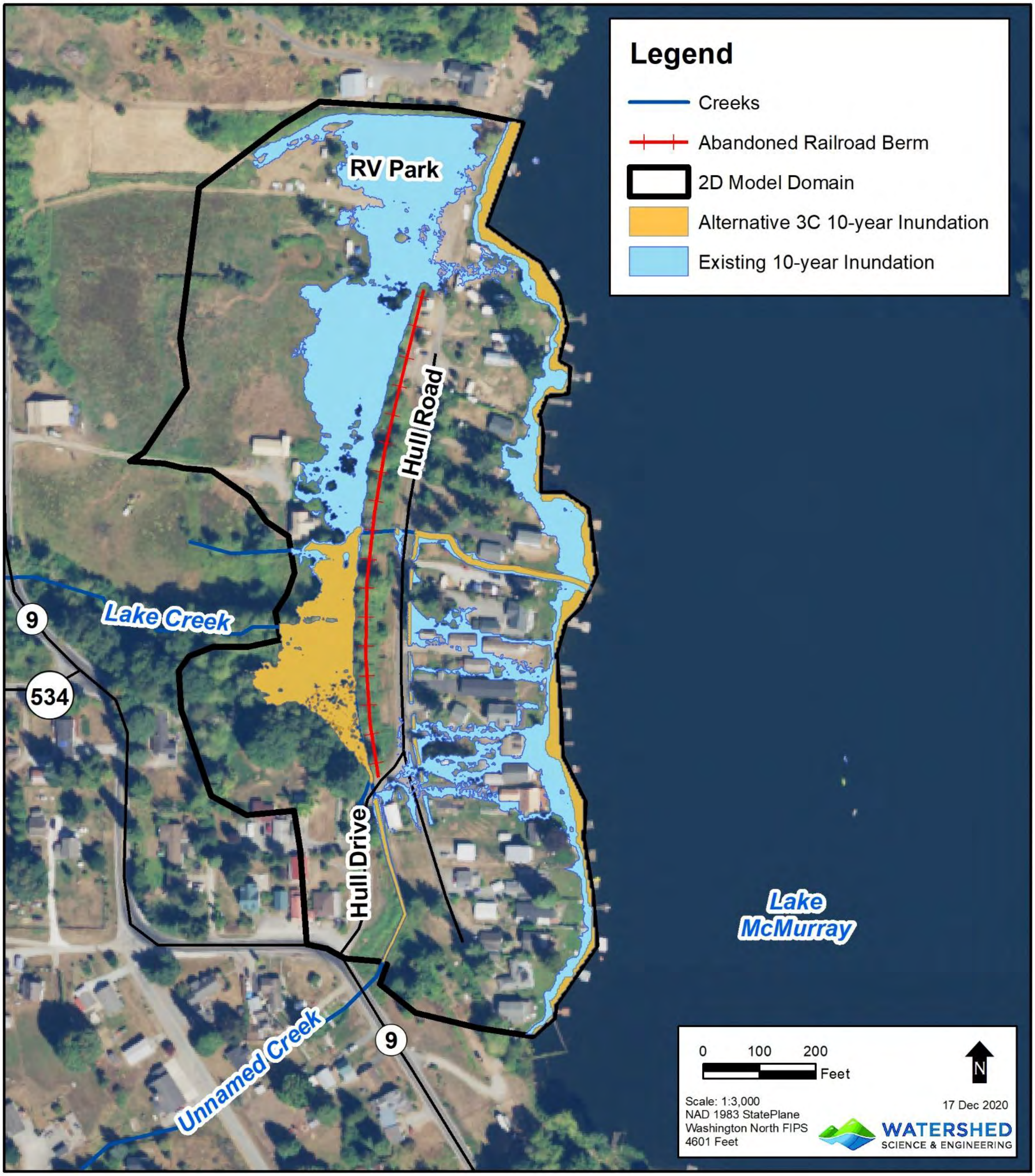

Figure 26. 10-year Flood Inundation Limits Alternative 3C vs. Existing Conditions.

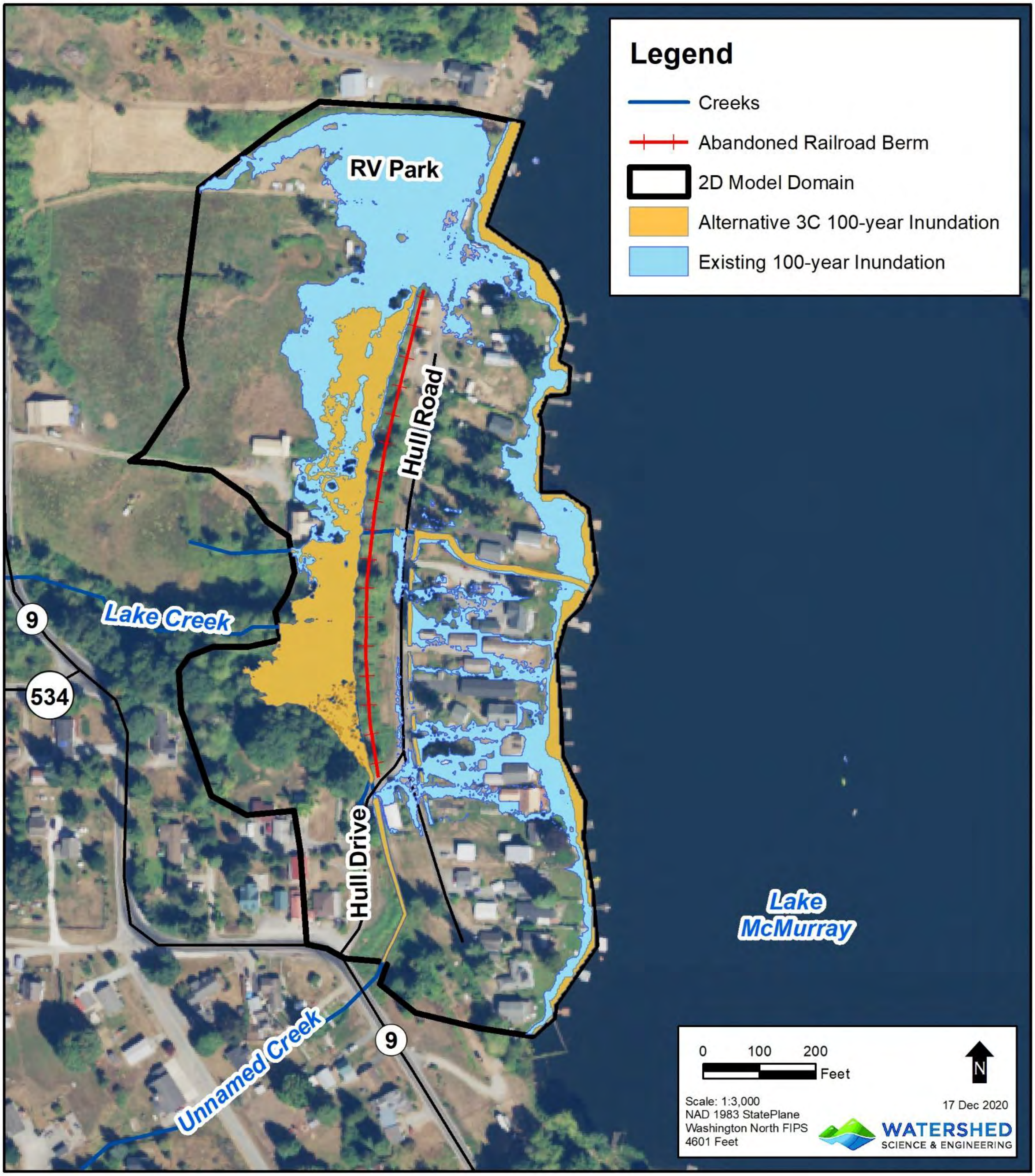

Figure 27. 100-year Flood Inundation Limits Alternative 3C vs. Existing Conditions.

Alternative 4 -- Remove the Abandoned Railroad Berm

Alternative 4 examined the benefit of removing the abandoned railroad berm and replacing it with a small floodwall or earthen berm along the west edge of Hull Road. A small replacement structure of some type is needed along Hull Road to prevent flooding of the road and lake front homes. Alternative 4 is identical to Alternative 2, except that the abandoned railroad berm has been removed and replaced. It does not include improvements to the Hull Road culvert or the channel between Hull Road and the lake. Figures 28, 29, and 30 compare the 2-, 10-, and 100-year model results, respectively, for Alternative 4 to those for existing conditions. When 100-year results in Figure 30 are compared to the Alternative 2 results in Figure 18, it shows that Alternative 4 has no benefit over Alternative 2.

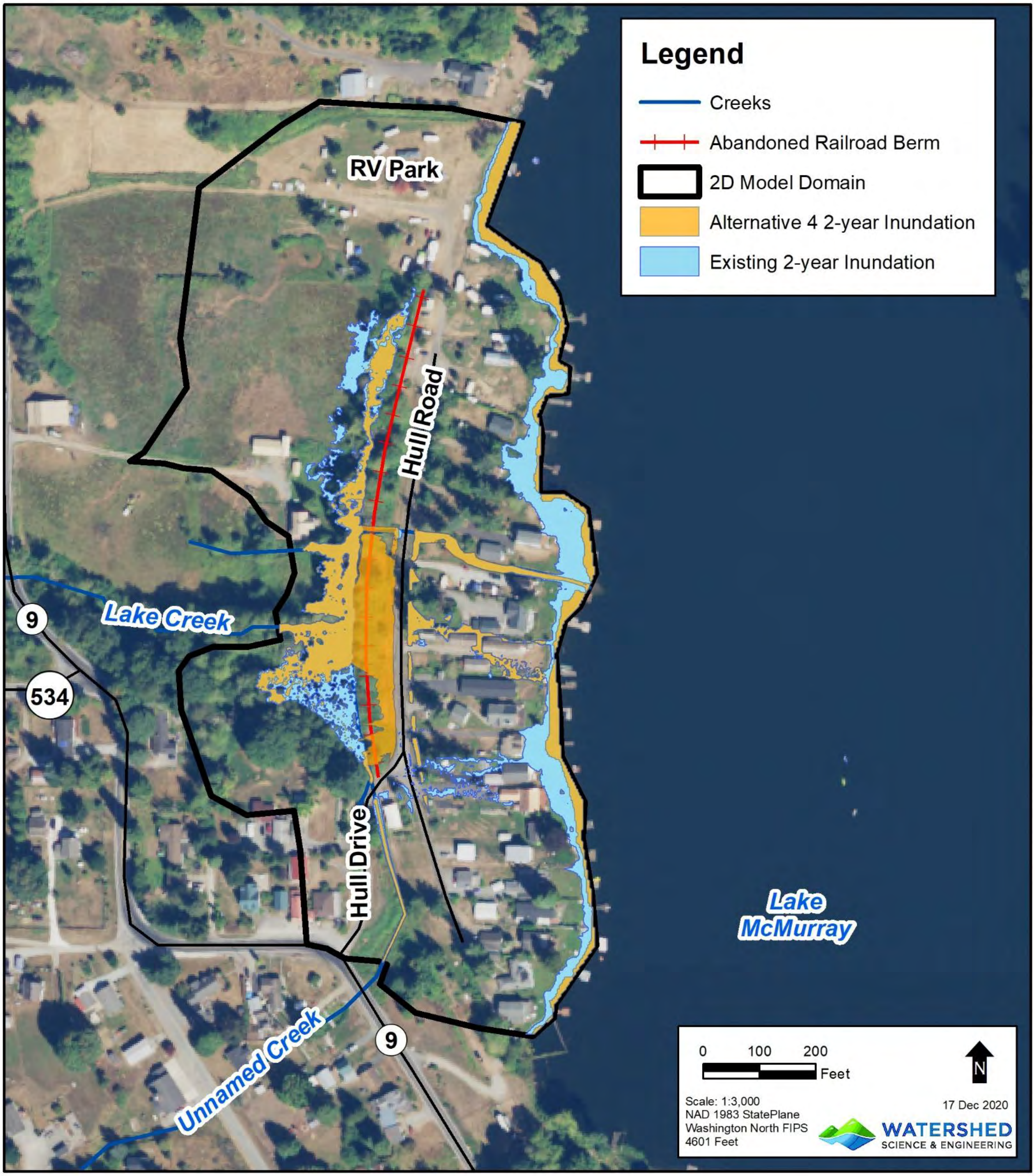

Figure 28. 2-year Flood Inundation Limits Alternative 4 vs. Existing Conditions.

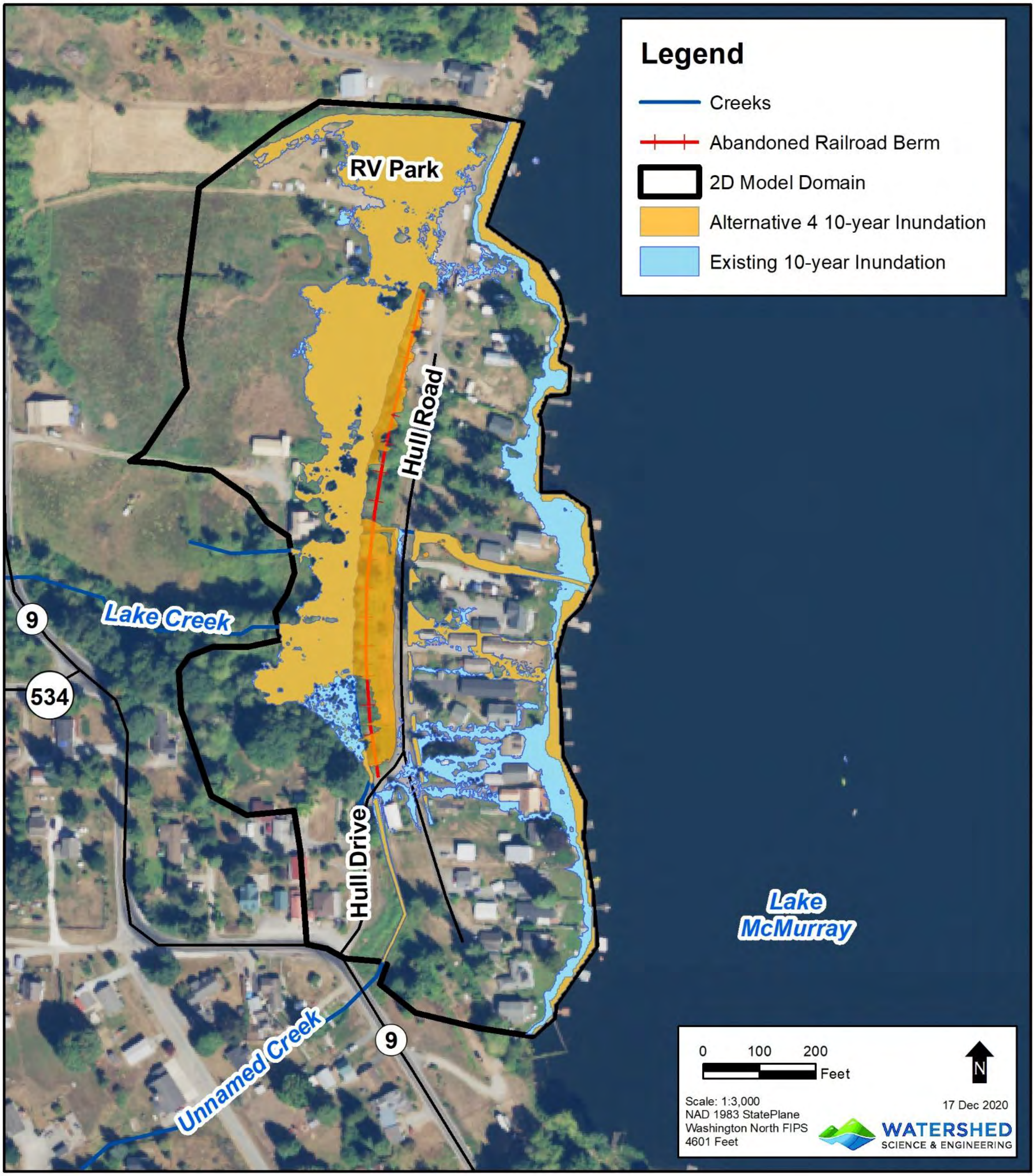

Figure 29. 10-year Flood Inundation Limits Alternative 4 vs. Existing Conditions.

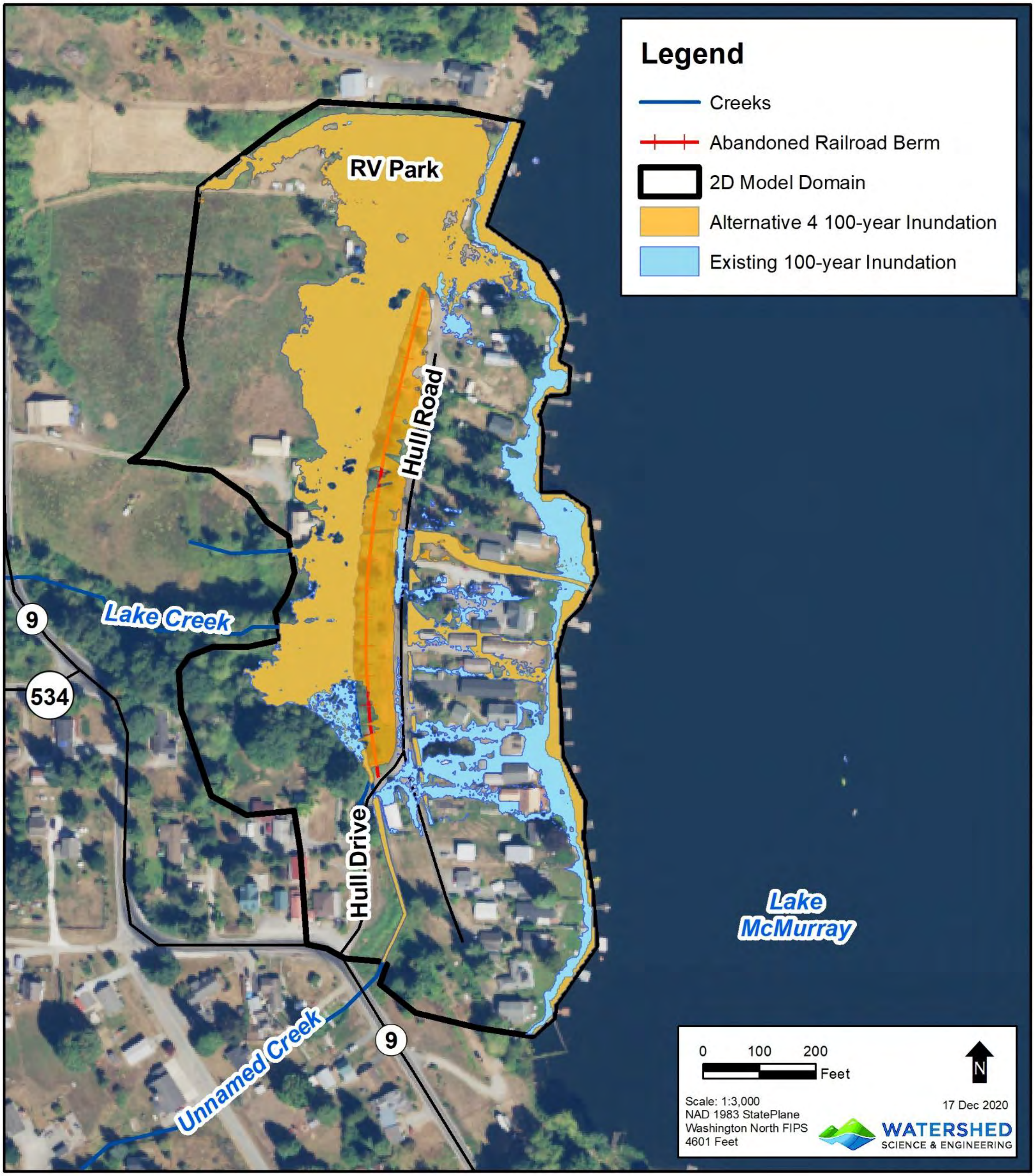

Figure 30. 100-year Flood Inundation Limits Alternative 4 vs. Existing Conditions.

Alternative 5 – Construct a New Stream Channel to the Lake

Alternative 5 involves the construction of a new channel to Lake McMurray at the north end of the abandoned railroad berm. The existing culverts under the abandoned railroad berm would be plugged and Lake Creek would be re-routed to Lake McMurray north along the upstream (west) side of the abandoned railroad berm. Figures 31, 32, and 33 compare the resulting 2-, 10-, and 100-year inundation limits, respectively, to those for existing conditions. The new outlet channel passes through the RV park which likely would not be acceptable to the park owners, however, the intent is to demonstrate that flooding of lake front properties along Hull Road can be reduced or eliminated if an alternative route can be found for Lake Creek. Unfortunately, there is no obvious path for a new outlet channel, because all parcels along the lake are private and all but one contains a home. A channel constructed along this alignment would also be very flat, which would require substantial maintenance to maintain adequate conveyance over time.

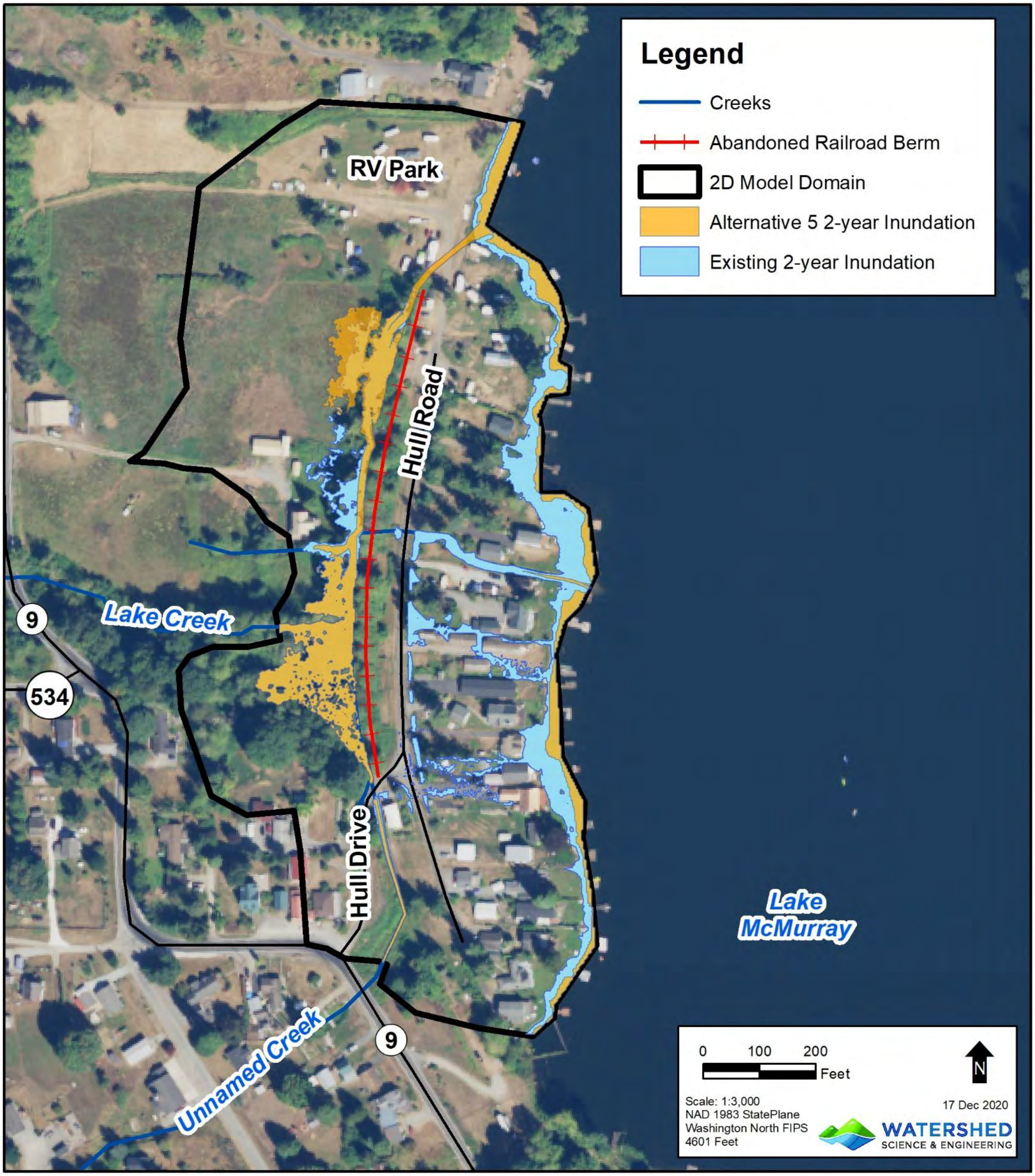

Figure 31. 2-year Flood Inundation Limits Alternative 5 vs. Existing Conditions.

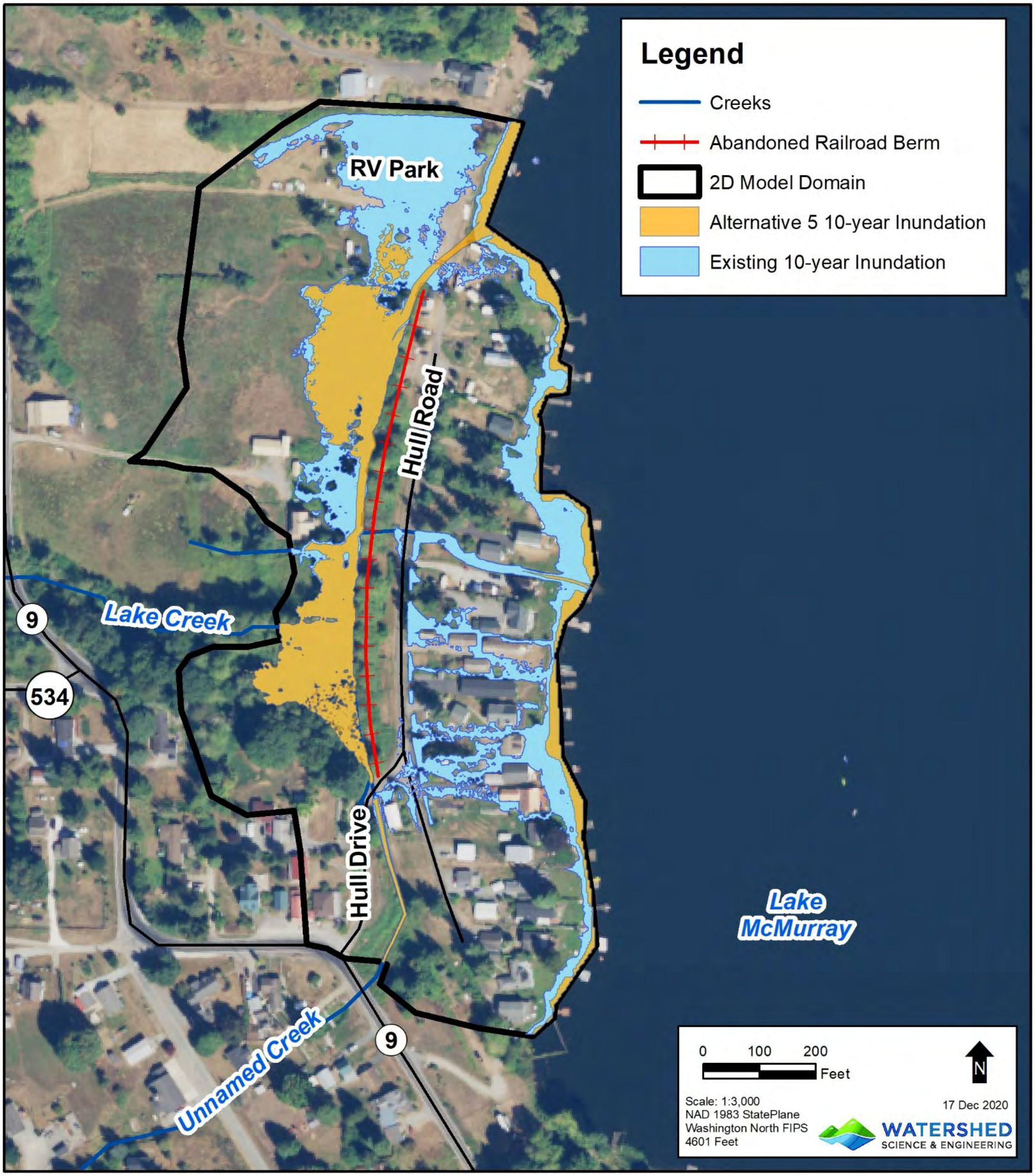

Figure 32. 10-year Flood Inundation Limits Alternative 5 vs. Existing Conditions.

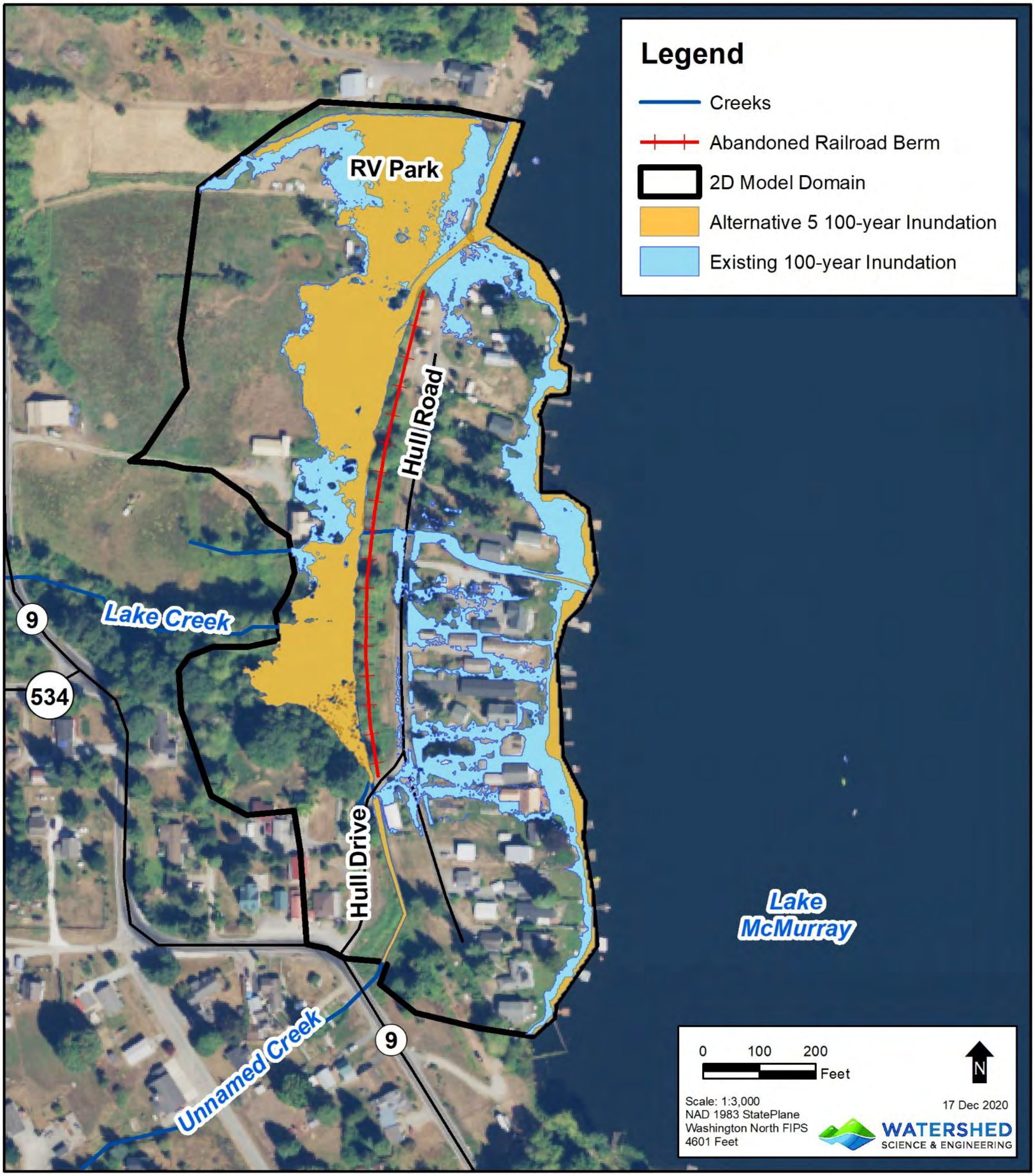

Figure 33. 100-year Flood Inundation Limits Alternative 5 vs. Existing Conditions.

4. CONCLUSIONS AND RECOMMENDATIONS

Based upon the investigation described herein, it is WSE's opinion / recommendation that the greatest benefit can be achieved if the following actions are implemented.

1. Continue to monitor beaver activity within the lake outlet channel in the reach that begins at the lake and ends downstream of the unnamed tributary that enters the channel downstream from McMurray Shore Drive. Beaver dams in this reach will reduce the capacity of the outlet channel which in-turn will cause lake levels to rise and flood lake front properties. The dams will also likely cause the lake to remain at flood stage for extended periods. Beavers currently are not building new dams or maintaining existing older remnant dams in this reach, however, they may in the future. A beaver management plan should be developed to allow the community to monitor beaver activity and if necessary, relocate beavers and dismantle dams to maintain the capacity of the lake outlet channel. Further investigations of and recommendations regarding the lake outlet are contained in Appendix A and B.

   Note: The improvement recommendations described in bullets 2, 3, and 4 below will continue to reduce flooding in the vicinity of Hull Road even if the lake level rises to a flood stage of 232.8 feet, the approximate level observed during 2015 and 2018 storms. WSE did not evaluate how the system would perform if the lake rose higher than 232.8 ft, for example, WSE did not run the model for a lake level of 234.3 feet which is the elevation of the 2009 storm as reported by Anchor (2010).

2. Increase the size of Hull Drive culvert to reduce flooding along four lake front properties at the base of Hull Drive in the 10- and 100-year events and reduce flooding on three others further north along the Hull Road roadside ditch. Note, however, that this will cause a slight rise in the water surface elevation and flood extents along the upstream (west) side of the abandoned railroad berm. The increase is less than 0.2 feet near the home located just west of the abandoned railroad culverts during the 10- and 100-year events and less than 0.1 feet in the 2-year event. To eliminate this rise, the improvements below would need to be implemented.

3. Increase the size of the channel between Hull Road and Lake McMurray, replace the Hull Road culvert with a fish passable culvert, and either clean, replace, or remove the abandoned railroad culverts. This will eliminate or reduce flooding at the house upstream of the abandoned railroad berm, in the RV park, and on five additional lake front properties during the 100-year event.

4. Develop and implement a long-term plan to maintain the channel upstream of Hull Drive and between Hull Road and the lake. Maintenance will require vegetation and sediment removal every two to five years. The frequency will depend upon how rapidly sediment deposits, which will depend upon the frequency and magnitude of floods. To reduce the growth of grass in the channel downstream from the railroad berm we recommend that some form of hedge-row be installed along the south side of the channel to create shade. Property owners must understand that it will be critical to maintain the channel, however, obtaining the permits to do so will be difficult and costly because the work requires excavation within the limits of the ordinary high water of the stream.

It is our opinion that the four actions described above should be implemented as a single package; however, if this is not possible, we recommend they be implemented in the following order:

- Action 1 – develop a beaver management plan. This action should be initiated regardless of whether improvements are made in the vicinity of Hull Drive and Hull Road. This is a high priority action because it impacts many lake front land owners and will improve the effectiveness of the Hull Drive and Hull Road improvements. However, completion of this action does not need to precede initiation of actions 2, 3, and 4.

- Action 2 – replace the culvert under Hull Drive. This action could be taken without Actions 3 and 4 if the property owners along the upstream (west) side of the rail road berm agree to accept the slight increase in flooding. If they are unwilling, then Actions 3 and 4 will be required.

- Actions 3 and 4 – these must be implemented together.

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Appendix A

Lake McMurray Outlet Investigation

Watershed Science & Engineering

WATERSHED
SCIENCE & ENGINEERING

506 2nd Ave, Suite 2700
Seattle, WA 98104

Memorandum

To: Emily Derenne - Skagit County Public Works

From: Jeff Johnson, P.E., Sarah Parker, P.E., and Colin Butler – Watershed Science and Engineering

Date: June 1, 2020, Revised January 7, 2021

Re: Lake McMurray Outlet Investigation Findings

INTRODUCTION

Lake McMurray waterfront properties flood due to rising lake levels caused by large long-duration winter rain events. The property owners believe the lake outlet channel is obstructed by beaver dams and debris and, therefore, does not have the capacity required to drain the lake during these rain events.

In 2019, Watershed Science & Engineering (WSE) completed a hydrologic and hydraulic investigation to identify solutions to reduce flooding on properties along Hull Road and Hull Drive located along the west side of the lake (Figure 1). The focus of the investigation was to examine flooding caused by Lake Creek and an unnamed tributary to Lake Creek. During the investigation, WSE determined that solutions to solve the flooding caused by these streams needed to consider measures to keep Lake McMurray water levels from rising during winter storms. High lake levels prevent Lake Creek from draining freely into Lake McMurray, causing water to back up and flood residential properties.

In response to these findings, Skagit County retained WSE to examine the lake outlet channel to determine if beaver dams or other obstructions are the cause of the elevated winter lake levels. WSE has completed the investigation and the findings are described in this memorandum.

Special Notes:

To avoid confusion, the reader should note that Lake Creek has two segments. Lake Creek flows into Lake McMurray at Hull Road and then out of Lake McMurray at the north end of the lake (Figure 1). It is the Lake Creek outlet channel that is the subject of this memorandum.

Subsequent to this field investigation of the Lake McMurray outlet, WSE completed a hydraulic modeling evaluation of potential outlet improvements which is summarized in a separate memorandum.

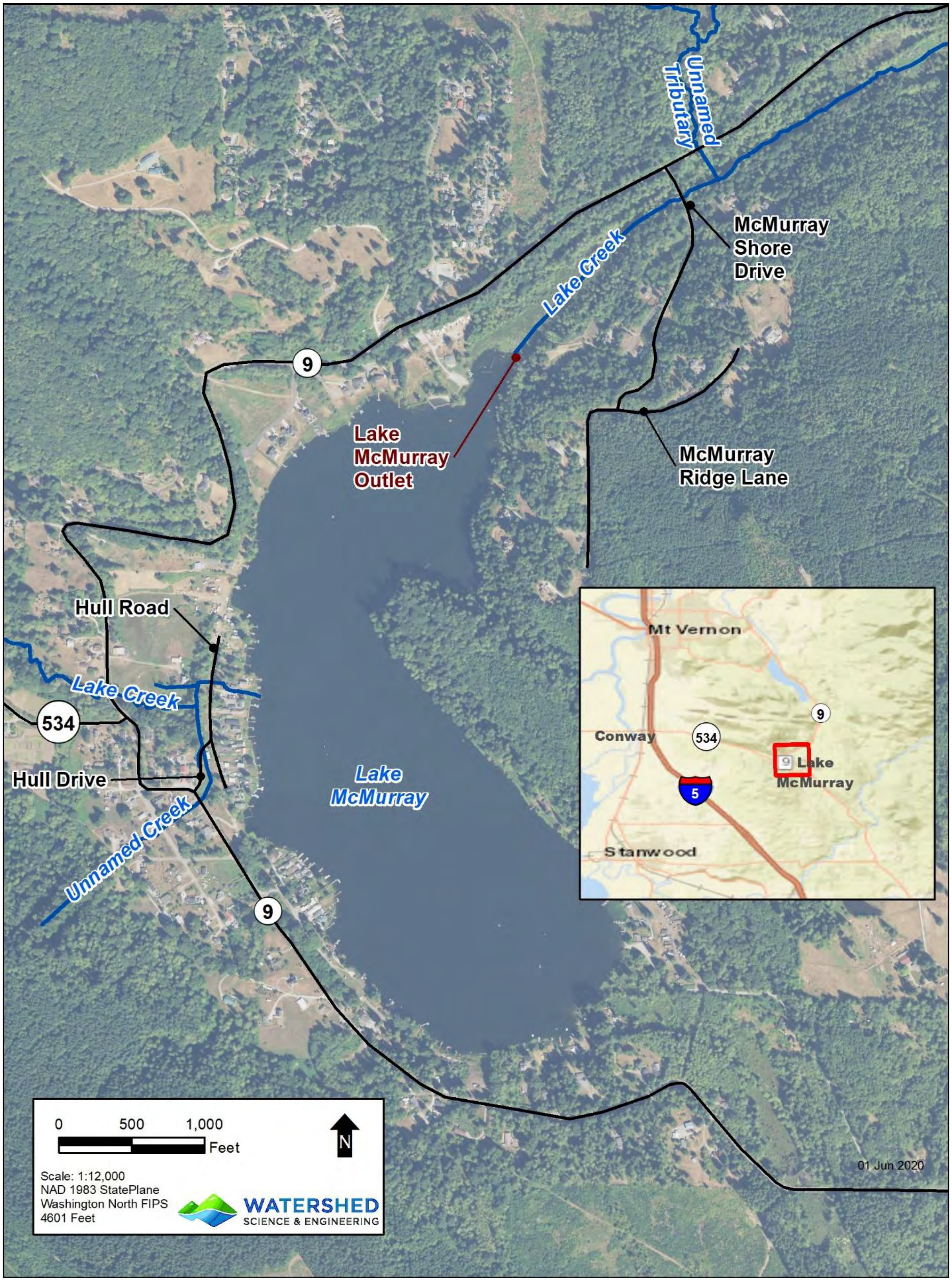

Figure 1. Location Map.

BACKGROUND

FLOOD PHOTOS PROVIDED BY LANDOWNERS

Flood photos from three different high lake level events were provided to the County by lakefront landowners. Photos 1 to 4 show examples of flooding that occurred in November 2015, February 2018, and during an event following these, for which the date is unknown. The property owners mentioned that the high lake levels typically occur during long duration heavy rains and that levels remain high for many days. They also said that during these events, lake levels rise 1 to 2 feet above the typical non-flood level. This information appears to confirm that inflows exceed outflows during long duration winter rain events. It is also reasonable to conclude that the lake outlet channel does not have the capacity needed to drain the lake rapidly enough during and after these rain events.

Photo 1. High lake levels during winter flood. Photo is viewing south at the location where Lake Creek flows into the Lake McMurray. (Photo provided to County by landowner, photo taken 11-15-2015).

Photo 2. High lake levels during winter flood. Photo is viewing north from the same location as Photo 1. (Photo provided to County by landowner, photo taken 11-15-2015).

Photo 3. High lake levels during winter flood. Photo is looking north from approximately 300 feet south of where Lake Creek enters Lake McMurray. (Photo provided to County by landowner, photo taken 2-5-2018).

Photo 4. Winter flooding caused by high lake levels. Photo is viewing south from the home that is located immediately south of where Lake Creek joins Lake McMurray. (Photo provided to County by landowner, date unknown).

Lake Outlet Channel Topography and Slope

The first task of the investigation was to examine the size, shape, and slope of the outlet channel, which as noted in the introduction is identified as Lake Creek. The topographic map in Figure 2 shows the planform size and shape of the outlet. The map was created from 2017 North Puget Sound LiDAR Data (Quantum Spatial, 2017). The colored area is the valley floor and the black contours define the confining hills. The LiDAR data does not penetrate the water; therefore, where water was present at the time of the LiDAR flight the figure shows the water surface, not the underlying bathymetry. Figure 2 reveals several features worth noting: 1) McMurray Shores Drive is clearly visible in the center of the figure; 2) the primary historical logging railroad route that follows the valley is visible in the form of a berm that passes through the heart of the valley floor; 3) near the left edge of the image, two earthen spurs extend from this primary berm, one to the south and one to the north. The southern spur extends a short distance then ends in the outlet channel, but reemerges a short distance downstream on the opposite (south) side of the valley floor. We suspect that there once was a trestle that bridged the outlet channel at this location. The spur extending to the north from the primary route is a siding that follows the northern toe of the valley wall and rejoins the primary berm near the right edge of the image.

WSE created a longitudinal water surface profile along the outlet channel starting at the lake outlet and extending approximately 3,850 feet downstream (Figure 3). For reference, the location of each station along the bottom axis of Figure 3 is shown in Figure 2. The profile was created from the 2017 LiDAR data, therefore, it represents the water surface elevation and not the channel bed. The profile contains a bumpy appearance in many locations due to vegetation. In these areas the LiDAR data did not capture the water surface because it was obstructed by vegetation. The fill that is McMurray Shore Drive is clearly visible, and the yellow line below the fill identifies the bottom elevation of the lowest of the two culverts that carry Lake Creek through the road fill. Culvert elevations were surveyed by Anchor Environmental in 2009 for a previous lake outlet channel obstruction investigation (Anchor, 2010).

Figure 3 reveals that water levels remain nearly flat from the lake to McMurray Shore Drive. The slope then increases slightly (0.002 feet/feet) along the first 300 feet downstream of McMurray Shore Drive, then steepens significantly along the remainder of the profile (0.008 feet/feet). The solid horizontal blue line in Figure 3 represents the lake water surface elevation that was surveyed by the County in July 2019 for the Hull Drive/Hull Road flood investigation. It represents a typical non-flood lake level. The water surface elevation on February 26, 2020, the day WSE first examined the outlet channel, is shown by the light green horizontal line at McMurray Shore Drive. It was approximately the same as the July elevation. The dashed horizontal blue line is an estimate of the February 2018 lake flood level estimated from the flood photographs presented above. The lake was approximately two feet higher than normal during that flood event.

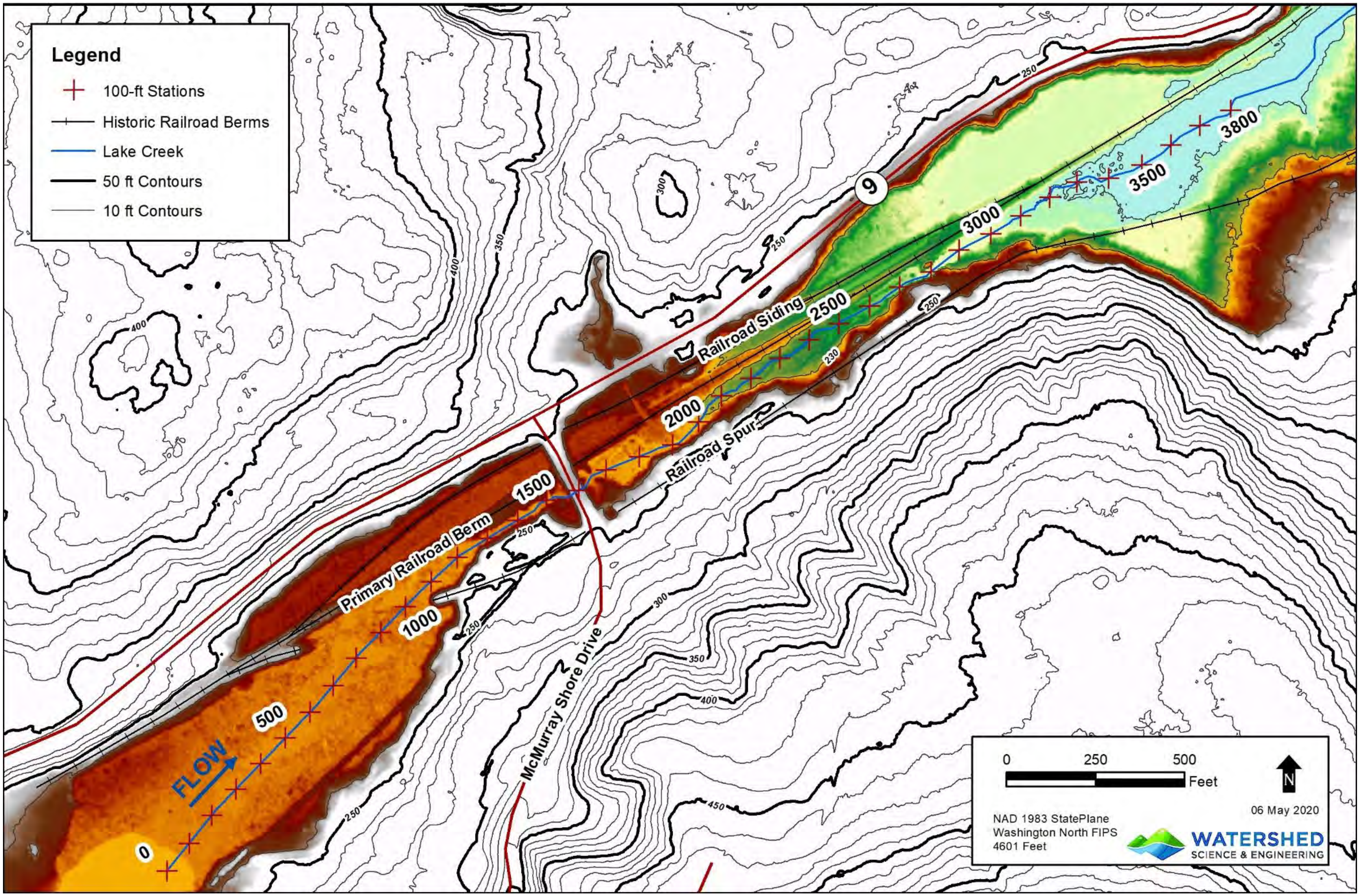

Figure 2. Lake McMurray Outlet Topography

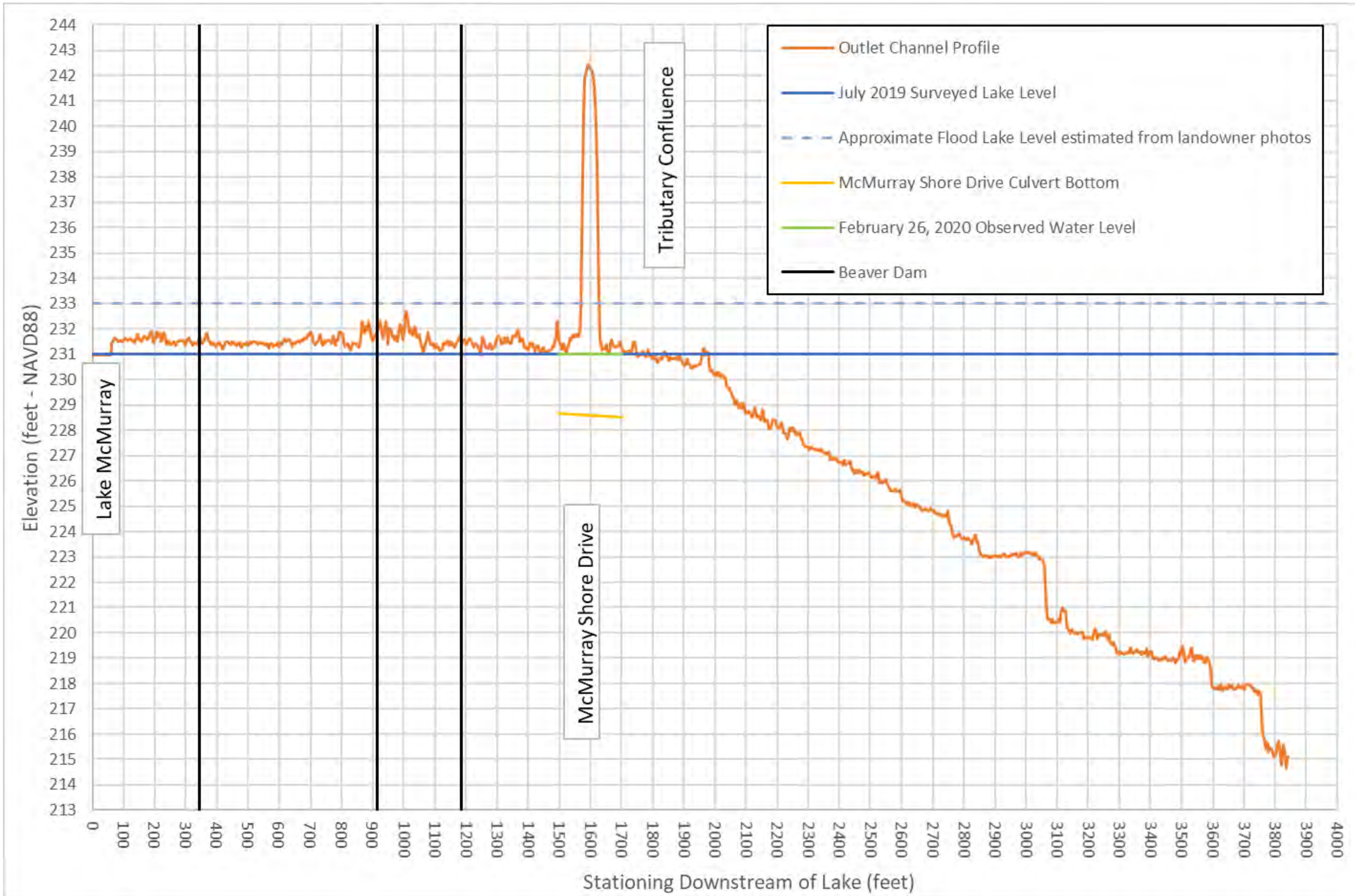

Figure 3. Lake Creek profile downstream of Lake McMurray outlet.

FIELD INVESTIGATION

WSE made two visits to the site to identify features that are limiting the capacity of the outlet channel, the first on February 26 and the second March 10, 2020. During the first site visit WSE examined the channel by walking along the primary railroad berm; however, it quickly became apparent that viewing features from the berm was of limited use because the outlet channel upstream from McMurray Drive is wide and partially obscured by trees (Figure 1). WSE determined that the setting was ideal for drone photography. WSE returned to the site on March 10, 2020 to collect drone photographs and videos, and to collect additional ground-based photographs and observations downstream from McMurray Drive by walking the stream. Figure 4 shows a composite aerial photograph of the outlet channel taken by the drone. Several obstruction features are identified in red and are discussed below.

OBSERVATIONS – REACH UPSTREAM FROM MCMURRAY SHORE DRIVE

Dense vegetation, woody debris and at least three abandoned beaver dams are contributing to a "cheese cloth" effect which is impeding flow. Photos 5 through 8 show the congested character of the reach and the three abandoned beaver dams identified in Figure 4. Each beaver dam is outfitted with a beaver deceiver, each in some level of disrepair. Sections of the beaver deceiver pipes have become untethered from their tiedowns and are now floating. The dams appear old and have holes in them suggesting that the beavers are no longer maintaining them and are not active in this reach. WSE did not see any evidence of recent beaver activity; however, Photo 8 shows a pile of beaver sticks next to the beaver dam in Photo 7. These were removed by someone, likely in an attempt to help the lake drain. The community has told the County they were working with Washington Department of Fish and Wildlife (WDFW) to obtain a permit to remove constructed dams but the County is not actively involved in that effort.

Photos 5 and 6 show that patches of vegetation and logs clog the outlet channel in many locations. One interesting obstruction feature is the wedge-shaped area of dense vegetation visible in Photo 7 adjacent to a beaver dam (vegetation is also shown in Photo 11). This is the site where we believe there once was a railroad trestle bridge. The vegetation wedge appears to follow roughly the alignment of the trestle, which may indicate that remnants from the bridge remain which have clogged with debris promoting the growth of vegetation. This, however, is purely speculation for we did not see remnant bridge features and it was not within our scope to conduct the detailed inspection that would be required to determine if remnants of the bridge remain.

Downstream from the northern most beaver dam (Photo 9) the channel is open and generally free from obstructions except for a few fallen trees (Photo 10). It is possible beaver dams may have existed in the reach in the past, but we did not see current evidence of any.

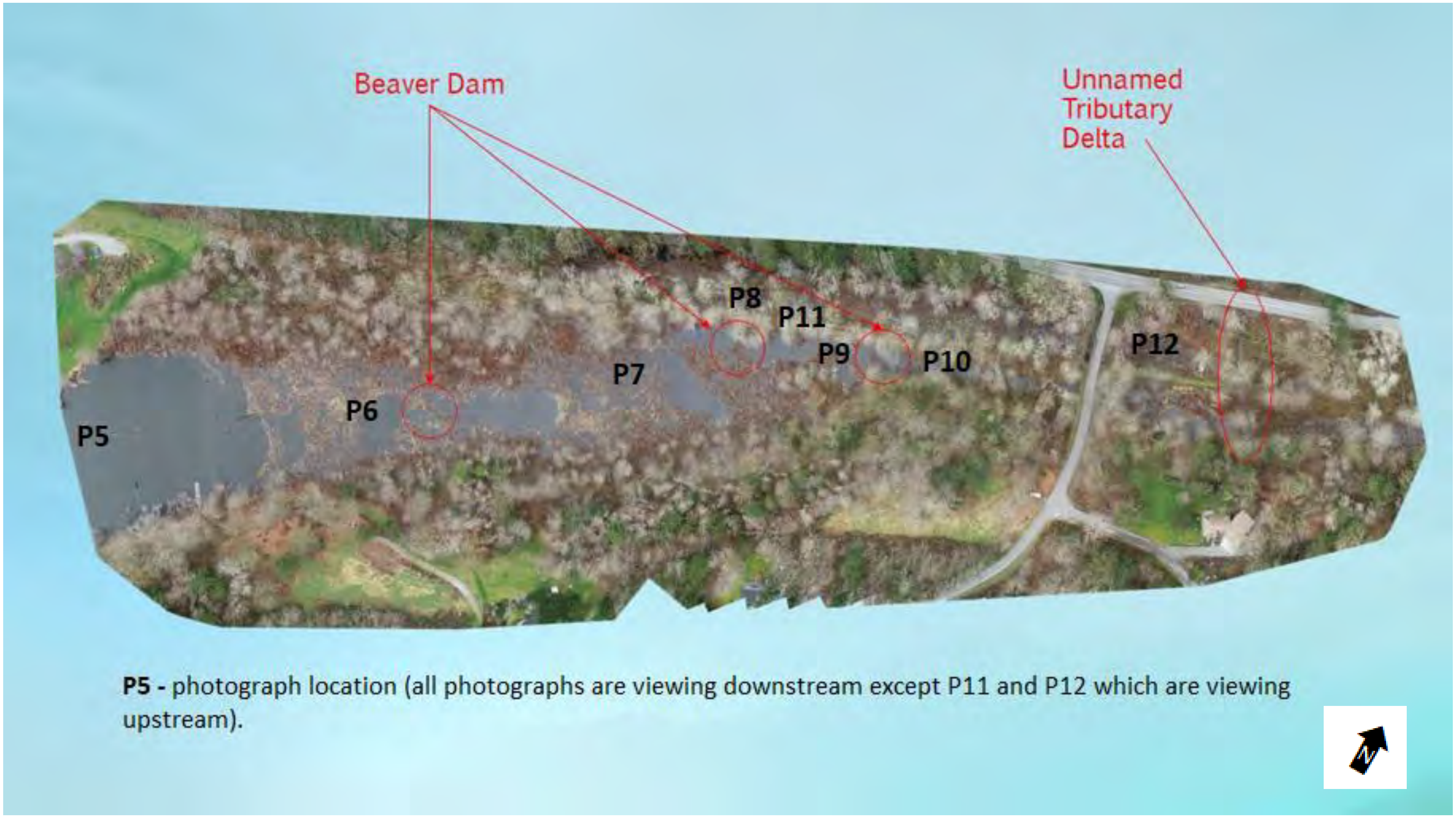

Figure 4. Drone Aerial with Photo Locations, date March 10, 2020.

Photo 5. Drone aerial looking downstream from Lake McMurray into the outlet channel (Photo taken March 10, 2020).

Photo 6. Beaver dam and Beaver Deceiver (circled in red) located near Station 300 in Figure 2 (March 10, 2020).

Photo 7. Beaver dam and beaver deceiver (circled in red) located near Station 900 in Figure 2. Note the thick stand of vegetation to the right of the beaver deceiver. We believe this was the site of an old railroad trestle, which may have something to do with why the vegetation has formed (March 10, 2020).

Photo 8. Viewing east to beaver dam in Photo 7 (Feb. 26, 2020). Sticks on the bank were removed by someone to open a hole in the dam.

Photo 9. Beaver dam and beaver deceiver (circled in red) located near Station 1200 in Figure 2 (March 10, 2020).

Photo 10. Viewing upstream (south) from McMurray Shores Drive (March 10, 2020). The channel is free of vegetation and other than a few logs, there are no significant features obstructing flow.

Photo 11. Viewing upstream (south) to the vegetation within the channel at the site of the old railroad trestle bridge (see Photo 7) (February 26, 2020).

Photo 12. Outlet of existing dual culverts under McMurray Shore Drive.

At McMurray Shore Drive ponded water was observed upstream, inside, and immediately downstream from the culverts indicating that the culverts were not obstructing flow on the day of the site visit; rather, something downstream from the road was causing the water to pond (Photo).

OBSERVATIONS – REACH DOWNSTREAM FROM MCMURRAY SHORE DRIVE

Figure 5 and Photo 13 show an unnamed tributary entering the lake outlet channel approximately 300 feet downstream of McMurray Shore Drive. After crossing under SR9 through a culvert, the unnamed tributary passes through both the abandoned railroad siding and the primary railroad berm before reaching Lake Creek. The tributary has created a large sediment delta at the confluence with Lake Creek. (The delta is the dark green feature at the confluence in Figure 5.) The delta partially obstructs flow because it rises 12 to 18 inches above the natural valley floor; however, it is not a complete barrier for it likely is overtopped by Lake Creek during major floods. The delta also constricts the outlet channel by pushing Lake Creek against the southeast valley. It is likely that the delta is one of the primary features obstructing the outlet channel, a finding that was also identified by Anchor QEA during their 2010 investigation of the outlet channel (Anchor, 2010).

Downstream from the unnamed tributary, Lake Creek meanders through a valley floor covered with thick vegetation. Throughout the reach there is evidence of beaver activity but no significant dams until station 3,700 feet. Here there is a large beaver dam to the left (northwest) of the primary railroad berm. The dam is not obstructing the outlet channel because it is on the opposite side of the berm from the stream.

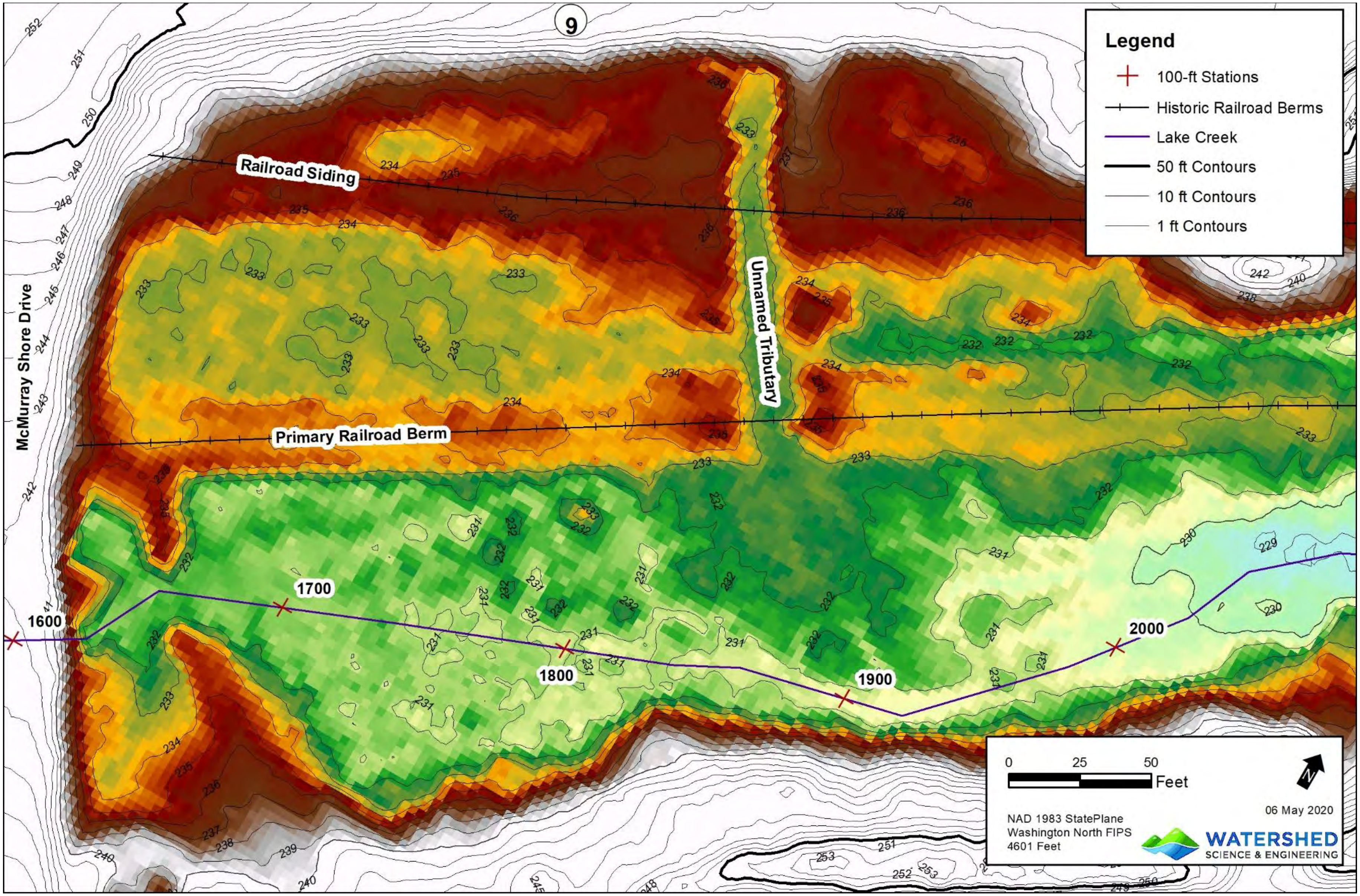

Figure 5. Lower Reach Topography near unnamed tributary to Lake Creek.

Photo 8. Looking downstream from McMurray Shore Drive. SR9 is on the left side of the photo. The green strip down the center of the photo is the top of the mainline abandoned railroad berm. The unnamed tributary is circled in red. (March 10, 2020).

Photo 9. Active beaver dam approximately 3,700 feet downstream of Lake McMurray (March 10, 2020). The primary railroad berm is covered with trees in the center of the photograph. Lake Creek is in the right side of the photo.

THE CAUSE OF ELEVATED LAKE LEVELS

Multiple features are working together to limit/reduce the capacity of the lake outlet channel. WSE cannot determine which features are having the greatest impact because we have not completed a hydraulic analysis, a task that is beyond the scope of this investigation and is included in a separate memorandum under an additional scope. However, it is our opinion that the two primary factors responsible are:

1. Vegetation, logs, and abandoned beaver dams are creating a "cheese-cloth-type" strainer effect upstream from McMurray Shore Drive.
2. The sediment delta created by the unnamed tributary 300-feet downstream from McMurray Shore Drive is likely obstructing the valley floor and constricting the channel.

SOLUTIONS

It is WSE's opinion that the most logical solutions are:

1. Upstream from McMurray Shore Drive, clear an unobstructed flow path through the existing vegetation, abandoned beaver dams, and logs.
2. Downstream from Lake McMurray Shore Drive, remove vegetation from the channel and all or a part of the sediment delta that is obstructing the valley floor and constricting the outlet channel. To slow the regrowth of the delta, consider widening the channel between SR9 and the spur railroad berm to create a sediment settling basin to encourage sediment to deposit before it reaches Lake Creek.
3. Manage beavers. If an unobstructed flow path is restored, we anticipate beavers will rapidly move back into and rebuild the existing dams or build new dams in the reach between Lake McMurray and the sediment delta. If they rebuild the existing dams, impacts may be reduced by repairing the existing beaver deceivers.

WSE recognizes that even though these may be logical solutions they may not be allowed due to environmental permit restrictions, feasibility, or required mitigation.

NEXT STEPS

WSE recommends the County:

1. Hold an on-site meeting with WDFW regulatory representatives to discuss WSE's finding and recommendations. The purpose is to determine if removing obstructions to will be permitted.
2. If the answer to number 1 is yes or likely yes, then determine how and if the beavers are able to be managed in-order to prevent them from damming the restored outlet channel.
3. If the answers to 1 and 2 are yes, conduct a hydraulic study to determine how to open an unobstructed corridor. This would include opening a path between the lake and McMurray Shore Drive, removing the sediment delta at the mouth of the unnamed tributary, and designing a sediment capture area along the unnamed tributary. The County will need to contact WSDOT to determine if they are planning to replace the SR9 culvert, for this will need to be considered when developing a plan for a sediment collection area.

CONCLUSION

Based upon the field investigation, WSE agrees that obstructions appear to have reduced the capacity of the lake outlet channel, which in-turn is causing lake levels to rise during long-duration winter rain events. This is not a new problem, for according to a timeline of events included in the Anchor QEA report, outlet channel obstructions have been a concern since at least 2001. The problem will not be easy to solve due to environmental permit restrictions which are likely to make it difficult (if not impossible) and expensive to clear a path through the congested reach. If a path were to be cleared, it will be an exceedingly difficult task to prevent beavers from moving back into and damming the restored reach.

REFERENCES

Anchor QEA. 2010. Lake McMurray Lake Level and Beaver Control Improvement Needs Evaluation Services. May 24, 2010.

Quantum Spatial. 2017. Western Washington 3DEP LiDAR Technical Data Report. September 29, 2017. Downloaded from Washington State Department of Natural Resources – Washington LiDAR Portal. https://lidarportal.dnr.wa.gov/

Appendix B

Lake McMurray Outlet Hydraulics Analysis

Watershed Science & Engineering

WATERSHED
SCIENCE & ENGINEERING

506 2nd Ave, Suite 2700
Seattle, WA 98104

Memorandum

To: Emily Derenne - Skagit County Public Works

From: Jeff Johnson, P.E., Sarah Parker, P.E., and Kaleb Madsen – Watershed Science and Engineering

Date: January 7, 2021

Re: Lake McMurray Outlet Hydraulic Analysis

INTRODUCTION

Lake McMurray waterfront properties flood due to elevated lake levels caused by large long-duration winter rain events. The property owners believe the lake outlet channel is obstructed by beaver dams and debris and, therefore, does not have the capacity required to drain the lake during these rain events.

In 2019, Watershed Science and Engineering (WSE) completed a hydrologic and hydraulic investigation to identify solutions to reduce flooding on properties along Hull Road and Hull Drive located along the west side of the lake (Figure 1). The focus of the investigation was to examine flooding caused by Lake Creek and an unnamed tributary to Lake Creek. During the investigation, WSE determined that solutions to solve the flooding issues for lake front landowners should also consider measures to improve Lake McMurray drainage during winter storms. High lake levels cause front yards of waterfront landowners to be inundated and prevent Lake Creek from draining freely into Lake McMurray. The findings of this initial investigation are included in the Flood Reduction Investigation for Lake McMurray, Hull Drive, and Hull Road report.

In response to these findings, Skagit County retained WSE to examine the lake outlet channel to determine if beaver dams or other obstructions are the cause of the elevated winter lake levels. During this second investigation WSE found that the lake level and its ability to drain after large storm events has been impacted by both sediment deposited in the lake outlet channel by an unnamed tributary just downstream of McMurray Shore Drive and by a vegetation and woody debris in the outlet channel upstream of McMurray Shore Drive. Three inactive beaver dams are present upstream from McMurray Shore Drive. All are porous or have been partially removed; therefore, water is passing through them. No active beaver dams were observed in the portion of the outlet channel that controls lake levels. Rather, beavers were observed well downstream in an off-channel area that does not impact the lake. They have likely abandoned the lake outlet channel because water is almost stagnant and is not flowing swiftly enough in the lake outlet channel to attract them. The findings of this investigation are included in the Lake McMurray Outlet Investigation memorandum.

To further investigate the lake outlet drainage issues, Skagit County retained WSE to complete a hydraulic analysis of the lake outlet and make recommendations on hydraulic effectiveness of potential improvements. To complete this task WSE developed a 1D/2D hydraulic model of the lake outlet channel. Conclusions of the hydraulic outlet analysis are summarized in this memo.

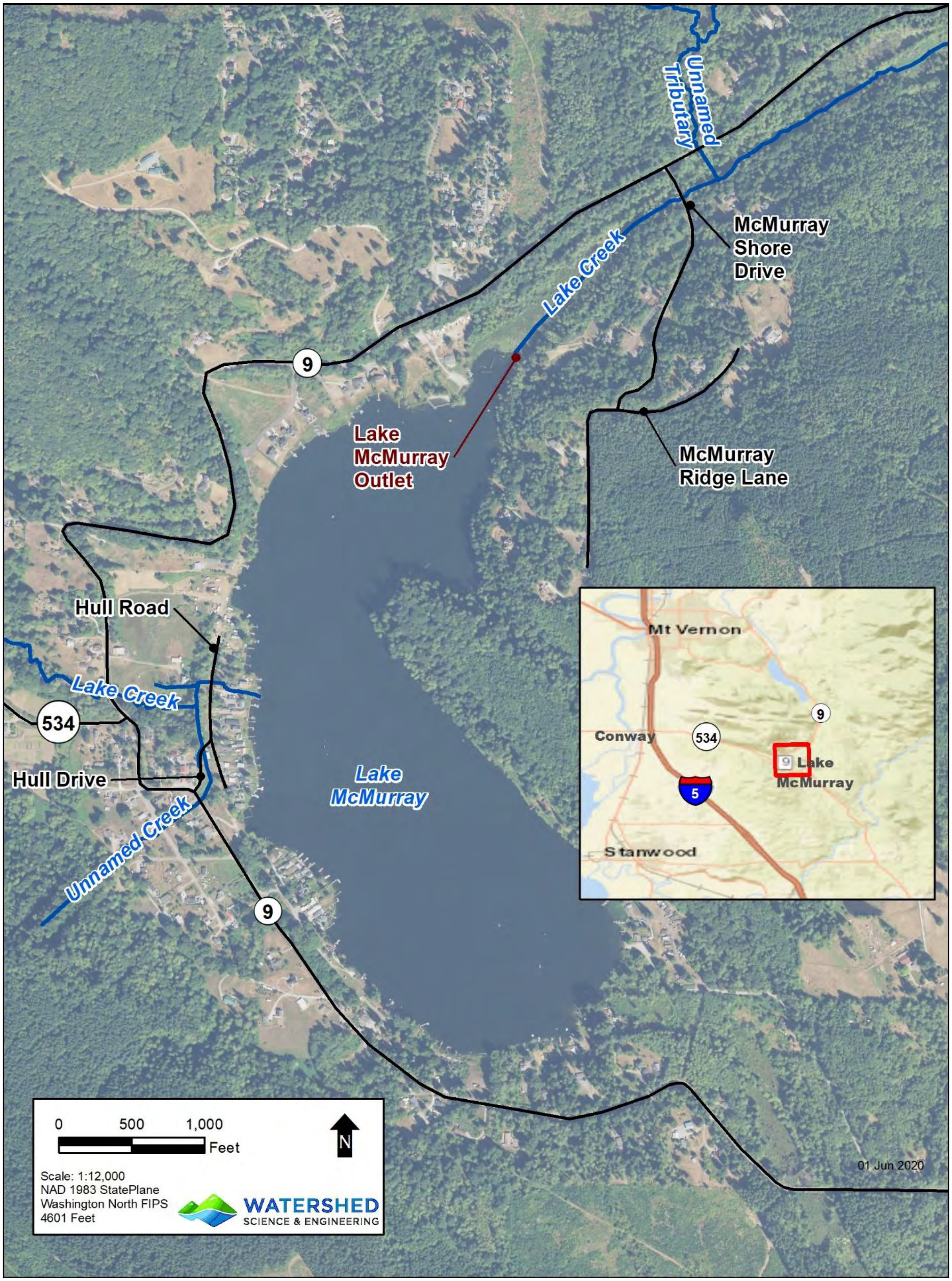

Figure 1. Location Map.

BACKGROUND

ISSUES IDENTIFIED IN PREVIOUS INVESTIGATION

The Lake McMurray outlet channel is a continuation of Lake Creek. The portion of Lake Creek that drains into Lake McMurray from the west was investigated in the first phase of WSE's flooding analysis. The lower portion of Lake Creek which flows out of the northeast corner of Lake McMurray is the focus of the second and third phases of WSE's investigation. In the previous phase of the Lake McMurray outlet analysis, WSE made on the ground observations and documented the condition of the channel by taking photos. Additionally, WSE obtained drone photography during a March 2020 site visit. During the site visits, WSE observed outlet channel conditions and looked for things that may be causing the impeded lake discharges. Figure 2 provides a zoomed in view of the lake outlet channel. The topographic contours shown in Figure 2 were generated using 2017 LiDAR data (Quantum Spatial, 2017).

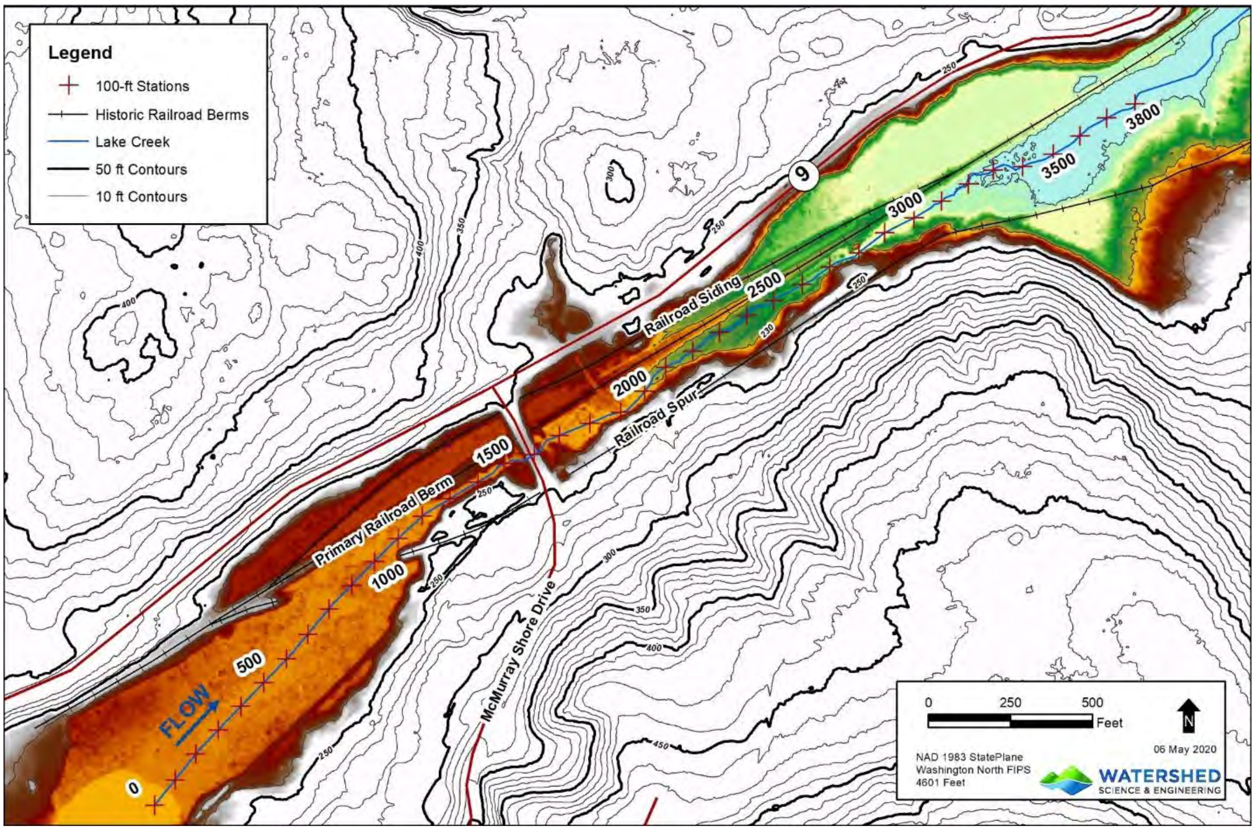

Figure 2. Lake McMurray Outlet Topography

As mentioned in previous memorandums, during the February and March site visits, WSE observed three existing beaver deceiver structures that were in disrepair. A few of the pipes in the beaver deceiver structures had become untethered from the bottom of the channel at one end or another causing one end of the pipe to float. Even though these are in disrepair, it does not seem to be the major contributor to impeded lake outlet flows. An example of one of the beaver deceiver structures is shown in Photo 1. These beaver deceivers are located upstream of McMurray Shore Drive where water is ponded and there is effectively very little flow. This would indicate that something downstream is controlling the ponding level of the lake.

Photo 1. Example of beaver deceiver in disrepair located upstream of McMurray Shore Drive. (March 10, 2020).

In addition to the beaver deceivers, thick vegetation and lots of woody debris were observed in the channel upstream of McMurray Shore Drive (Photo 2). This roughness in the channel would be expected to impede flow and slow drainage of the lake during and after a storm event, but did not appear to be the major control on lake levels.

Photo 2. Drone aerial looking downstream from Lake McMurray into the outlet channel (Photo taken March 10, 2020).

Moving downstream, approximately 21 inches of ponded water was observed within the culverts under McMurray Shore Drive during the February 2020 site visit (Photo 3). This also indicated that something downstream of the culverts and not the culverts themselves were controlling lake level.

Photo 3. Outlet of existing dual culverts under McMurray Shore Drive.

Approximately 300 feet downstream of McMurray Shore Drive, WSE observed a small unnamed tributary which empties into Lake Creek after passing through a culvert under SR 9 (see Figure 3 and Photo 4). This unnamed tributary has deposited sediment at its confluence with Lake Creek, creating a sediment delta that constricts the channel width and therefore flow in Lake Creek. Upstream of this point water appears ponded. Downstream of this point water begins flowing freely again. This would indicate that this constricted channel section is controlling lake water levels during low flows and we suspect that it is at least partly responsible for increased lake levels during storm events.

Photo 4. Looking downstream from McMurray Shore Drive. SR9 is on the left side of the photo and the unnamed tributary is circled in red. (March 10, 2020).

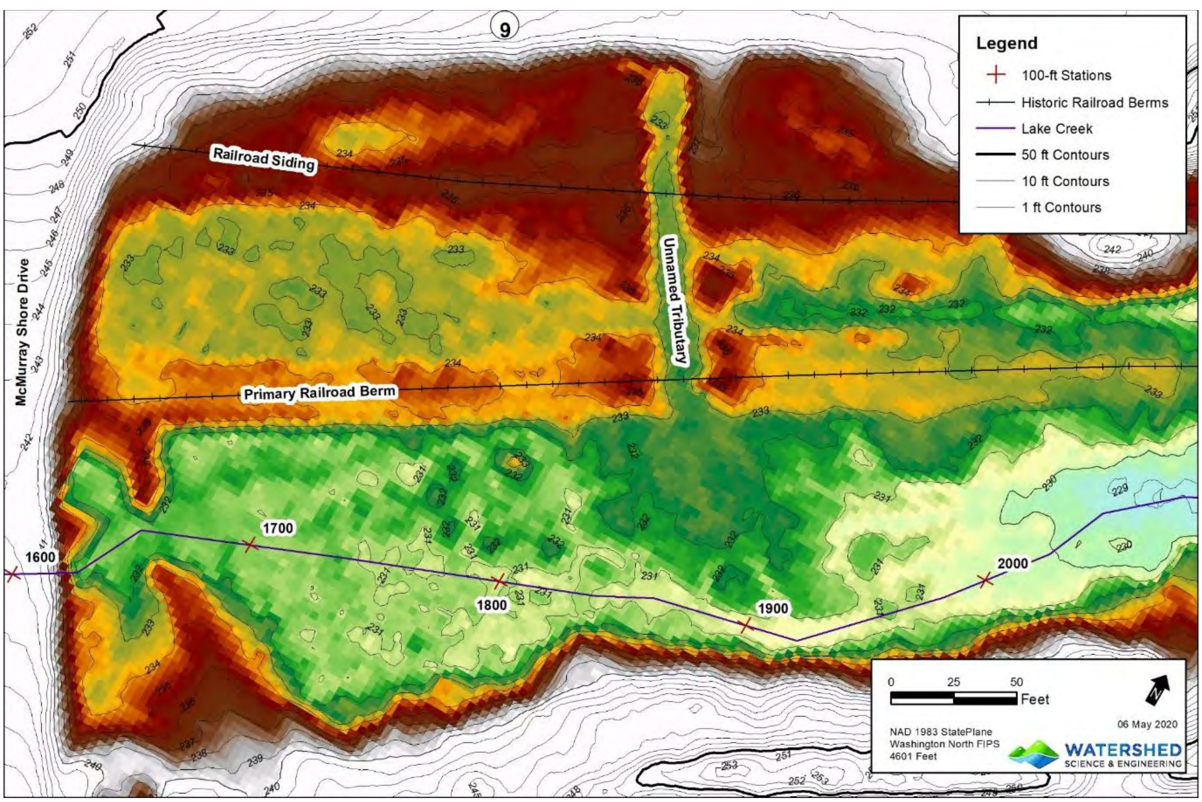

Figure 3. Lake Creek Topography downstream of McMurray Shore Drive.

Inspection of the 2017 LiDAR data also revealed that water levels remain nearly flat from the lake to McMurray Shore Drive (Figure 4). The slope of the water surface then increases slightly (0.002 feet/feet) along the first 300 feet downstream of McMurray Shore Drive, then steepens significantly along the remainder of the profile (0.008 feet/feet). It is this flat section of the stream that is having difficult time draining the lake.

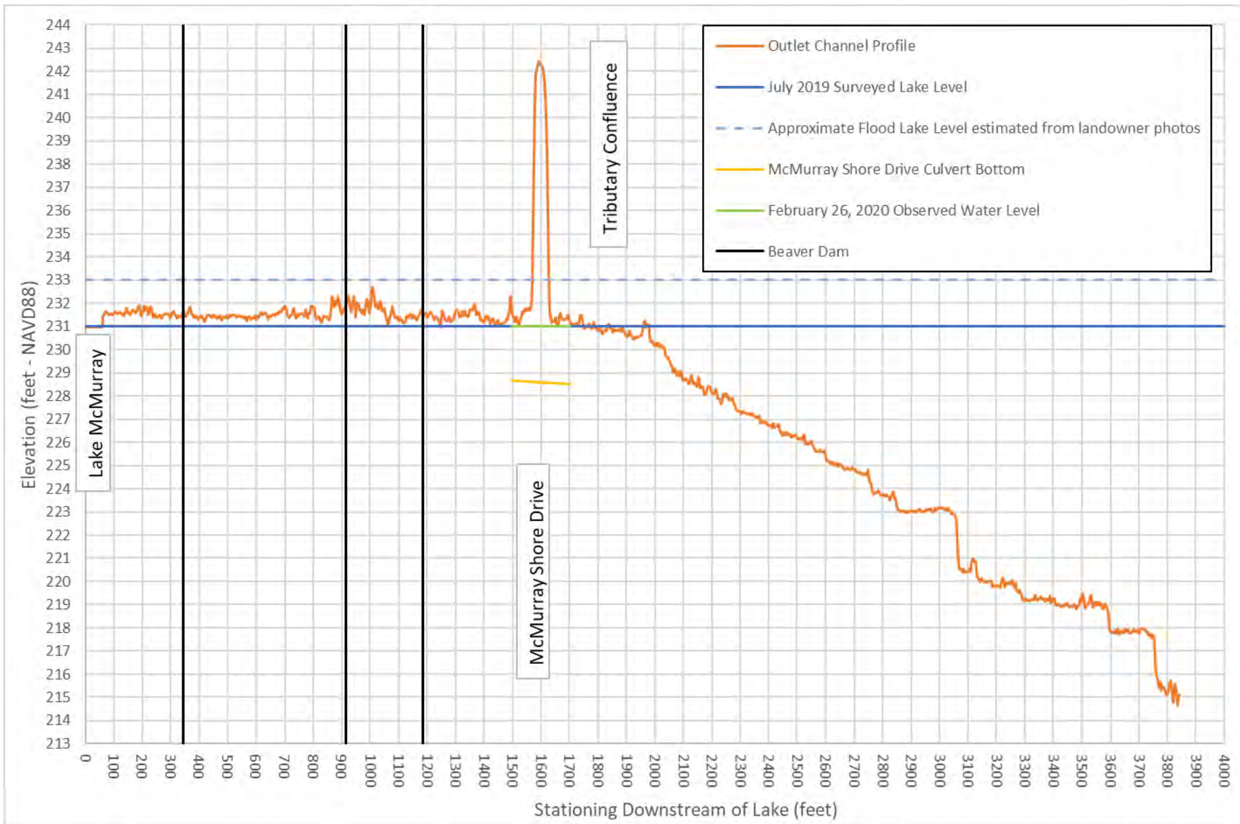

Figure 4. Lake Creek profile downstream of Lake McMurray outlet.

POTENTIAL DRAINAGE IMPROVEMENTS TESTED WITH HYDRAULIC MODEL

Based on the conclusions in the previous phase of the Lake McMurray outlet investigation, WSE constructed a 1D/2D hydraulic model of the lake outlet channel to test the performance of three different drainage improvements. The improvements included:

1) Strategic vegetation and/or debris clearing in outlet channel upstream and downstream of McMurray Shore Drive.
2) Partial removal of the sediment delta formed by the unnamed tributary.
3) Completely removing the unnamed tributary sediment delta and increasing the channel slope downstream of McMurray Shore Drive.

The third alternative is likely impossible to permit due to the large amount of in-channel excavation required and the feasibility and mitigation required to do such an action, but it is included to determine if such a major change would improve conditions significantly.

In addition to the three improvement alternatives above, WSE also analyzed what would happen if beavers reoccupy the outlet channel. As WSE observed during the February and March 2020 site visits, beavers are not actively damming the lake outlet channel, likely because the unnamed tributary sediment delta is causing water to pond upstream. This probably has reduced flow velocities enough that beavers are not attracted to the outlet channel. Higher flow velocities that would occur through implementation of improvements could attract beavers back to the outlet channel. To demonstrate the impact of beaver reoccupation, WSE used the hydraulic model to analyze the effects of beavers constructing a new dam just downstream of the McMurray Shore Drive culverts (Figure 5). According to neighbors, beavers have frequently built and maintained dams at this location in the past.

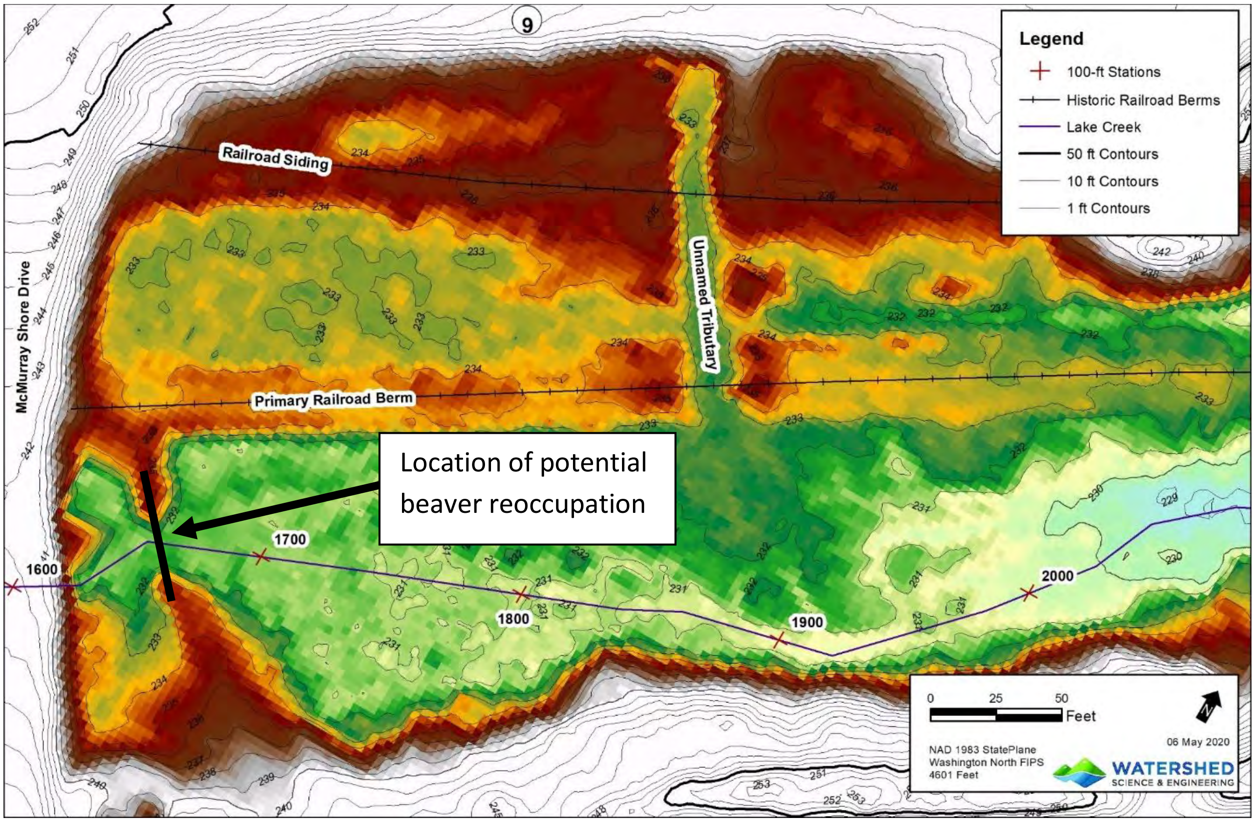

Figure 5. Lower Reach Topography near unnamed tributary to Lake Creek.

HYDRAULIC ANALYSIS METHODS

To evaluate effectiveness of each of the proposed improvements, WSE used both 1D and 2D components of an unsteady hydraulic model known as HEC-RAS which was created by the US ARMY Corps of Engineers (USACE-HEC, 2019). The unsteady version of the hydraulic model allows for resultant flows and water surface elevations to be modeled and viewed through time. WSE used the latest version of the software (version 5.0.7) to perform the hydraulic analysis.

MODEL TOPOGRAPHY

The hydraulic model relied primarily on 2017 North Puget Sound LiDAR Data (Quantum Spatial, 2017) to represent the outlet topography. A limitation of LiDAR based topography is that elevations below the water surface are not captured. Therefore, WSE supplemented the LiDAR data with channel inverts collected during a previous analysis of the lake outlet (Anchor, 2010). WSE used the channel invert data and aerial imagery to burn a channel into the model topography that approximated the existing conditions outlet channel.

EXISTING CONDITIONS MODEL SETUP

At the upstream end of the hydraulic model, Lake McMurray was represented as a storage area. To simulate a storage area in HEC-RAS, a table of storage volumes corresponding to lake levels must be input, otherwise known as a “stage-storage” curve.

A stage-storage curve for Lake McMurray was obtained from the Big Lake Drainage Management Plan report (Montgomery Water Group, 2006). The Lake McMurray stage-storage curve from the Big Lake report provided volumes in Lake McMurray up to a stage of 232.48 feet. WSE extended the stage-storage curve up to an elevation of 235 feet using the 2017 LiDAR data.

To evaluate the effectiveness of potential improvements, the model was run assuming the lake was at an elevated flood level of 234.3 feet at the beginning of each model run. This is the highest lake elevation ever reported for the lake and occurred during a storm in 2009 (Anchor, 2010). Each alternative was evaluated on the basis of how quickly lake levels returned to an elevation of 231 feet. This lake level is considered normal or a non-flood elevation as previously determined by landowner input.

The Lake McMurray outlet channel was represented by 1D cross sections from approximately 620 feet to 1,580 feet upstream of McMurray Shore Drive. The 1D section of the model then flowed into the portion of the model that was represented using 2D calculations. The 2D section of the model extends from approximately 620 feet upstream to 690 feet downstream of McMurray Shore Drive.

The model requires the user to input land cover type in the form of Manning's n coefficients. Manning's n values represent flow roughness which the model uses to calculate energy losses as the flow moves through or over each land cover type. WSE used engineering judgement and experience to estimate appropriate Manning's n values based upon field observations and review of the March 2020 drone aerial imagery. To represent existing conditions, a Manning's n value of 0.08 was applied to the main channel in the 1D section of the outlet model. In comparison, a roughness value of 0.06 was used for Lake Creek in the Hull Road analysis. This difference in Manning's n represents the difference in roughness caused by vegetation and woody debris in the lake outlet channel verses grass in Lake Creek near Hull Road.

The culverts under McMurray Shore Drive were not explicitly represented in the model. This simplification was made because the culverts are sufficiently tall to pass flows without pressurizing. The invert of the culverts are 228.67 feet (Anchor, 2010). During a site visit, WSE measured the culverts and found that they were each 7 feet high by 10 feet wide. Therefore, the soffit (top of the culvert opening) elevation of the culverts are 235.67 feet which is higher than the highest lake level simulated in the model. The culverts were represented in the model as a single 20-foot-wide constricted channel section cut through the road fill in the model topography.

Downstream boundary conditions in the model were set to normal depth with a slope of 0.008 feet/feet.

Figure 6 shows the hydraulic model layout including the Lake McMurray storage area section, the 1D section, and the 2D sections of the hydraulic model.

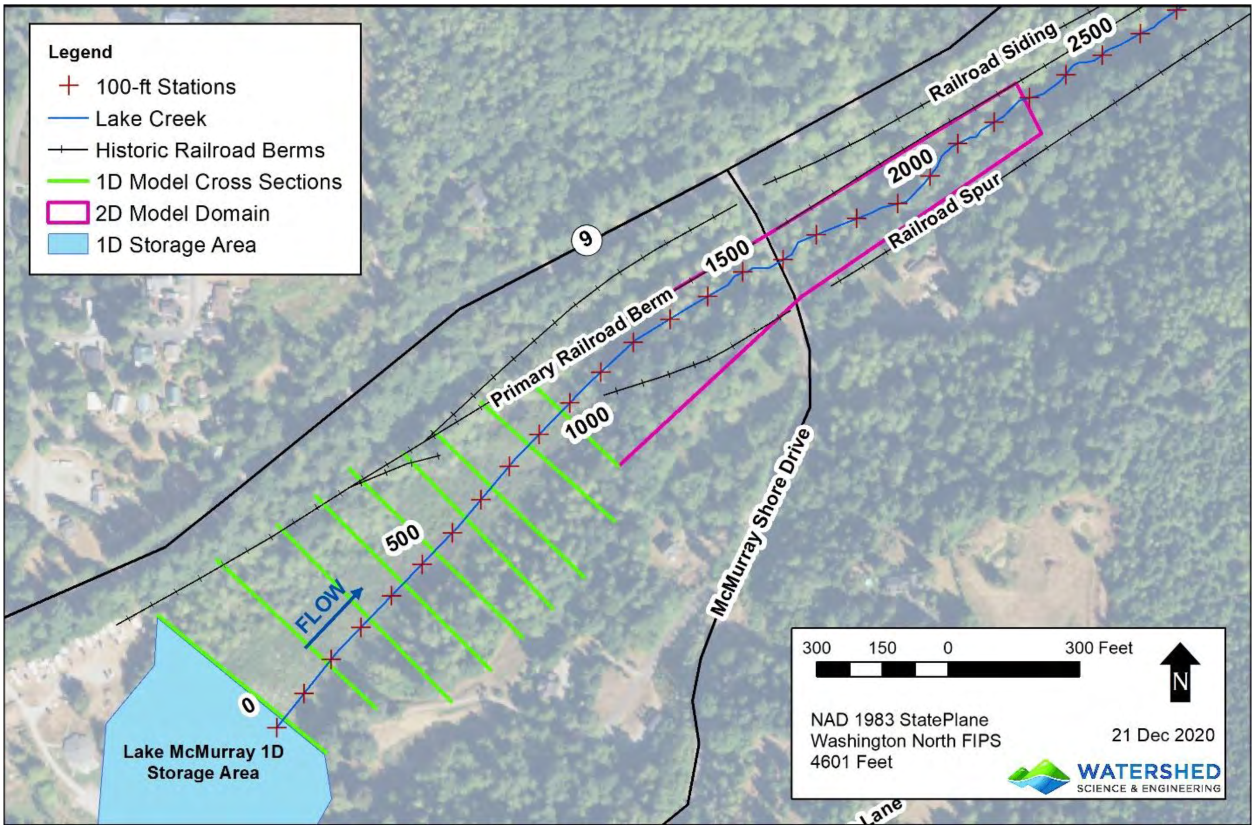

Figure 6. Hydraulic Model Layout

PROPOSED CONDITIONS MODEL SETUP

Once the existing condition hydraulic model setup was complete, the three drainage improvement alternatives and the beaver dam scenario were each represented in the hydraulic model.

The vegetation removal alternative was represented in the model simply by decreasing the Manning's n Roughness value from 0.08 to 0.05 in the 1D section of the model and in the 2D section of the model, downstream of McMurray Shore Drive. The channel section from McMurray Shore Drive upstream to the 1D/2D model boundary is already free of vegetation and is represented by a Manning's n value of 0.05; therefore, the roughness value in this section of the model was preserved under the vegetation removal alternative.

In the partial sediment delta removal alternative, the model topography was modified to represent a modest excavation that may be acceptable to regulators. Figure 7 compares the model topography for existing conditions to the partial sediment delta removal alternative.

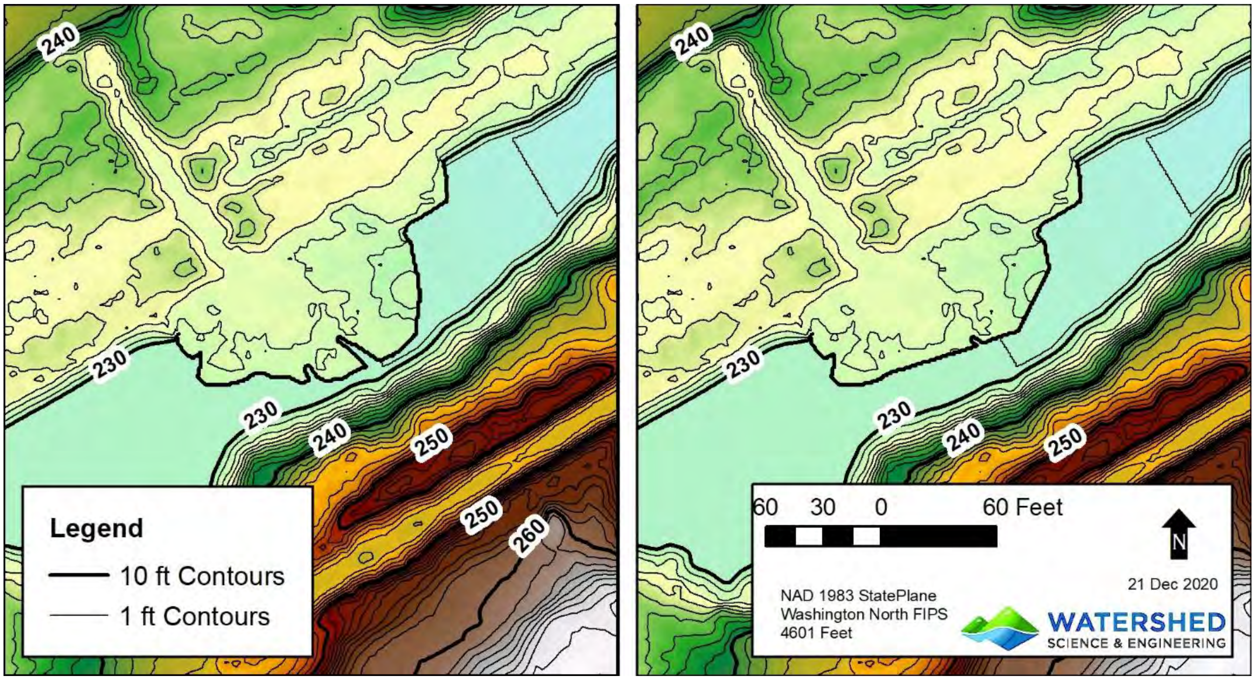

Figure 7. Comparing existing conditions topography to partial sediment delta removal topography.

Under existing conditions, the channel has an adverse (uphill) slope downstream of McMurray Shore Drive. This is shown by the rising portion of the blue line in Figure 9. For alternative 3, the entire sediment delta was removed and the channel profile was excavated to create a descending channel slope downstream of McMurray Shore Drive. This is shown by the orange line in Figure 9. Figure 8 compares the topography at the sediment delta for existing conditions and complete removal.

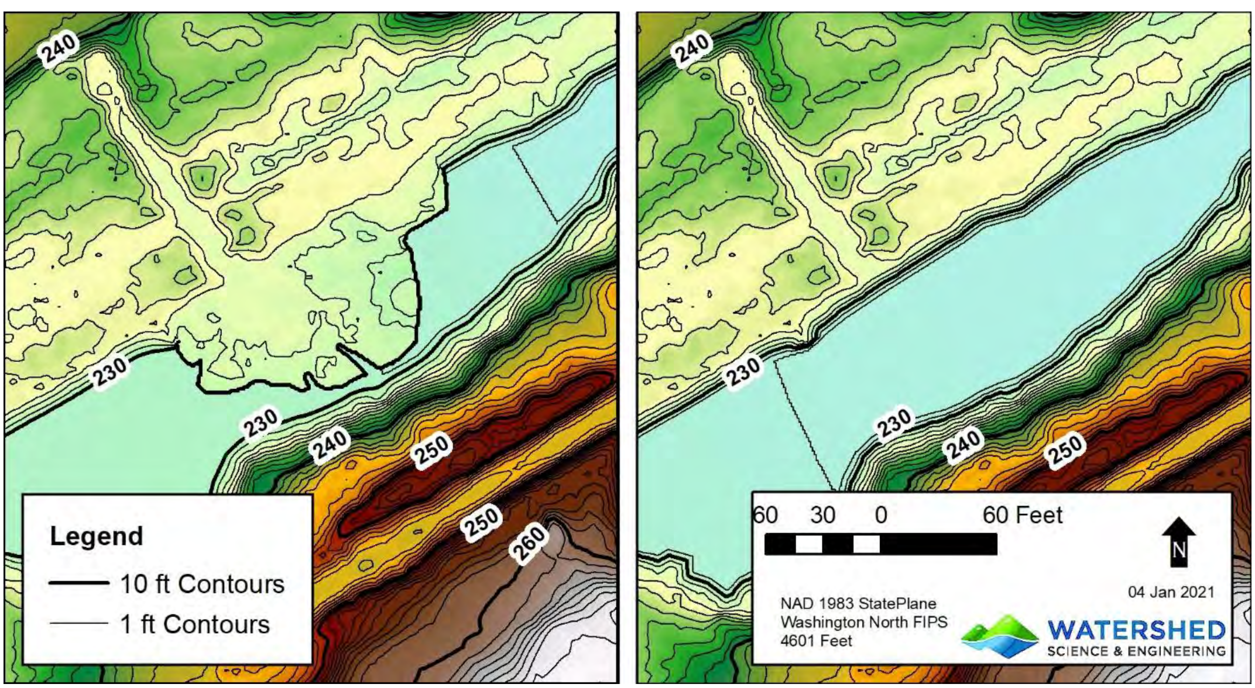

Figure 8. Comparing existing conditions topography to full sediment delta removal topography.

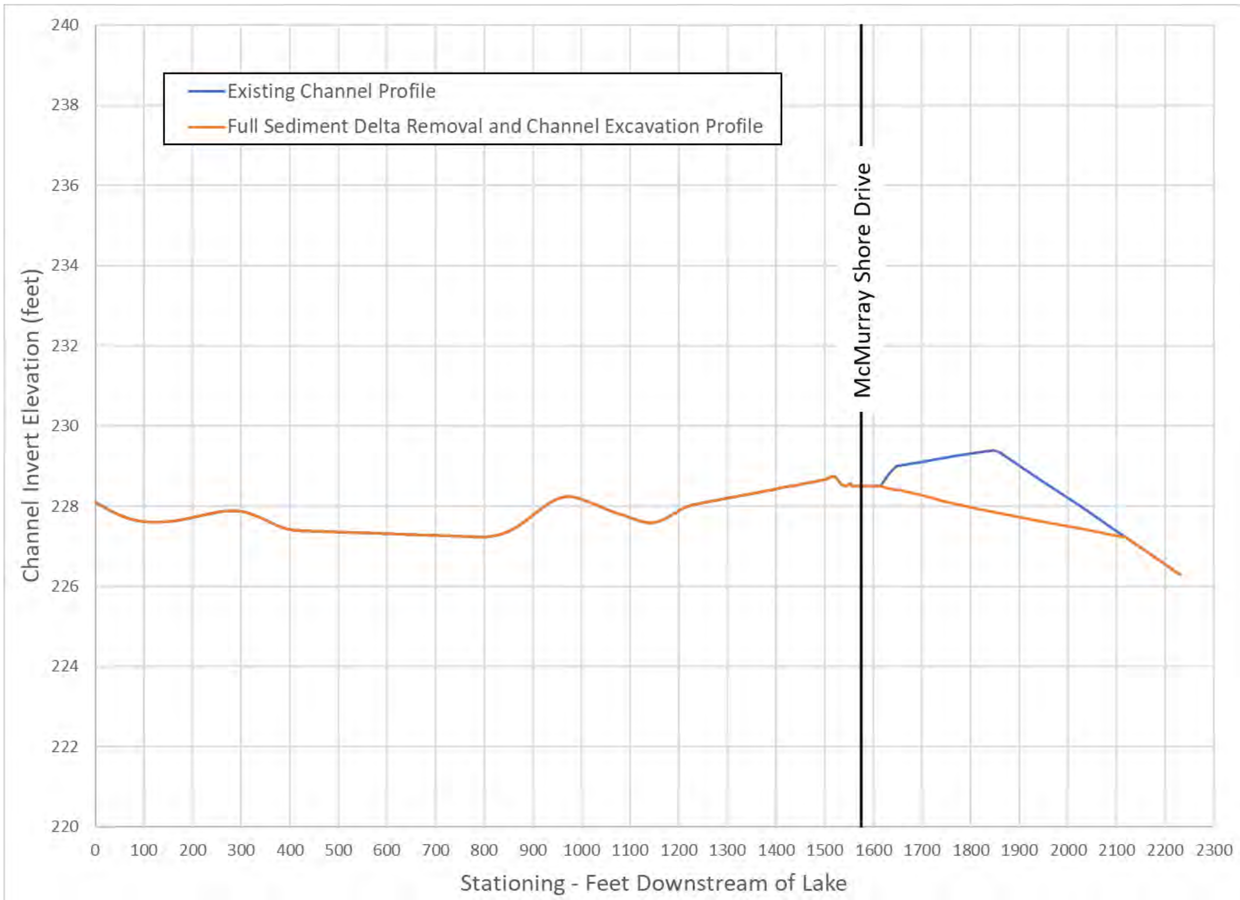

Figure 9. Comparing existing condition channel profile to the full sediment delta removal and channel excavation profile.

To test the beaver dam reoccupation scenario, the existing condition model was modified to include a weir (small dam) approximately 2.5 feet in height at the location downstream from McMurray Shore Drive identified in Figure 5. This height was chosen because 2.5 is a realistic height a beaver could successfully construct a dam in this location.

HYDRAULIC ANALYSIS RESULTS

Results from the hydraulic analysis were used to compare the effectiveness of the improvement alternatives to existing conditions. The beaver dam test was also compared to the improvement alternatives and existing conditions to understand the effects of beaver reoccupation. Table 1 reports the amount of time it takes for Lake McMurray to drain from a flood level of 234.3 feet to a non-flood level of approximately 231.0 feet for each alternative and the beaver reoccupation scenario. Figure 10 shows the lake level through time for each of the modeled scenarios.

Note – the simulations assume that no flow is entering the lake while it is draining, a scenario that would not occur. This simplifying assumption had to be made for it was not within the scope of this investigation to complete the detailed hydrologic modeling required to account for lake inflows. The drainage times listed in Table 1 are meant to show the relative benefits or impacts of each scenario and do not represent the actual time it would take to for the lake to drain in response to a storm event. Accounting for lake inflows would change the lake drainage times reported for each scenario, but would not impact the conclusions about relative benefit of each scenario compared to one another.

Table 1. Comparison of Drainage Times for Existing Conditions, Improvement Alternatives, and Beaver Dam Reoccupation

Hydraulic Scenario	Time for Lake McMurray water surface elevation to return to normal level (non-flood) levels (Hours)
Existing Conditions	119
Vegetation Removed	103
Partial Sediment Delta Removal	83
Full Delta Removal & Channel Excavation	65
Beaver Dam Reoccupation	Greater than 144 hours (Limit of Simulation)

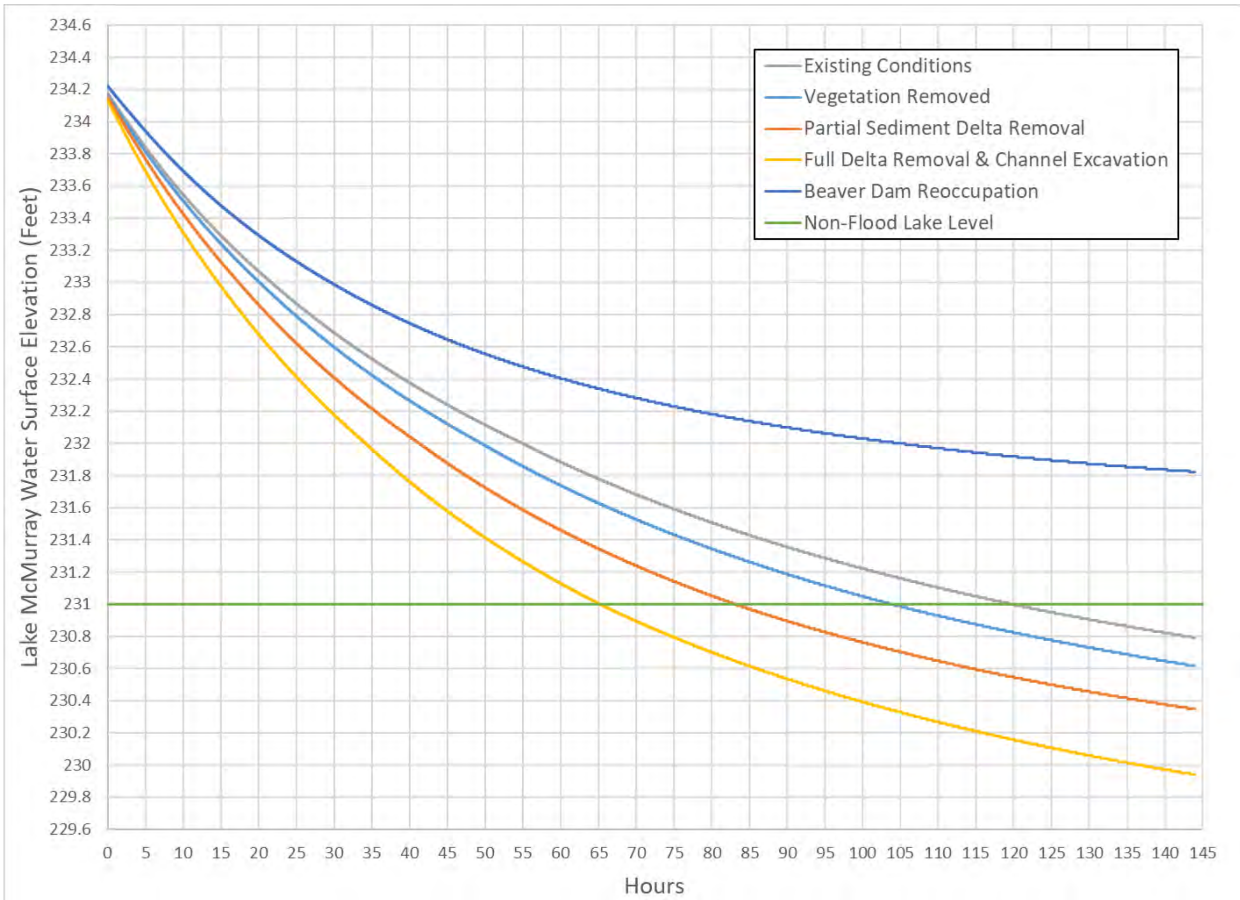

Figure 10. Lake Drainage Time for Each Hydraulic Scenario compared to Existing Conditions

Under existing conditions, the model predicts that it would take 119 hours, or just less than 5 full days for the lake to return to elevation 231.0 ft. The vegetation removal alternative improved drainage times by 16 hours, or a little more than one-half day, the partial sediment delta removal alternative improved drainage times by 36 hours, or 1.5 days, and the full delta removal and channel excavation alternative improved drainage times by 54 hours, or 2.25 days. The beaver dam reoccupation scenario demonstrated the potential negative effect if beavers reoccupy the outlet channel. In the beaver dam scenario, the lake took greater than 144 hours, or 6 days, to drain from the 2009 high lake elevation to a non-flood level. The reality, however, is that the lake would likely only drain to the elevation of the top of the beaver dam; therefore, the lake could remain at flood stage for many weeks or months.

Figure 11 compares the water surface profiles for each modeled scenario at the beginning of the model simulation when the lake is at the flood stage of 234.3 feet. The figure reveals that the beaver dam scenario results in the flattest water surface slope between the lake and the example dam location.

Figure 12 compares the water surface profiles for each modeled scenario at the end of the model simulation (at hour 144). Figure 12 shows that either leaving the sediment delta in place, partially or fully removing it impacts the time it takes for the lake to drain; however, the level eventually drains to non-flood levels for all three conditions. The simulated beaver dam scenario reveals and illustrates what we believe is the greatest concern, for theoretically the lake will only drain to the elevation of the top of the dam and will not return to elevation 231.0 feet, unless a portion of the dam is removed.

Note that in both Figure 11 and 12, the regraded channel bottom was used in the full sediment delta removal scenario only. The other four scenarios used the existing conditions channel bottom.

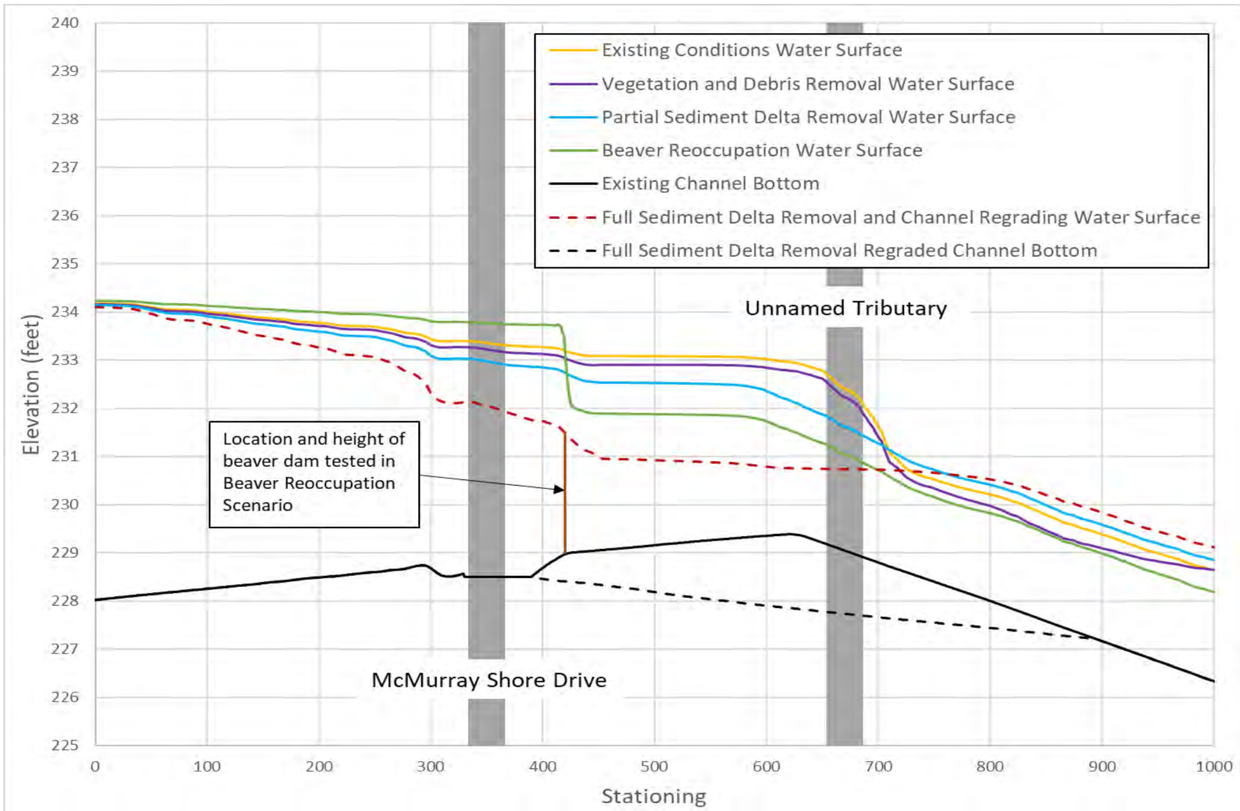

Figure 11. Water surface elevation profiles along the lake outlet channel at beginning of model simulation

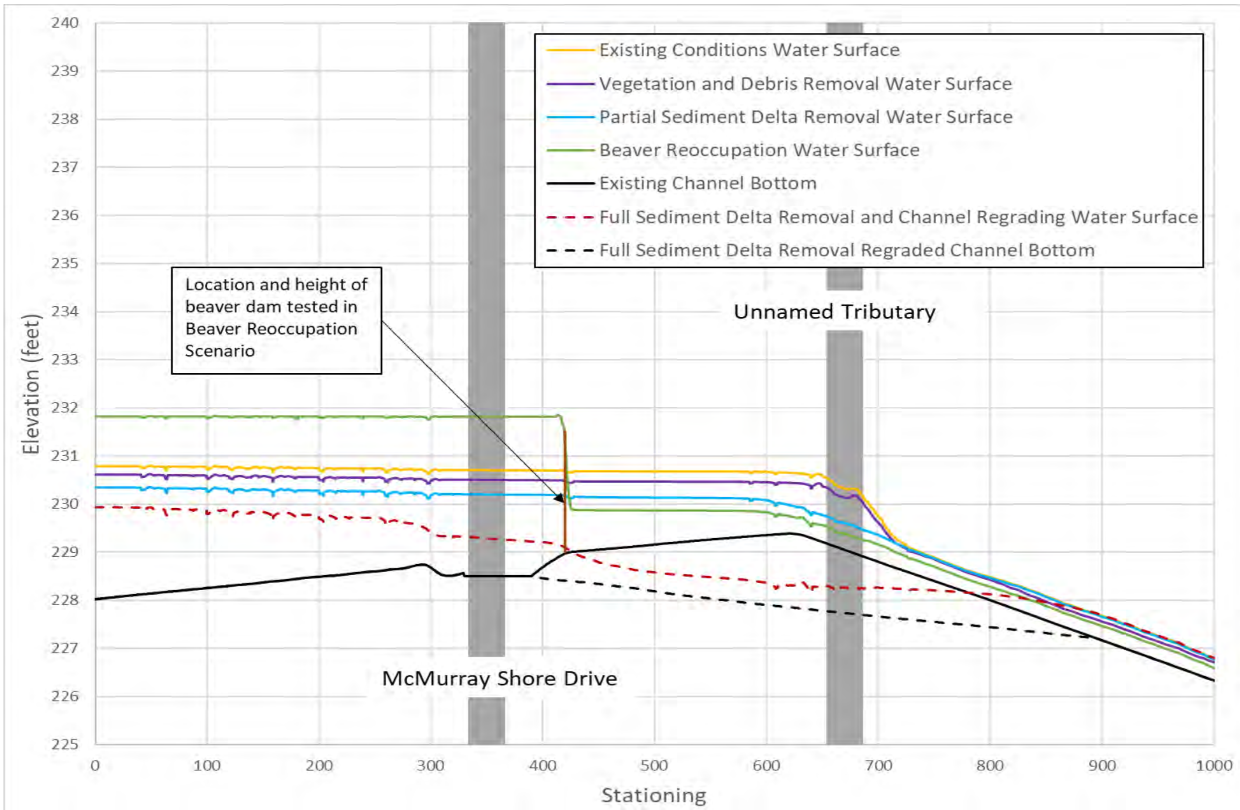

Figure 12. Water surface elevation profiles at end of model simulation (144 hours after beginning)

Based upon the model results, it is WSE's opinion that beaver dams pose the greatest risk to lake levels. If beavers reoccupy the lake outlet channel, an aggressive beaver dam management program will be required to maintain lake outlet flow. Vegetation removal/management combined with partial excavation of the unnamed tributary delta would be an improvement; however, if these improvements increase velocities in the outlet channel, beavers may reoccupy the reach. Due to the history of beaver dams in this location and the fact that beavers are currently very active just a short distance downstream, increasing the velocity will likely be met by new beaver activity. Removing portions of beaver dams and/or relocating beavers can be difficult for it requires state permits and significant time, energy and money to do effectively. Full removal of the delta and excavation of the channel combined with vegetation removal/management would provide a significant improvement, however it will likely be difficult to permit. If the partial or full delta alternative is selected, a sediment basin immediately downstream from the SR9 culvert should be included to extend the life of the delta excavation.

HULL ROAD IMPROVEMENT IMPLICATIONS

The analysis completed by WSE to evaluate potential improvements to reduce flooding in the vicinity of Hull Road assumed that lake levels would remain at a non-flood level of 231 feet. This assumption was made because it was assumed that a feasible solution would be found to keep the lake outlet channel free of obstructions and thus lake levels low during rain storms. Based on the Hull Road flooding analysis, WSE recommended improving the Lake Creek channel from Hull Road to the lake, replacing the existing Hull Road culvert with a fish passable 12-feet wide by 3-feet tall concrete box culvert, and improving the plugged culverts under the abandoned railroad berm located west of Hull Road. Alternatives 3A, 3B, and

3C all included these recommendations with the difference between them being the treatment of the abandoned railroad culverts. Alternative 3A simulated replacement of the culverts with a 12-foot wide by 3-feet tall concrete box culvert. Alternative 3B simulated replacement of the culverts with an open cut, which was modeled as a trapezoidal shaped excavation in the existing railroad berm with an approximately 12-foot bottom width, 50-foot top width and 2 horizontal feet to 1 vertical foot side slopes. Alternative 3C simulated cleaning of the existing railroad culverts. All three alternatives produced similar hydraulic results. For simplicity only Alternative 3B is re-examined here. Figures 13-15, which are taken directly from the Hull Road investigation, compare maximum flood extents under existing conditions to those of Alternative 3B assuming the lake level is at a non-flood stage of 231 feet for the 2-year, 10-year, and 100-year events, respectively.

Knowing that it could be difficult to maintain an unobstructed lake outlet channel for perpetuity, WSE completed an additional set of Hull Road improvement model runs during this lake outlet investigation to determine if the proposed Hull Road improvements would continue to reduce flooding when lake elevations rise to elevation 232.8 feet. Flood photos provided by landowners indicate that the lake rose to approximately 232.8 feet during floods in November 2015 and February 2018. At this level the front yards of lake front properties are severely inundated. Figures 16-18 compare the maximum flooding extents under existing conditions and Alternative 3B for the 2-year, 10-year, and 100-year events respectively with a lake elevation of 232.8 feet. The model results reveal that the proposed improvements at Hull Road will still significantly reduce flooding during the 2-, 10-, and 100-year storm events even if the lake remains at a flood stage of 232.8 feet. WSE did not test the performance of the Hull Road improvements for an elevated lake level of 234.3 feet, which according to Anchor (2010), is the highest level ever recorded and occurred during a 2009 storm.

As stated in the Hull Road report, the restored section of the Lake Creek channel between Hull Road and Lake McMurray will be prone to sedimentation and vegetation colonization. To maintain the flood reduction benefits of Alternative 3B, it will be crucial to implement a maintenance program to remove sediment and vegetation as needed to maintained channel capacity. Sedimentation in this section of channel will occur more rapidly during storms that occur when lake levels are elevated because backwater from the lake will extend further up the channel.

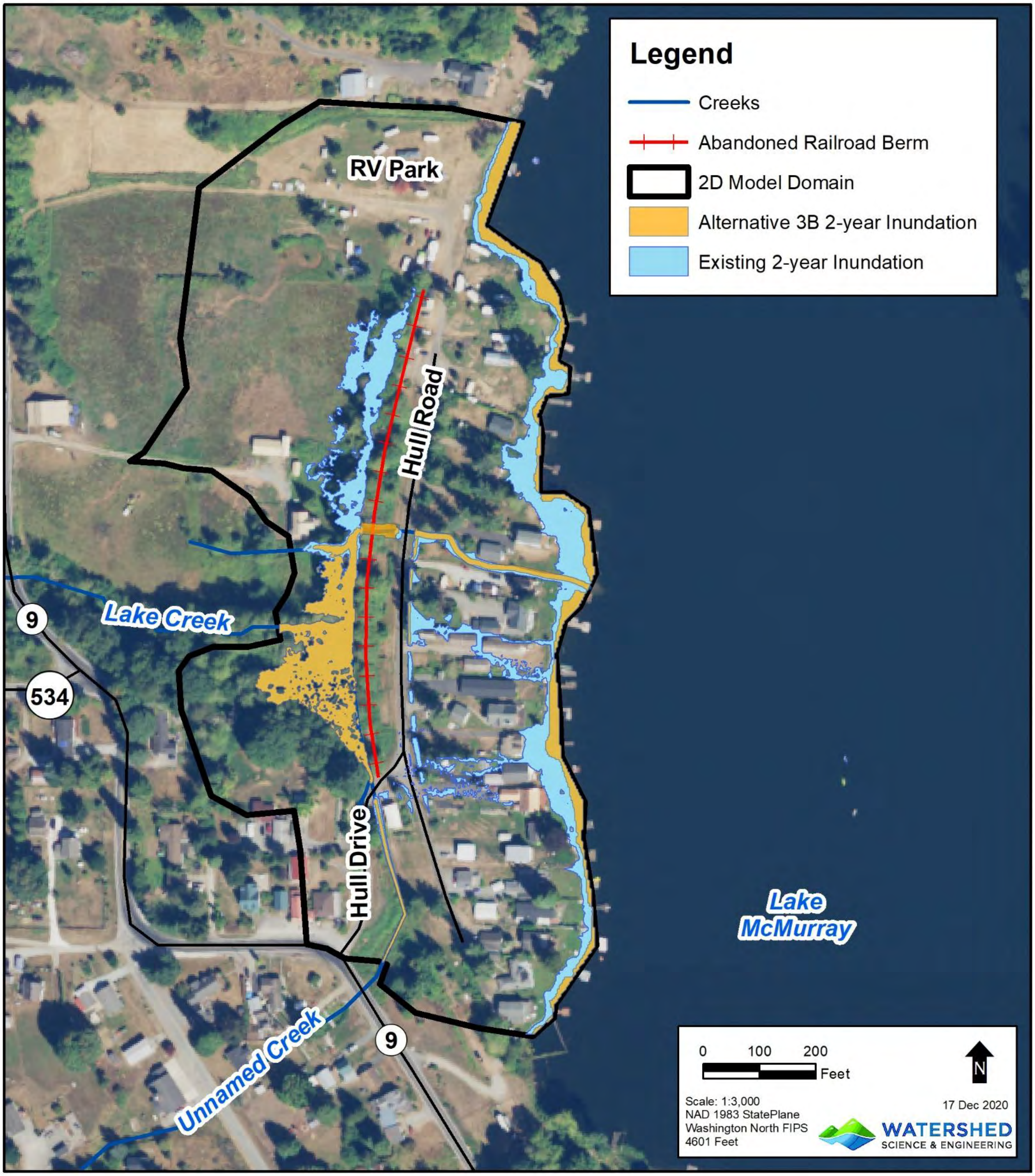

Figure 13. 2-year Flood Inundation Limits Alternative 3B vs. Existing Conditions (Lake Level = 231 feet)

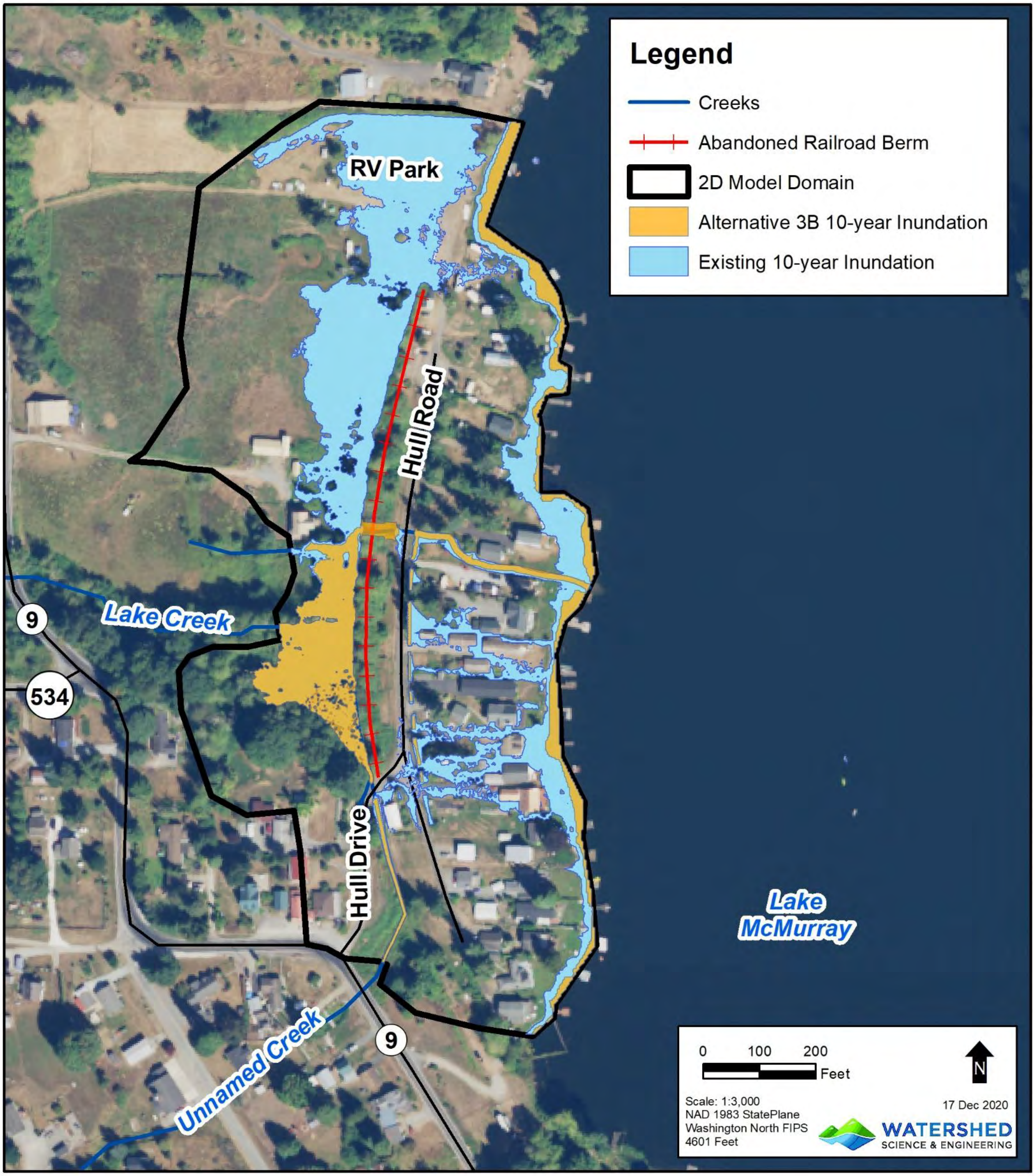

Figure 14. 10-year Flood Inundation Limits Alternative 3B vs. Existing Conditions (Lake Level = 231 feet)

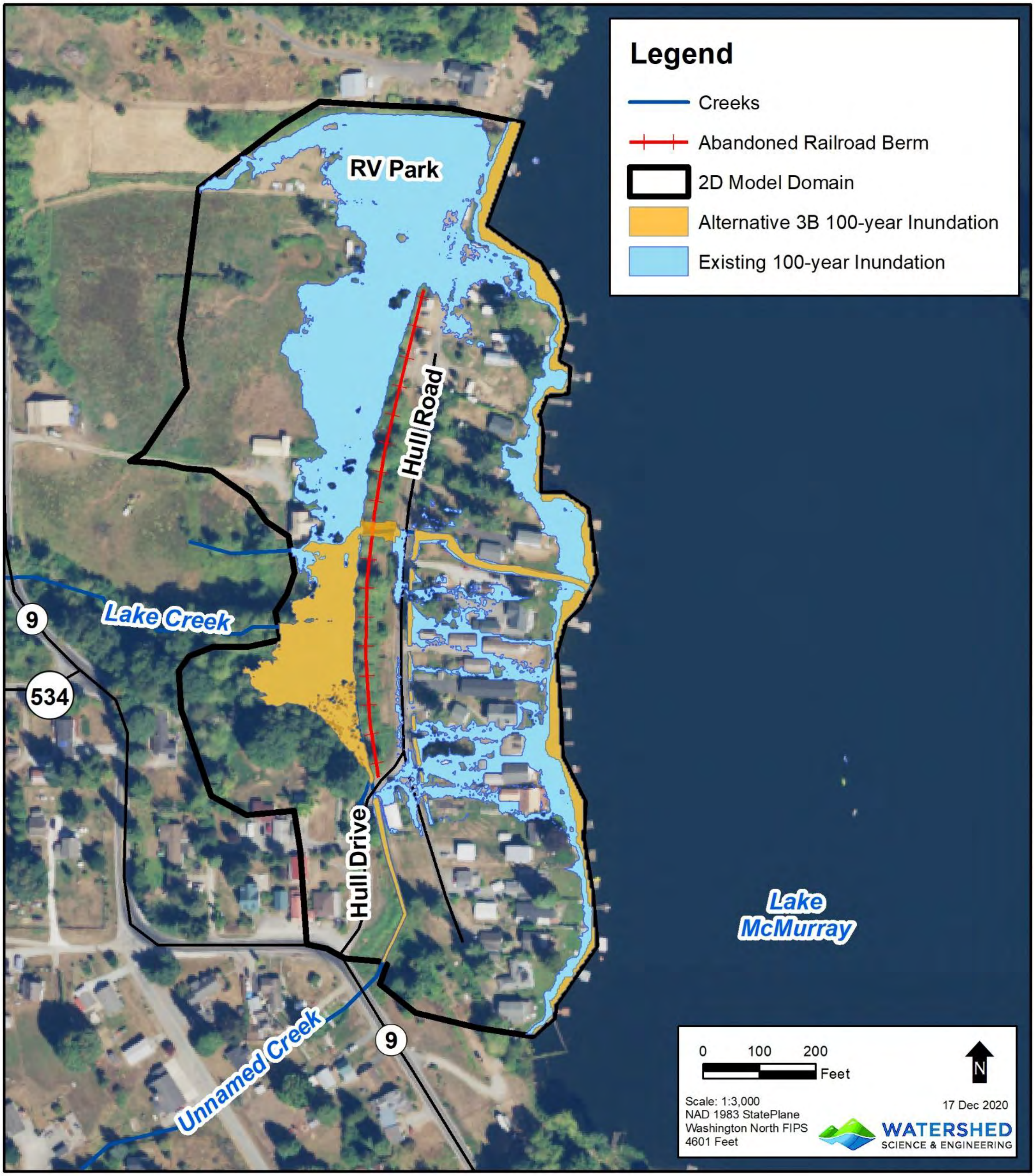

Figure 15. 100-year Flood Inundation Limits Alternative 3B vs. Existing Conditions (Lake Level = 231 feet)

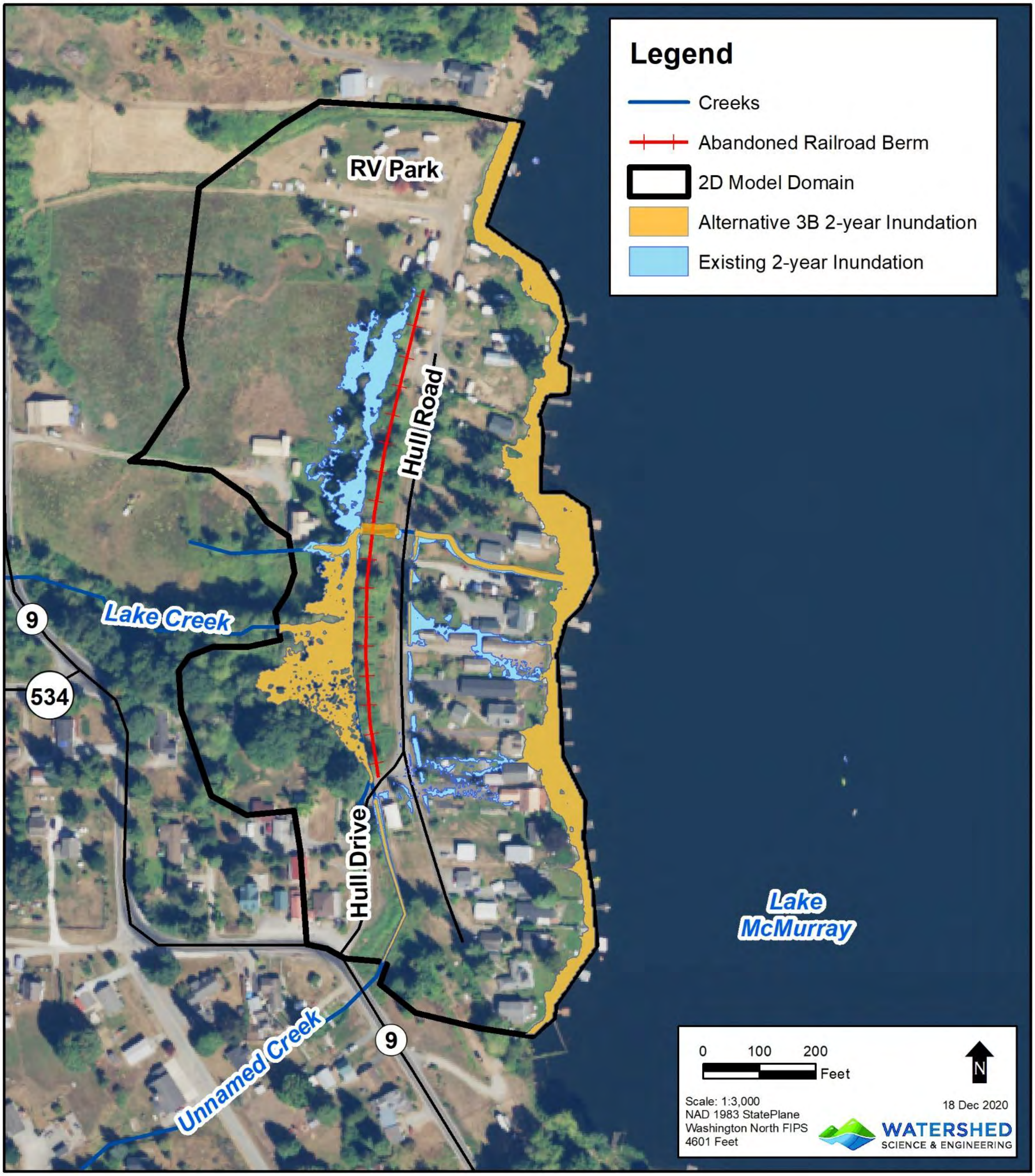

Figure 16. 2-year Flood Inundation Limits Alternative 3B vs. Existing Conditions (Lake Level = 232.8 feet)

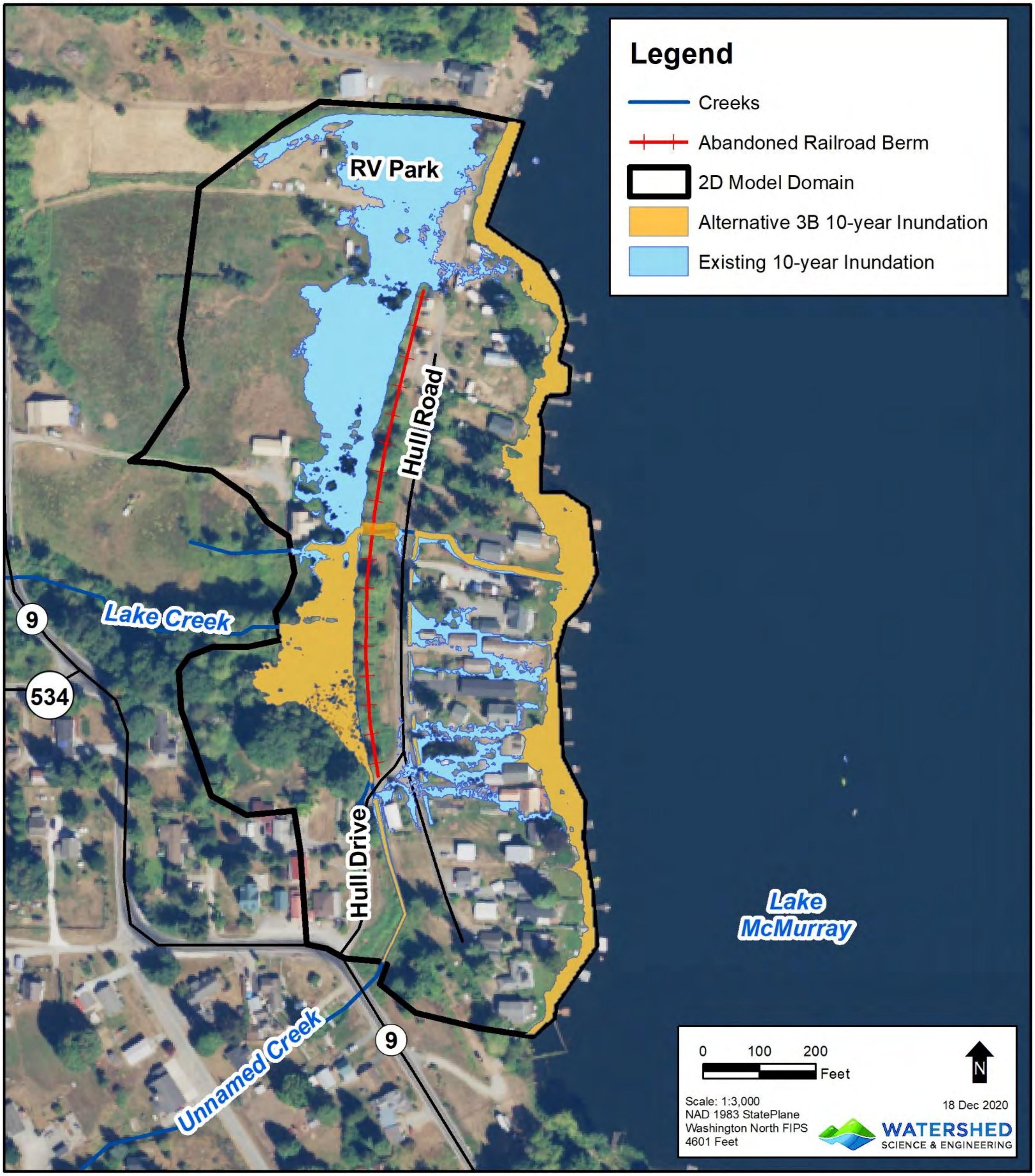

Figure 17. 10-year Flood Inundation Limits Alternative 3B vs. Existing Conditions (Lake Level = 232.8 feet)

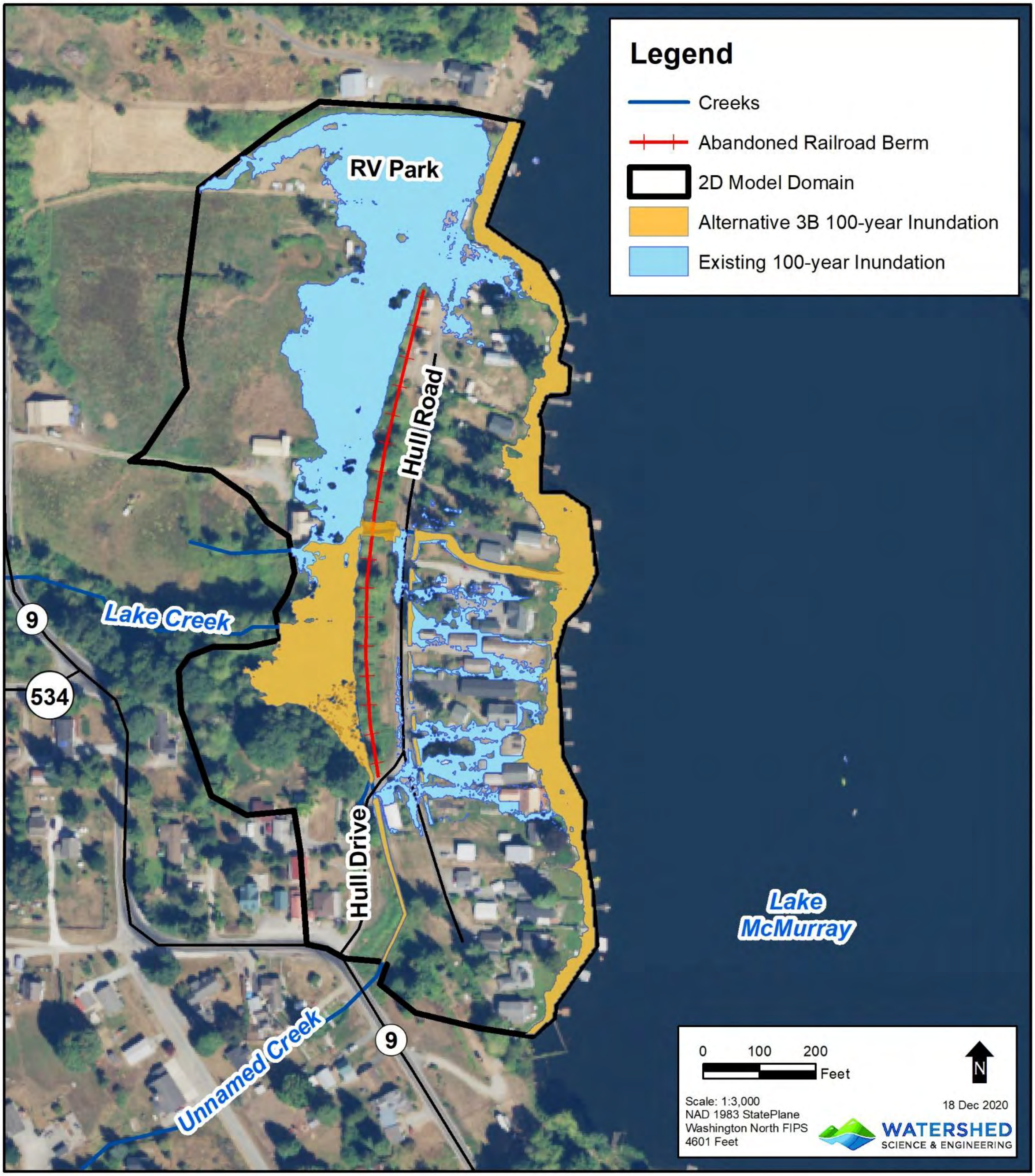

Figure 18. 100-year Flood Inundation Limits Alternative 3B vs. Existing Conditions (Lake Level = 232.8 feet)

CONCLUSION

Based upon the lake outlet channel hydraulic model results, it is WSE's opinion that beaver dams pose the greatest risk to lake levels. If beavers reoccupy the lake outlet channel, an aggressive beaver dam management program will be required to allow the lake to freely drain. If beavers build and maintain dams in the outlet channel, the lake will likely drain to the elevation of the top of the highest beaver dam and remain there for an extended period of time following the rain event. The beaver dam could, and likely would, cause the lake level to be elevated well above existing conditions.

Existing vegetation within the outlet channel and the unnamed tributary delta both have an impact on lake levels; therefore, both vegetation removal/management and the partial or full excavation of the unnamed tributary delta will increase lake outflows. However, even without these improvements, the lake will drain, it will just take longer to do so. Our primary concern is that by making these improvements, one may actually make conditions worse and much harder to manage, for the improvements will increase velocities within the outlet channel which may entice beavers, which are extremely active just downstream, to reoccupy and build new dams in the reach. As demonstrated, active beaver dams could cause lake levels to rise significantly and prevent the lake from draining. This could cause lake front properties to remain flooded for much longer periods than they would under current outlet channel conditions.

Full removal of the delta and excavation of the channel will provide a significant improvement; however, it will likely be difficult to permit. If it is permittable it may require significant and costly mitigation. If the partial or full delta alternative is selected, a sediment basin immediately downstream from the SR9 culvert should be considered to extend the life of the delta excavation. This would require a separate sediment analysis and basin design for the unnamed tributary.

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