APPENDIX B

Detailed Hydraulic Modeling Analysis

Memorandum

To: Interested members of the public

Date: 11/19/15

From: California Tahoe Conservancy

Subject: Upper Truckee River and Marsh Project Flood Modeling

Please find the attached technical memorandum, which details recent updates to the flood modeling for the California Tahoe Conservancy's (Conservancy) Upper Truckee River and Marsh Restoration Project (Project). The memo details recent updates to the flood modeling for the Conservancy's Upper Truckee River and Marsh Restoration Project (Project). The Conservancy and its consultants first completed flood modeling in 2005 to assess the potential flood effects from Project Conceptual Alternatives, and the Conservancy used these 2005 modeling results in the Project draft environmental document. We have completed another, more detailed and extensive modeling effort to verify the information presented in the draft environmental document and ensure the recommended alternative will not result in adverse flood impacts. While the particular methods and models differed, both modeling efforts demonstrate that the Project will not increase flood hazards to adjacent developed areas. The following paragraphs provide additional background and context, along with a summary of the recent flood modeling study with references to specific sections of the technical memorandum.

Flooding of areas adjacent to river channels is a natural process, and large winter precipitation flood events have historically inundated the Marsh and several adjacent developed areas. The Federal Emergency Management Agency (FEMA) and City of South Lake Tahoe (City) designated floodplain extends across the Project site and into some areas of the adjacent residential neighborhoods. In January 1997 a multi-day rain-on-snow event resulted in very high flow rates on the Upper Truckee River (UTR). While flow estimates for that flood varied due to damage incurred at the United States Geological Survey gage, the estimated range of the 1997 peak flow is comparable to the statistical 100-year event analyzed by FEMA in their subsequent floodplain mapping studies. Conservancy staff visited the Tahoe Island and Sky Meadows neighborhoods during the 1997 flood and documented the conditions through various photos, some of which are included in the attached memo. Conservancy consultants visited several of these same areas in 2000 and surveyed the elevation of 1997 flood indicators at representative locations. These data points have been useful for later calibration of the flood models.

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The Conservancy contracted for technical assistance from Cardno Inc. (Cardno) to perform the updated Project flood modeling. Cardno developed two-dimensional hydraulic models for the existing and proposed conditions, using the FEMA approved XP Solution's Stormwater &Wastewater Management Model (XPSWMM model). The Conservancy and Cardno selected this model because it uses detailed topographic and site information, and also because it successfully represents the complex flow patterns in the shared floodplain of the UTR and Trout Creek, and surrounding urban areas. As detailed in the attached technical memorandum, the Cardno modeling effort includes numerous conservative approaches and assumptions to replicate the "worst case" flooding scenario. The Conservancy requested this approach to reduce uncertainties while providing the highest level of technical assurance that the Project will not adversely impact nearby private properties.

Cardno prepared the attached technical memorandum, which documents the details of the model, including the model inputs, outputs and processing, along with the model results for the existing and proposed conditions. Cardno modeled the 10 and 100-year events, based on parameters and guidance from a recent 2012 FEMA modeling effort.

The modeled 100-year flood extent under the existing condition scenario aligns very closely to the mapped FEMA regulatory 100-year floodplain, and the surveyed flood indicators from the 1997 flood event. The proposed Project does not impact the 100-year flood extent and elevations on the private properties surrounding the Marsh. Pages 4-7 and 6-6 of the technical document display the 100-year model results under the existing and proposed conditions, and Figures 7-2 and 7-3 show the net change in flood depths in the proposed condition. Some areas in the center of the Marsh and near the barrier beach demonstrate increased flood depths, which is consistent with the Project objectives to improve wetness and habitat in these areas. The model results on these figures show that the private and residential properties adjacent to the Marsh do not experience increased floodwaters as a result of the Project.

The UTR watershed is the largest contributor of stream-borne sediment into Lake Tahoe and it exhibits degraded terrestrial and aquatic habitats due to historic land-use impacts. The Project will provide regionally significant benefits to wildlife habitat and water quality, and it will build upon the cumulative benefits of other nearby restoration projects. The Project will improve the natural processes and functions of the UTR, including the beneficial overbank inundation processes in the middle of the marsh, without increasing flood hazards to neighboring private properties.

For questions regarding the flood memorandum or the Project, please contact:

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Upper Truckee River and Marsh Restoration Project – Updated Flood Modeling Memorandum

Detailed Hydraulic Modeling Analysis

3022196, Amendment 13

Cardno
Shaping the Future

Document Information

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1 Synopsis

This technical memo summaries the purpose, assumptions, input data, methods, and results of two-dimensional (2D) hydraulic flood modeling performed by Cardno, Inc. (Cardno) to simulate the existing and proposed (Preferred Alternative) conditions for the California Tahoe Conservancy's Upper Truckee River and Marsh Restoration Project (Project). This memo includes background information as context to facilitate reading it as a discrete report, but it is intended as a companion and appendix to the Final EIR/EIS/EIS for the Project, which includes substantial additional relevant information. The memo also integrates and cross references data from prior Project-related studies completed during several years of planning, as cited within the following text where appropriate.

Cardno applied the XPSWMM ('Stormwater & Wastewater Management Model') developed by XPsolutions http://xpsolutions.com/assets/downloads/xpswmm/xpswmm_Reference_Manual.pdf (XP solutions 2015) to the Project analysis. XPSWMM is a Federal Emergency Management Agency (FEMA) approved hydraulic model and selected for this Project in particular to represent the complex 2D flow patterns in the shared floodplain of the Upper Truckee River and Trout Creek, and surrounding urban areas and to take advantage of recently acquired detailed topographic information (LiDAR and field survey).

The simulations included both the 100-year (1 percent annual chance) peak flow and the 10-year event. The 100-year event represents the regulated floodplain and the 10-year event is included since some residential areas along the margins of the Project boundary have experienced flooding during flows smaller than the 100-year event. The selected model input flows match the 2012 FEMA Flood Insurance Study (FIS) for both the Upper Truckee River and Trout Creek. Assumptions consistent with FEMA protocols were made regarding the model head boundary (starting lake elevation of 6229.1 feet), roughness coefficients, and floodplain boundary mapping protocols. Conservative assumptions regarding the duration of peak flows and saturated antecedent soils were made for both the existing and proposed conditions.

The existing conditions model output for the 100-year flow was compared with observed flood data from the flood-of-record (1997), which has an estimated peak flow similar to the FEMA 100-year peak flow. Surveyed elevations of the 1997 flood indicators in the adjacent neighborhood and photographs taken during the flood help substantiate the existing conditions model performance. Results of the 10-year existing conditions simulation were also consistent with historical observations and reports of neighborhood nuisance or hazardous flooding.

The preferred alternative conditions 2D XPSWMM model was developed by modifying the existing conditions model to reflect the topographic and roughness changes associated with the proposed Project. However, a conservative, worst-case scenario was emphasized. All topographic and vegetation changes within the State-owned portions of the study area, which are desired, essential, and definite elements to be implemented, are included in the model. However, the topographic and vegetation changes proposed for private lands which require separate approvals and agreements were not included in the model. This is a conservative assumption, since the topographic changes proposed on private land are of a nature (i.e., lowering terraces to form floodplains; net cut) that would provide additional flood conveyance. Additionally, the proposed vegetation changes on private land would reduce roughness and better direct flood flow paths. It is expected that if some or all of these "optional" elements (i.e., those on private lands) are included in the Project, flood conditions would be improved. Therefore, modeling only the state land actions is a worst-case analysis. If the additional actions were to occur, the proposed condition results would be neutral or beneficial relative to the results reported herein.

Comparison of the proposed versus existing conditions water surface elevations, water depths, and flow vectors and velocities for the 100-year flood demonstrates that the Project can achieve the desired modifications in hydraulics and ecosystem benefits to the channel and across the marsh without increasing flood hazards to surrounding developed private land.

2 Background

Project Context

Restoration planning for the Upper Truckee River and Marsh Restoration Project (Project) began in the early 1990s and the initial phase of wetland restoration within the study area, the Lower West Side Restoration Project (LWS Project), was completed by the California Tahoe Conservancy (Conservancy) in 2002. The Conservancy has performed numerous technical and planning steps to develop the Project over a span of nearly 20 years, including several analyses specifically addressing flooding processes and flood hazards. The most recent prior flood-related studies include: assessing historical hydrology and hydraulic processes and functions and describing direct human disturbances to the river channel(s) and floodplain (Conservancy and DGS 2003); reviewing and surveying modern observations of flooding in adjacent neighborhoods; conducting one-dimensional hydraulic HEC-RAS modeling for a wide range of flows to craft and compare conceptual restoration alternatives (Conservancy and DGS 2005); and, analyzing the impacts of the Action and No-Action Alternatives in the draft EIR/EIS/EIS (Conservancy and Others 2013).

Purpose and Scope

The flood analyses reported herein have been performed by Cardno under our Upper Truckee River and Marsh Restoration Project 3022196, Amendment 13 Scope of Services, to develop an existing and proposed two dimensional hydraulic model to simulate flooding events and ensure that the proposed condition model will meet the Project's objectives to avoid increasing flood hazards and comply with the City and FEMA regulations. This study was performed during preparation of the final environmental impact report/environmental impact statement/environmental impact statement (Final EIR/EIS/EIS) to provide robust analysis of the flooding conditions and refine the Preferred Alternative description.

The model development and results underwent an internal quality control review by a qualified P.E. hydraulic engineer that is a CFM (Certified Floodplain Manager) and was not directly engaged in building the model.

The modeling efforts described herein focused on providing quantitative, spatially detailed information regarding the worst-case flooding scenario(s) of most importance for assessing flood hazards (i.e., the 100-year runoff event with a high lake level) as part of environmental impact assessment. Modeling of the 10-year event was also included in the assessment since some of the adjoining neighborhoods have historically experienced flooding under streamflows less than the 100-year event. Simulation of both the 100-year and 10-year conditions provides the opportunity to verify that the desired re-establishment of frequent overbank flows and inundation in the middle of the marsh could be achieved under the Preferred Alternative without any adverse change to flood hazards in adjacent developed areas.

Limitations

The modeling scenarios in Cardno's authorized scope of work did not focus on combinations of lake level and streamflow that might be used to simulate conditions of importance to some final design topics that depend on the details of 'in-channel' conditions and low to normal streamflows (e.g., 2-year events or seasonal low flow conditions). The 2D model constructed in this study can be revised during final design to assist with such additional channel design decisions. However, use of the model scenarios and results presented herein should be limited to assessing performance and final design elements related to overbanking conditions and flood hazards.

FEMA Framework

The Federal Emergency Management Agency (FEMA) issues Flood Insurance Rate Maps (FIRMs) used by the City of South Lake Tahoe (CSLT) to implement floodplain management policies and regulations in the City, including the project vicinity. Since Project planning began, the FEMA FIRMs for the City and surrounding unincorporated areas of El Dorado County have been revised several times to adjust for various land use changes in and around the study area, and updates in topographic or hydrologic data. For example, improvements to the U.S. 50 bridges at the Upper Truckee River and Trout Creek crossings in the mid-1990s, urban build-out in the watershed, record peak flood events (1997), and restoration of the LWS wetlands occurred during the decades since the initial FEMA maps were issued in 1978.

A 2008 FEMA update compiled previous data and converted the prior data to a digital format. Base topography from several sources (including the 2002 one-foot-interval Light Detection and Ranging [LiDAR] from the City) was integrated in 2010 modeling. At that time, the vertical datum for topography and the water surface elevations was updated to North American Vertical Datum (NAVD) 88. The most recent Flood Insurance Study (FIS), revised April 3, 2012, indicates that updated hydrology was applied in a one-dimensional (1D) HEC-RAS hydraulic model: 100-year peak flows of 7,376 cubic feet per second (cfs) on the Upper Truckee River and 948 cfs on Trout Creek, respectively (FEMA 2012). The HEC-RAS modeled water surface elevations were extrapolated by FEMA to define floodplain boundaries using two sources of one-foot contours, supplemented with USGS 7.5-minute topographic quadrangle map contours (FEMA 2012).

The 2012 FIS and associated FIRMs (FEMA 2012b and 2012c) delineate the effective regulatory floodplain for the Project vicinity at the time of our present analyses. The FIRM panels are reproduced in the Final EIR/EIS/EIS and can be accessed on the web at http://msc.fema.gov/portal/search?AddressQuery=96150 .The digital FIRM map information is overlain on the Project base aerial with the Project Boundary in Figure 2-1 for reference. Nearly all of the Project study area is within the boundary of the effective FEMA 100-year floodplain, except the upland areas adjacent to the Highland Woods subdivision, between Cove East Beach and the Sailing Lagoon, and along the margins of the Tahoe Keys Marina. The Upper Truckee River and Trout Creek channels, adjacent areas, and the shared floodplain in the central meadow are in the designated floodway. Some residential areas adjacent to the study area, including portions of Tahoe Island (from the northern intersection of Tahoe Keys Boulevard and Michael Drive east along Colorado Court to the southeast end of Colorado Avenue and including the corner of Michael Drive east of Oregon Avenue) and several lots in Sky Meadows are within the FEMA floodplain fringe west of the Upper Truckee River. A few lots in Al Tahoe (along El Dorado Avenue, Edgewood Circle, and the west end of Lily Avenue) are on the edge of the regulatory floodplain east of Trout Creek.

Source: Cardno 2015, incorporating FEMA 2012b and c (digital FIRM panels 0386F and 0387F).

Figure 2-1: Effective 2012 FEMA Flood Insurance Rate Map Boundaries in the Project Vicinity

3 Hydraulic Model

The hydraulic model selected for this analysis is XPSWMM (XP Stormwater and Wastewater Management Model), a hydrodynamic modeling software program that simulates two-dimensional flow and provides water elevation, depth and velocity output. XPSWMM is EPA tested and FEMA approved (http://www.fema.gov/hydraulic-numerical-models-meeting-minimum-requirement-national-flood-insurance-program). XPSWMM was selected for this Project to minimize inherent uncertainties associated with computer models such as parameter uncertainty and numerical uncertainty. Because it is a two-dimensional (2D) platform, XPSWMM is able to better simulate input parameters such as topography and roughness. For example, instead of using a one-dimensional (1D) model that "reads" the topography and roughness values at a limited number of cross-sections and interpolates the conditions in-between the cross-sections, the 2D XPSWMM model "reads" the topography and roughness values at thousands of grid cells that comprise the input topographic surface. To reduce numerical uncertainty, XPSWMM's simulation engine uses a self-modifying time-step that continually adjusts to ensure improved stability and flow balance. In terms of numeric output, 1D HEC-RAS models produce results for limited points along each cross-section (e.g., left overbank, channel, and right overbank), while XPSWMM produces results along the edges of each cell throughout the two dimensional grid. As a result, it is generally acknowledged that 1D model results cannot be directly compared to 2D model results, but that 2D model results are more detailed and achieve a higher level of model certainty than 1D models. The XPSWMM model input and output parameters are described in general in the following section. The purpose of this overview is to give the reader a clear understanding of the methods and variables that are utilized to represent conditions for any model run using XPSWMM. In Section 4, model input and output parameters are described as they are applied to simulate the existing conditions, and in Section 5 model input and output parameters are described as they represent the proposed (Preferred Alternative) condition. The same general methods and approaches for input parameters and model scenarios were applied for the existing and proposed conditions, as further explained in Sections 4 and 5.

XPSWMM Model Input Parameters

Topography

DTM

Elevation data is integrated into XPSWMM via a Digital Terrain Model (DTM) in the form of a Triangular Irregular Network (TIN). DTMs can be "built" in XPSWMM from several types of data including: point files, ESRI grid files, or contour shape files.

Grid Properties

Grid polygons in XPSWMM define the hydraulically active area(s) of the DTM and the level of detail of the topography. The user-defined grid polygon consists of cells with equal horizontal and vertical lengths in a uniform orientation. Hydraulic calculations utilize the elevations at the center and mid-sides of each cell: water level is calculated at the center of the cell, and velocity is calculated at the mid-sides of the cell. Although "small" grid sizes allow the model to read and generate information at a greater level of detail, cell sizes smaller than six square feet can cause model instability.

Flow constrictions

Flow constrictions allow the user to define points, lines, and polygons that modify the flow width, percent blockage, and energy losses within an area of the grid. Flow constrictions are used to simulate the effects of bridges or other known obstructions across a waterway.

Inactive areas

Inactive polygons define the areas where two-dimensional flow cannot occur. Examples of inactive areas include houses, buildings, or other structures that would not be overtopped during simulated flows (the model will simulate the water surrounding any isolated inactive polygons and be 'higher' than if the inactive polygons are not defined). The inclusion of known inactive areas in a two-dimensional model is an iterative process and only applied in the areas that may be subject to flow, not necessarily throughout the model boundary. To the degree that calibration data and observations allow, including inactive areas in a model facilitates a more realistic representation of how flows route through the system.

Land use polygons

Land use polygons allow the user to define distinct infiltration and roughness characteristics for different areas in the model. Parameters such as soil type, percent impervious, and Manning's n can be specified for each land use polygon. Manning's n is a roughness coefficient representing the resistance to flow, and used in the Manning's equation for calculating flow in open channels. It is an empirically derived value that is dependent on many factors, including channel bed and floodplain surface materials and sizes, vegetation type, density, seasonal conditions. Roughness also varies with water depth relative to the roughness of the channel and floodplain surfaces. Standard scientific literature and engineering references, field observations, as well as professional judgment are all applied when selecting Manning's n value ranges for model input.

Boundary/Flow Conditions

Head boundary

A head boundary is a polyline representing the elevation of the water surface (head) at an edge of the model grid polygon, to indicate starting water surfaces or controlling water surfaces at the downstream end or other margins of a model boundary.

Flow boundaries/Input Flows

Time-series flow data (such as the design flow or hydrograph to be modeled) can be entered either via a one-dimensional node or a two-dimensional polyline. 1D/2D interface polylines allow flows to be transferred from one-dimensional features (nodes) to the two-dimensional grid in the model. 2D/2D interfaces can be used when the user defines two or more juxtaposed grid polygons (for the purposes of representing more or less detailed topography and/or different cell orientations in different areas).

Simulation

The simulation window allows the user to input the simulation start and end time (runtime) and the simulation time-step (how frequently the model performs calculations during the runtime).

XPSWMM Model Output Parameters

After the model has completed a simulation, various methods are available to interpret results. XPSWMM output data that doesn't require post-processing consists of colored or shaded displays representing water surface elevations, water depths, and water velocities during each time-step of the simulation. The density of output information matches the selected grid scale, which affects how some output data displays. For example, velocity data along channel areas with a smaller grid would have more vectors displayed, but shouldn't imply higher volume of flow.

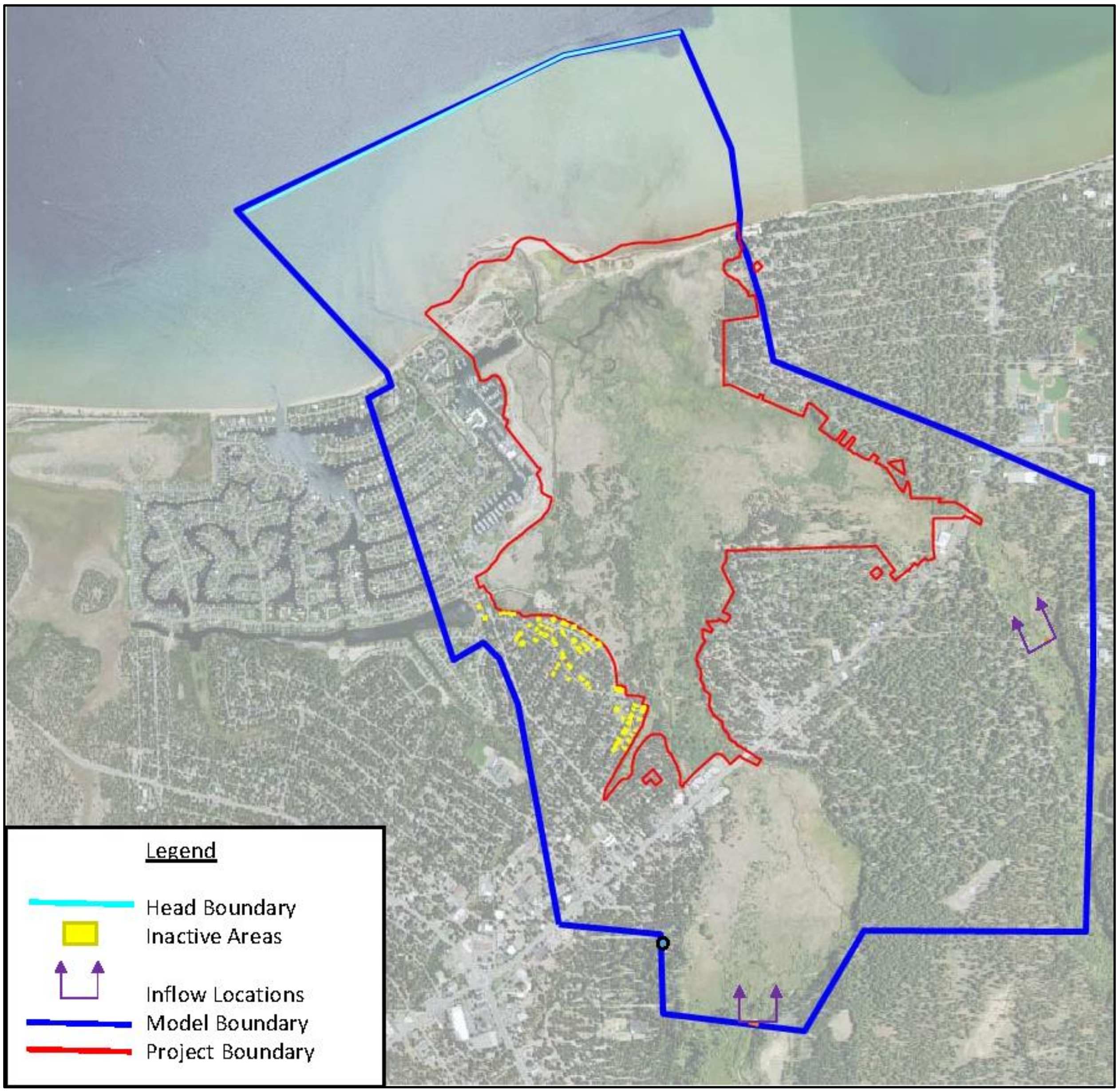
The user is able to "watch" the display as it progresses from one time-step to the next and is able to "pause" at any point in the simulation to export the results produced during that time-step. Additionally, the user is able to quickly view results during the time-steps that produce the maximum or minimum values of the selected output parameter (i.e., max or min water depths).

XPSWMM Output Interpretation/Post-Processing

XPSWMM provides two-dimensional model output in the same manner that it allows two-dimensional input: in the form of point files, ESRI grid files, or shape files that can be analyzed and/or graphically displayed in GIS.

4 Existing Conditions

The Project boundary includes the Upper Truckee River and Trout Creek channels and all adjacent areas of the marsh from Lake Tahoe up both streams to US 50 (Figure 4-1). The Conservancy determined this Project Boundary for the purposes of project development and environmental documentation, and all areas potentially affected by direct Project activities were included in the Project Boundary regardless of property ownership. The Final EIR/EIS/EIS specifies the areas which are proposed for construction and access under the preferred alternative. The "existing" conditions hydraulic model represents the topography and condition of the channels, vegetation and built-environment features in the Project vicinity as of 2013. For the purposes of simulating hydraulic conditions during major flood events, the model boundary must extend beyond the Project Boundary. This allows the model to reflect the flows entering from the upstream watersheds, the bridge crossings under US 50 at the Upper Truckee River and Trout Creek, and interactions with Lake Tahoe (Figure 4-1).



Source: Cardno 2015

Figure 4-1: Project Area, Model Area, Inactive Areas, Head Boundary, and Flow Boundaries

Existing Conditions Model Input Parameters

<u>Topography</u>

DTM

To support the detailed hydraulic model development, one-foot-interval LiDAR topographic data that became available in 2011 for the study area (TRPA 2011) were combined with 2013 bathymetric cross section survey data along the Upper Truckee River (spaced every 50–100 feet along the alignment) and lower Trout Creek to create a digital elevation model (DEM) of the existing ground surface for the Project study area and the entire model extent. The horizontal datum of the DEM is California State Plan Coordinate System Zone II US Foot, and the vertical datum is NAVD88 to match the vertical datum used in the 2012 FIS (FEMA, 2012).

Grid Size

The existing grid polygon determines the hydraulically active areas of the model and extends throughout the model boundary (Figure 4-1). The grid size selected in the channel alignments is 20 feet by 20 feet (~16,500 cells) and the grid size through the remainder of the model boundary is 40 feet by 40 feet (~63,000 cells).

Flow constrictions

Structures known to have the potential to constrict flow in the model area include the two US 50 bridges crossing the Upper Truckee River and Trout Creek. Additionally, the pedestrian bridges downstream of the US 50 bridges on the Upper Truckee River and Trout Creek are represented in the model. Bridge locations, shapes, dimensions and elevations are included into the XPSWMM model.

Inactive areas

Inactive areas established in the existing conditions model include the footprint of houses near the project boundary in locations where previous modeling and the FEMA maps showed the potential for flow interaction. The inactive polygons were traced in the model using a georeferenced background aerial. Designating inactive area polygons assists in accurately depicting obstacles to flow that could modify flow routing and/or occupy flood storage space and contribute to net higher water surfaces, so this step is a conservative (i.e., worst-case) modeling assumption.

Land use/Land cover polygons

To represent existing conditions, the recent FEMA 1D HEC-RAS flood modeling used roughness coefficients (Manning’s n) that ranged from 0.02 to 0.1 within channels and from 0.02 to 0.12 in the floodplain (FEMA FIS 2012). Several years prior, the 1D HEC-RAS modeling for the Project by Cardno (2005) distinguished several roughness classes to represent the details of vegetation and land cover mapping in the study area, and applied coefficients ranging from 0.02 to 0.09 (Table 4-1). For the present study, updated digital vegetation mapping files prepared by Conservancy staff (2014) were available and imported into the model as polygon boundaries for assigning existing conditions roughness values (Figure 4-2). The roughness values applied to various vegetation types and land cover conditions in the study area (Table 4-1) are more conservative than the values previously applied in the Project’s 1D HEC-RAS model and span the range used in the FEMA study, even including higher roughness assumptions for willows than the roughest assumption used in the 2012 FIS. Areas not assigned a specific roughness value default in the model to n =0.06, a reasonable representation of the mixed cover and material types. As an additional conservative assumption, soils for all cover types are assumed to be 100% saturated, representing a worst-case flooding scenario (i.e., winter rain-on-snow event or spring runoff event when antecedent rainfall and/or temperature has formed saturated or frozen ground conditions).

Table 4-1: Land Cover Types and Assigned Model Roughness Coefficients

Land Cover Type	Manning's n Value	
	ENTRIX (2005)	Cardno (2015)
Channel	0.035	0.04
Conifers	0.07	0.10
Grass	0.05	0.06
Scrub	0.08	0.10
Street	0.02	0.02
Willows	0.09	0.15

Source: ENTRIX, in Conservancy and DGS 2005; Cardno 2015

Boundary/Flow Conditions

The Project and model boundaries for the existing condition scenario are as depicted in Figure 4-1.

Head boundary

The downstream head boundary in the model represents the control that the water elevation of Lake Tahoe has on flow and stage conditions (Figure 4-1). For the existing conditions scenario, the head boundary elevation is set to 6229.1 feet, which represents the legal high lake limit and is most likely associated with worst-case flooding conditions in the Project area.

Flow conditions

To assess the effect of large magnitude, low-frequency floods and the FEMA regulatory floodplain, the 100-year (1% annual chance) peak flow is input to the model. To assist with screening for potential changes to nuisance or hazardous flooding under smaller, more frequency events, the 10-year (10% annual chance) peak flow is also modeled. Some of the neighborhoods along the west margin of the Project boundary (i.e., in the Tahoe Island and Sky Meadows neighborhoods) have experienced ponding and flooding during fairly small (i.e., > 10-year) peak flows (Figure 4-3).

Our existing condition model assumed the same peak flow values as in the 2012 FEMA FIS (Table 4-2), which are similar to those used in the prior modeling by Cardno (dba ENTRIX). The Upper Truckee River and Trout Creek input locations are upstream of the US 50 bridges (Figure 4-1). The 10-year flow inputs are routed via a 1D node within each river channel. The 100-year flow inputs are routed via a 2D flow line to represent inputs across the floodplain as well as the channel(s).

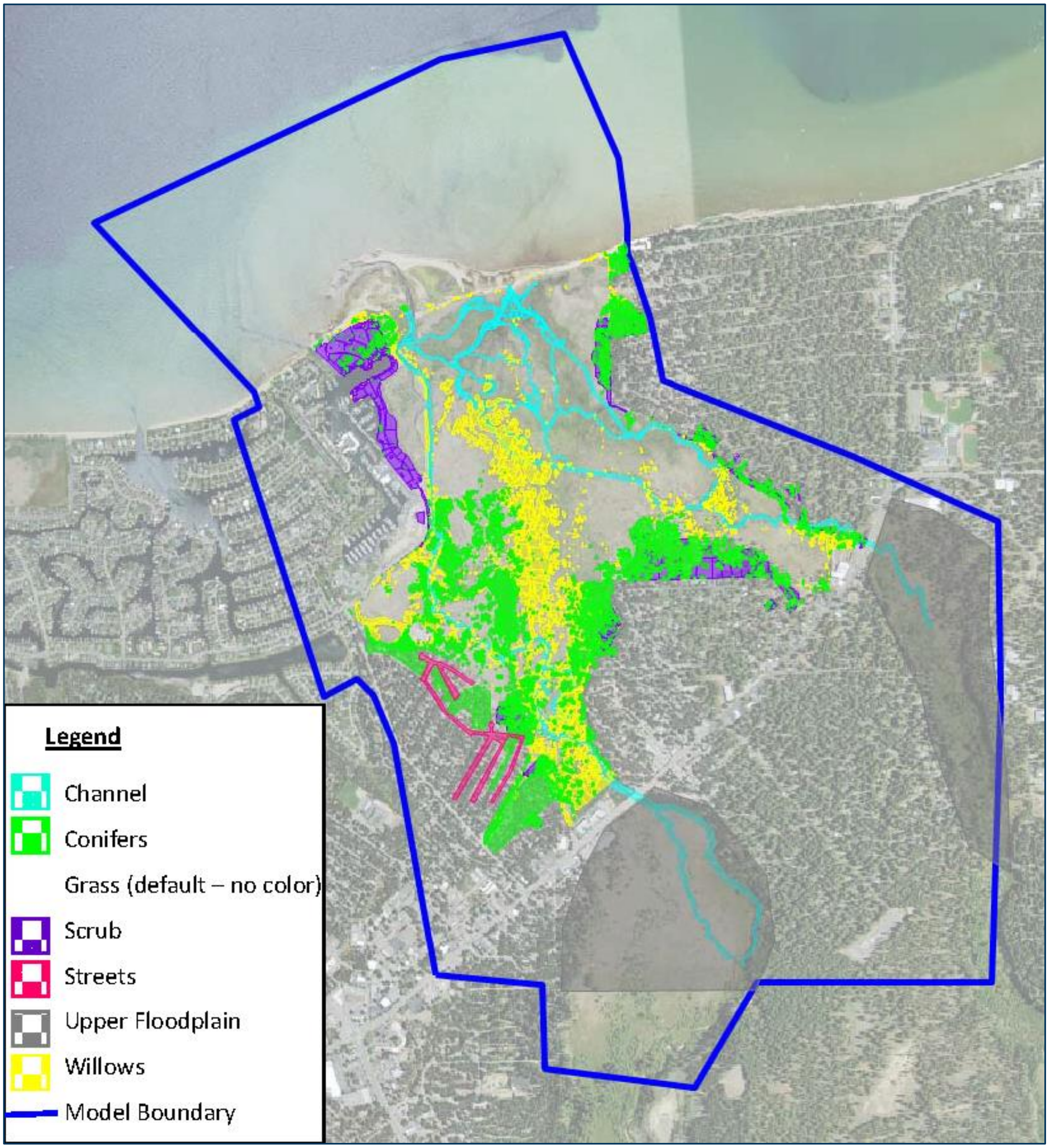
Table 4-2: Upper Truckee River and Trout Creek Peak Flows (cfs)

Water Body	FEMA		ENTRIX	
	100-year	10-year	100-year	10-year
Upper Truckee River	7,376	2,347	7,650	2,550
Trout Creek	948	391	900	380

Source: FEMA FIS 2012; ENTRIX 2003 (cited in Conservancy and DGS 2003)

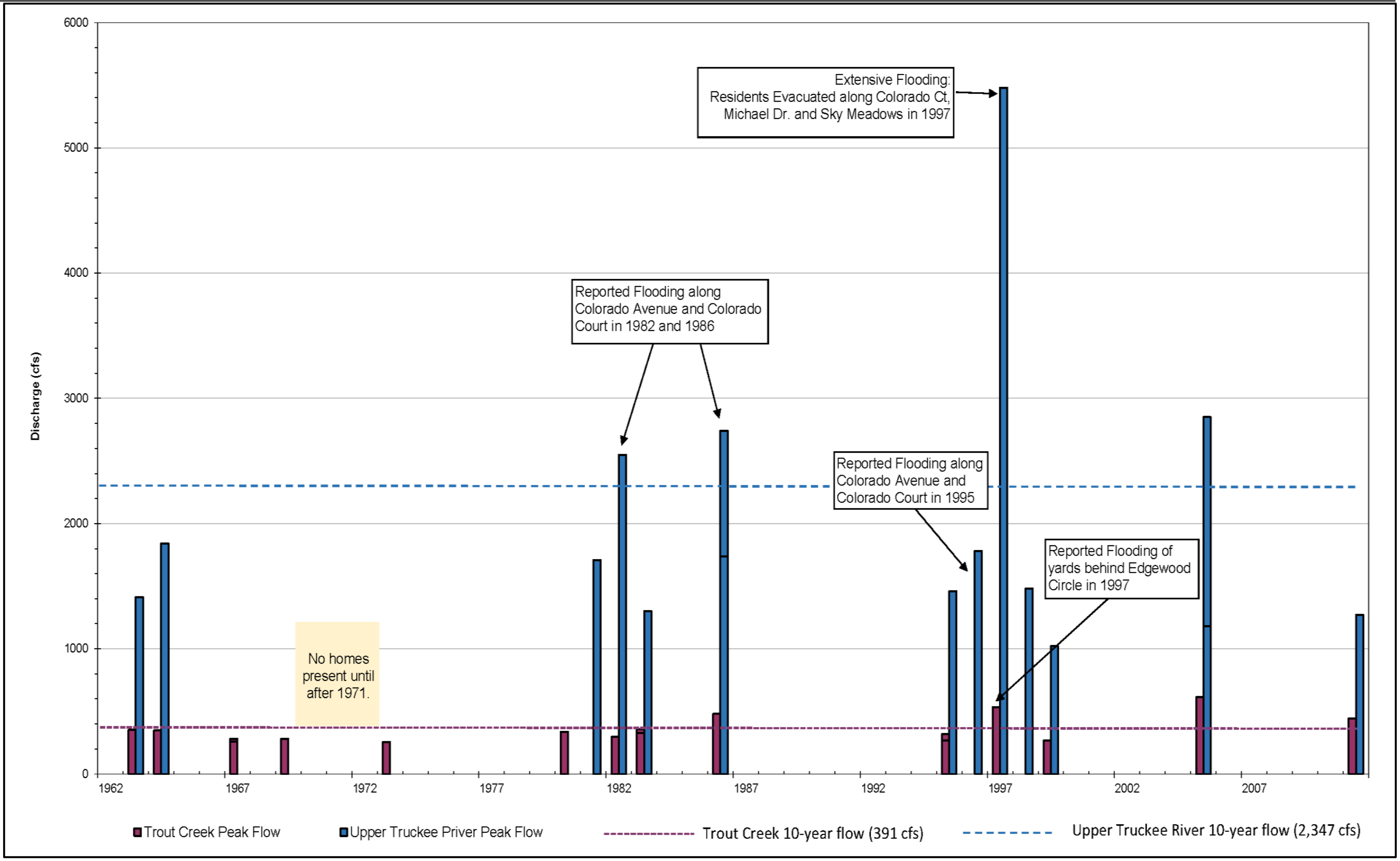
Simulation

The peak values were modeled as "steady state" (continuous) over a 12-hour duration. The purpose of this extended duration is to allow adequate travel time for the model to route peak flows through the system. This approach was applied since the topography has a very low slope and relatively high roughness values. Therefore, low velocities of floodplain flow can result in travel times of several hours from the points of the upstream inflow locations to the outfall location (downstream head boundary). The 2012 FEMA FIS did not specify whether their model was a steady state or an unsteady state model, so applying a constant peak inflow as input for the XPSWMM model remained conservative. A sensitivity analysis was performed using the hydrographs developed by Cardno for prior 1D modelling efforts, and XPSWMM results did not show substantial differences between the steady state and unsteady state output.



Source: California Tahoe Conservancy, 2014

Figure 4-2: Land Use/Cover Types as of 2014 as Roughness Polygons for the Existing Condition



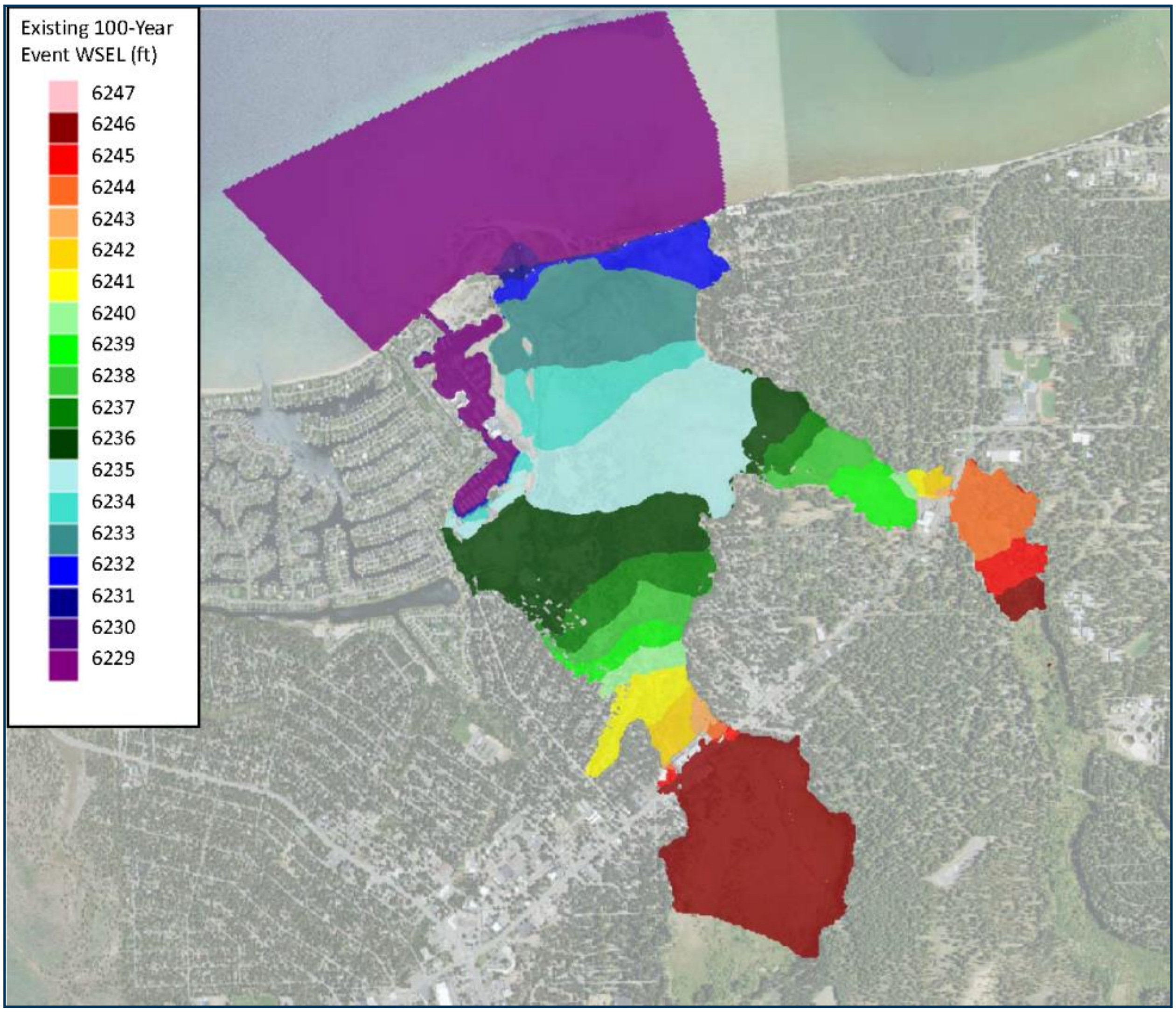
Source: Cardno 2015

Figure 4-3: Reported Historic Neighborhood Flooding in the Project Vicinity

Existing Conditions Model Output: 100-Year Event

Water Surface Elevations

The simulated water surface elevations (WSELs) for existing conditions under the 100-year flood event along the Upper Truckee River range from 6,229 feet in the lake, 6230 feet at the mouth of the river, 6235 feet in the middle of the marsh and 6240 at the Sky Meadows drainage to 6,245 feet at the US 50 Bridge and 6,247 feet at the upstream model extent (Figure 4-4). Along Trout Creek, the WSEL is slightly lower at the US 50 Bridge (~6244 feet) (Figure 4-4).



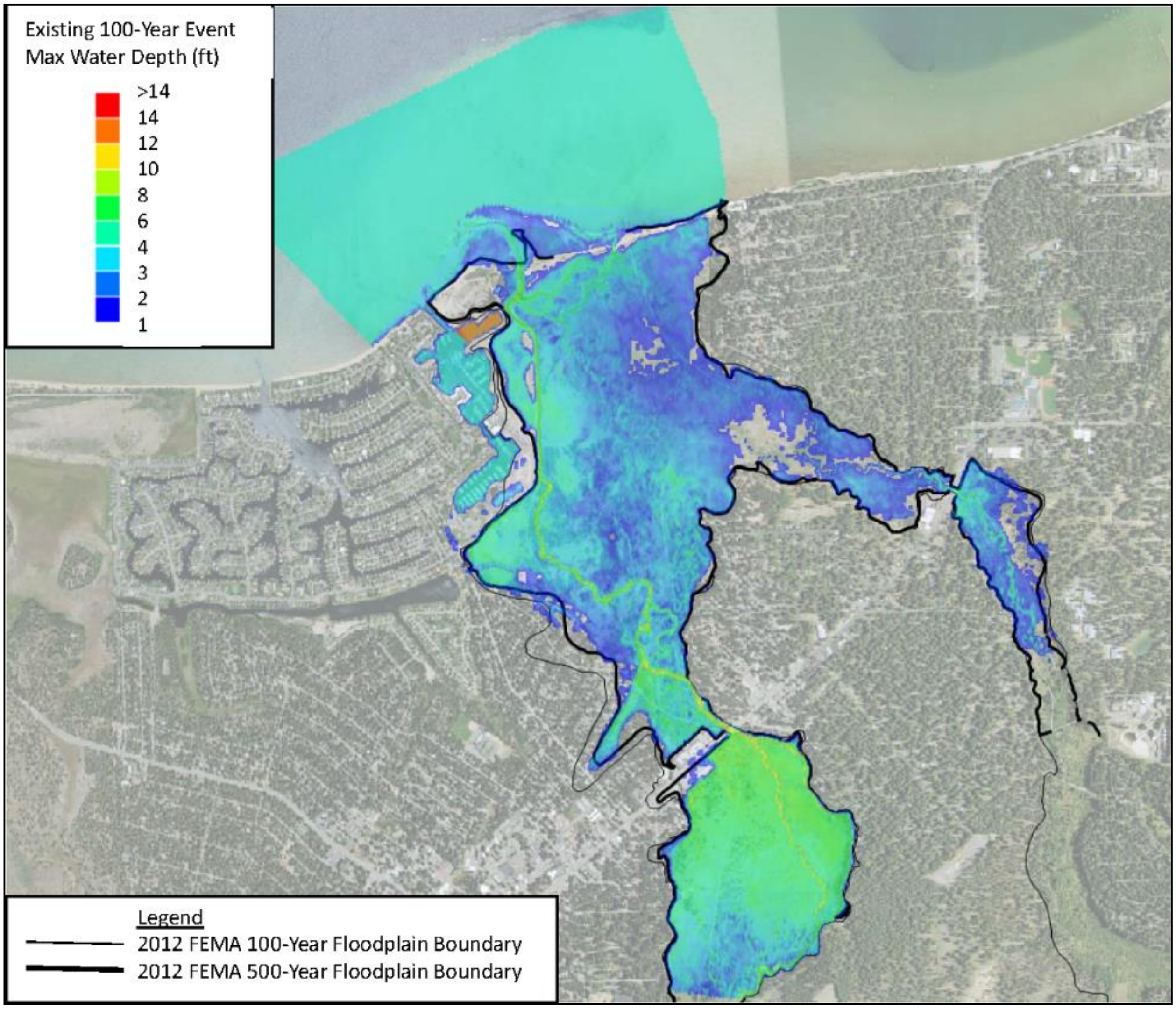
Source: Cardno 2015

Figure 4-4: Existing Condition 100-Year Flood Simulated Water Surface Elevations

Water Depth

The simulated maximum water depths for existing conditions under the 100-year flood event are up to 10 to 12 feet in the Upper Truckee River channel, and 1 to 2 feet deeper in the Sailing Lagoon (Figure 4-5). We depict areas simulated to have one or more feet of water depth to focus on active floodplain areas and to be consistent with FEMA floodplain mapping protocols. Modeled 100-year flood water depths are moderately deep (4 to 6 feet) across the upstream valley reach on the Upper Truckee River, in the western corner of the floodplain by the TKPOA yard (by the intersection of Tahoe Keys Boulevard with East Venice Avenue), along the existing channel on the western third of the Project area, and in the deepest sections of the existing lagoon at the confluence of Trout Creek (Figure 4-5).

Water depths are shallow (1 to 2 feet) along the southwest margin of the floodplain, in much of the middle of the marsh, and in portions of the Trout Creek corridor and northeast edge of the site (Figure 4-5).

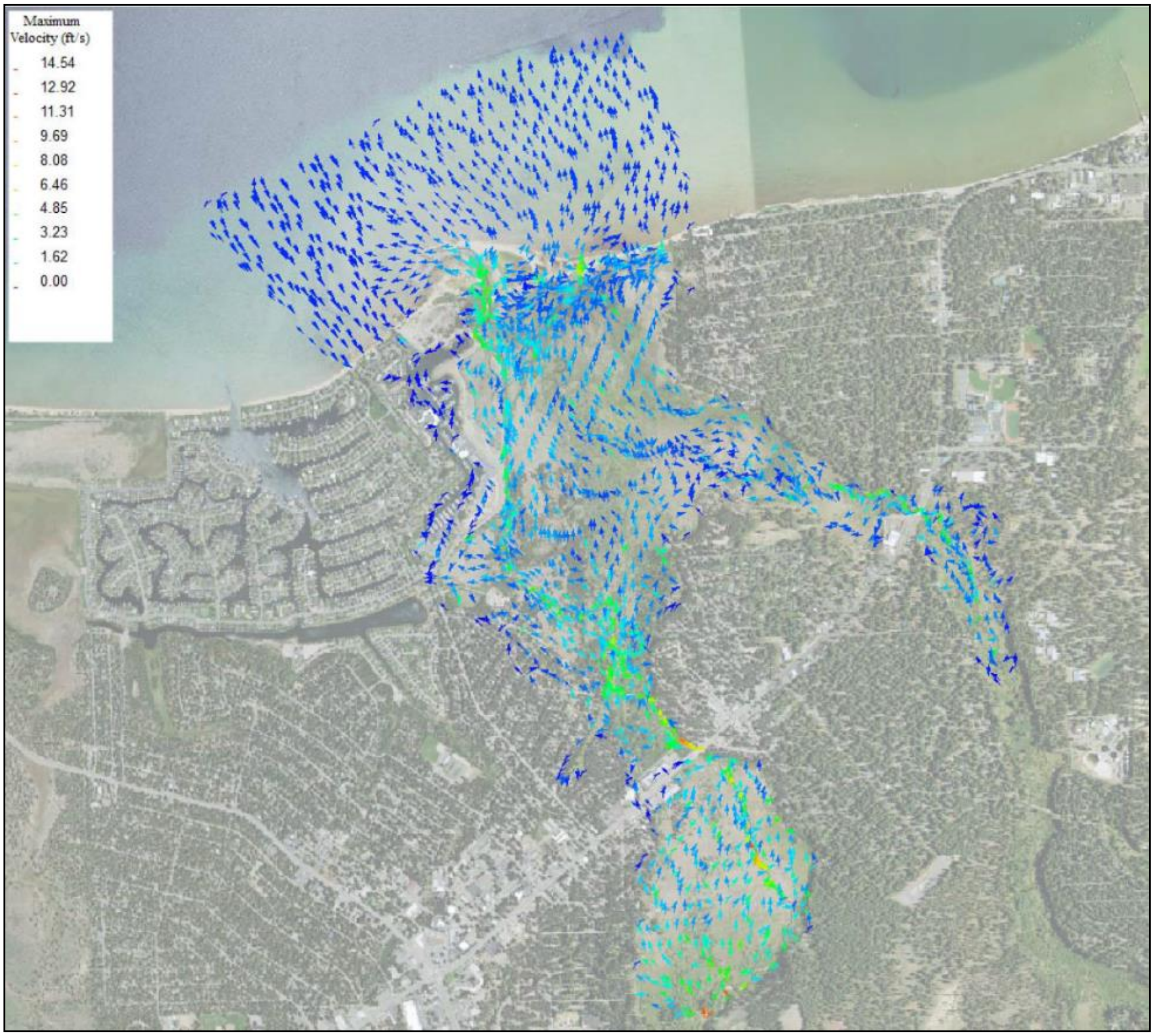


Sources: Cardno 2015; FEMA 2012

Figure 4-5: Existing Condition 100-Year Flood Simulated Water Depths

Flow Direction and Velocity

The simulated 2D model flow directions and velocities for the 100-year event under existing conditions indicate that the margins of the inundated floodplain area experience low-velocity movement and multi-directional eddies (Figure 4-6). This suggests and is consistent with an overall backwater influence from the assumed high lake stand (6,229 feet) up this low gradient river reach. As expected, some higher velocity, more organized and directed flow occurs along the main river channel and multi-thread reaches, in the main channel of both the Upper Truckee River and Trout Creek just downstream of the US 50 bridges, and where the channels exit through the beach ridge into Lake Tahoe (Figure 4-6).The maximum velocities within the model boundary are in the channel just downstream of the US 50 bridge and in a couple of isolated channel sections upstream.



Source: Cardno 2015

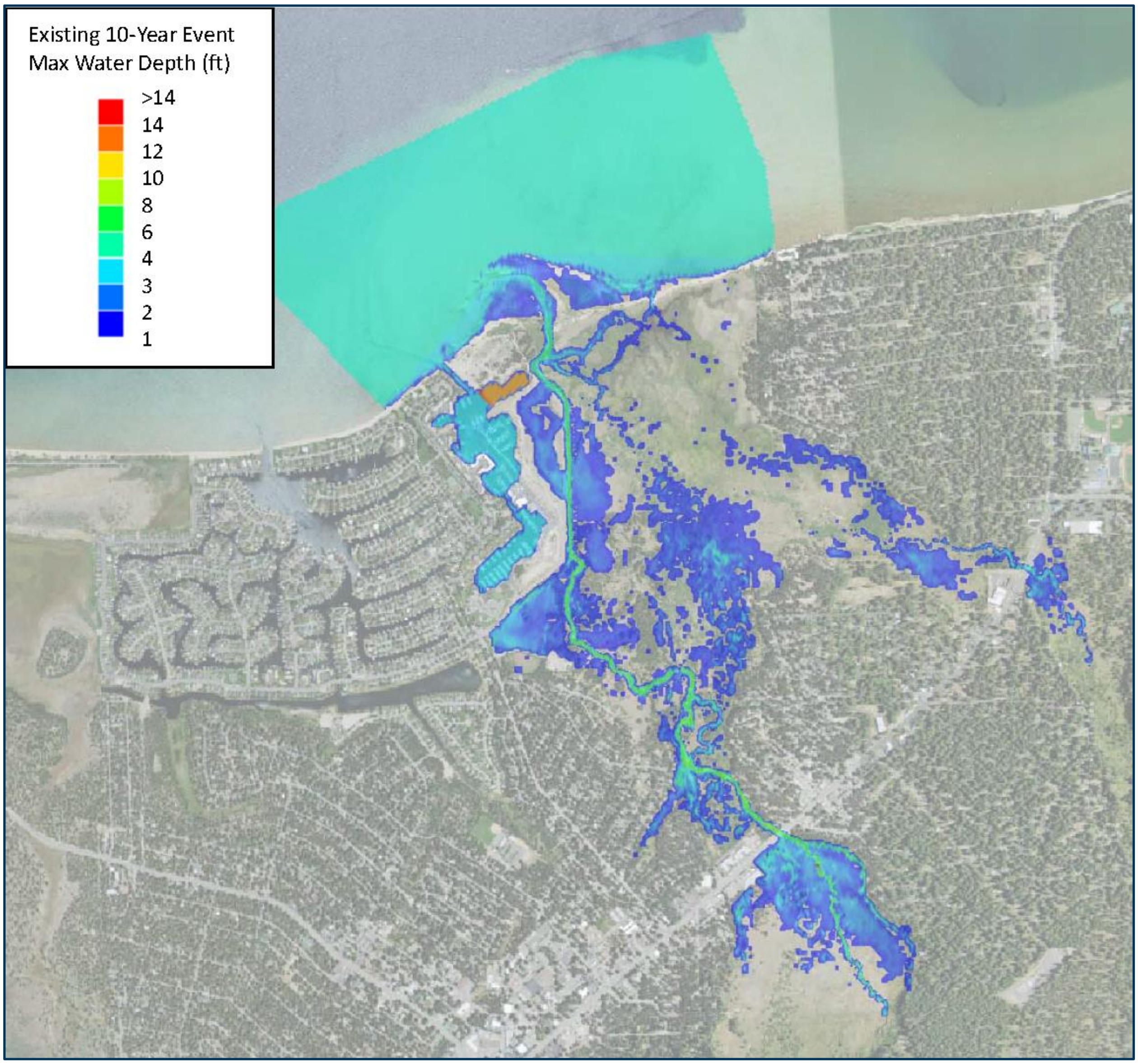
Figure 4-6: Existing Condition 100-Year Flood Simulated Flow Directions and Velocities

Existing Conditions Model Output: 10-Year Event

Water Depth

The simulated maximum water depths for existing conditions under the 10-year flood event range up to 6 to 8 feet in the Upper Truckee River channel, and up to 14 feet in the Sailing Lagoon (Figure 4-7).

Modeled 10-year flood water depths are moderately deep (3 to 4 feet) in the existing secondary channel in the valley reach on the Upper Truckee River and near its confluence with the side drainage north of Sky Meadows, in edges of the floodplain by the TKPOA yard, in a few areas along the existing channel on the western third of the site, and in a few deep sections of the existing lagoon at the confluence of Trout Creek (Figure 4-7). Most of the marsh has shallow (1 to 2 foot) or very shallow (less than 1 foot) inundation.

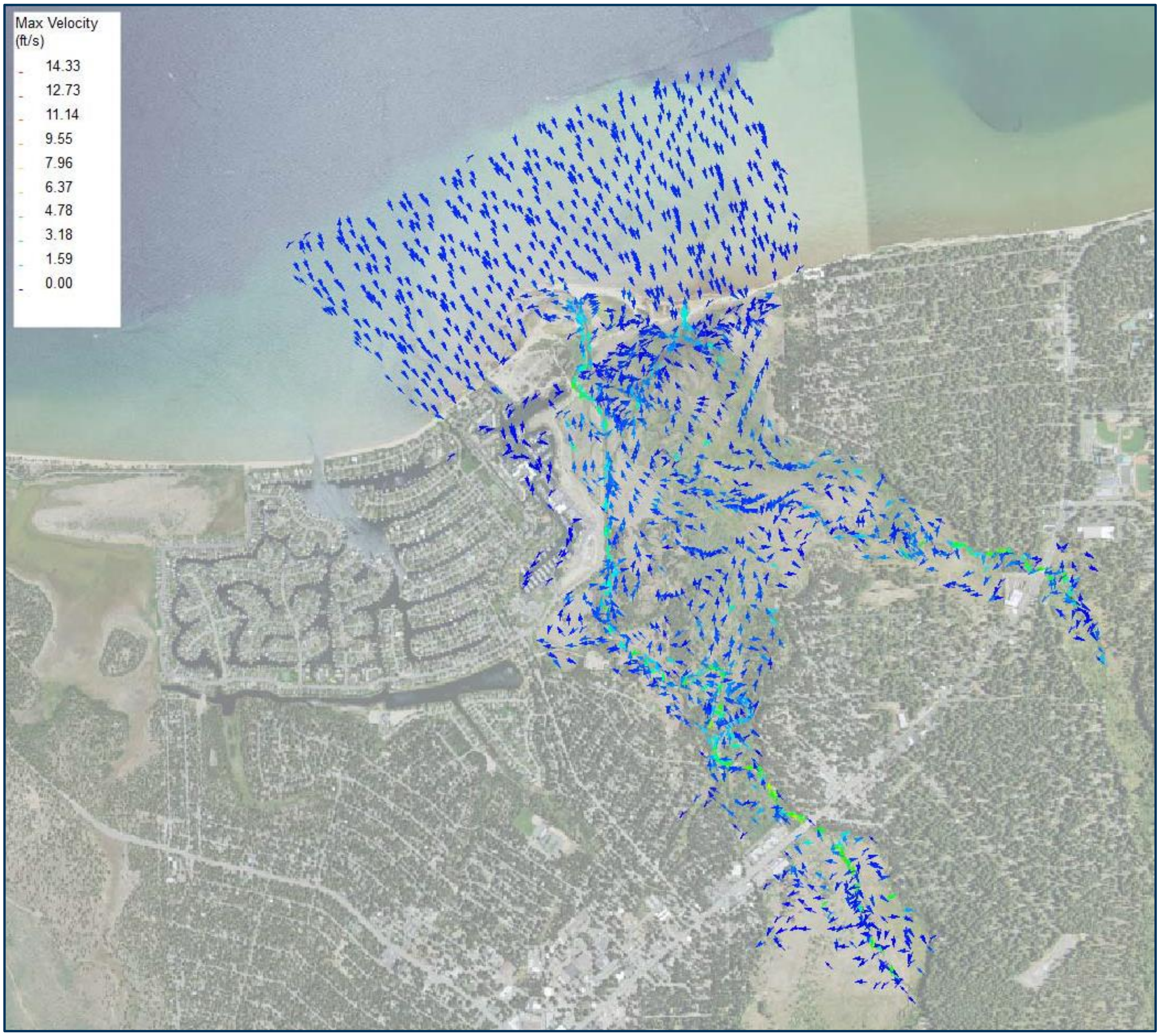


Source: Cardno 2015

Figure 4-7: Existing Condition 10-Year Flood Simulated Water Depths

Flow Direction and Velocity

The simulated 2D model flow directions for the 10-year event under existing conditions (Figure 4-8) have a very similar pattern to the 100-year event with low-velocity movements and multi-directional eddies, as well as distinct flow pathways along the existing channel alignments and across a few portions of the floodplain (i.e., on the southwest edge). The range of velocities differ from the 100-year event, with lower and more localized maximum velocities near the bridges, in the deep spots of the Upper Truckee River channel, and where the river crosses the beach ridge at the mouth (Figure 4-8).



Sources: Cardno 2015

Figure 4-8: Existing Condition 10-Year Flood Simulated Flow Directions and Velocities

5 Existing Conditions Discussion

The 100-year event peak flow of 7,376 cfs used in this simulation is the same as that in the 2012 FEMA FIS and it lies within the estimates for the 1997 flood flows (~5,500 to 8,200 cfs by the USGS and USACE, respectively). Therefore, the 1997 flood event observations provide an opportunity to compare with model results for the 100-year existing conditions. These data have been used to calibrate/validate the existing conditions model results from the 2D XPSMM simulations and were also used during the earlier 1D HEC-RAS model calibration (Conservancy and DGS 2005). A couple of representative photographs taken by Conservancy staff during the 1997 flood event indicate the observed depths of flood waters in the Tahoe Island (Figure 5-1) and Sky Meadows neighborhoods (Figure 5-2).

In 2000, Cardno conducted an engineering survey of 1997 flood indicators at four locations within these two affected neighborhoods based on photographs, homeowners' recollections, and remaining flood debris/damage marks (Figures 5-3 and 5-4). The surveyed elevations of the flood water indicators at specific locations and the corresponding XPSWMM 100-year existing model water surface elevations at the same location are listed on the aerial base maps. The observed and modeled flood elevations are very close. All 1997 flood indicator elevations are slightly higher than the XPSWMM existing conditions water surface elevations except for at the location of 2366 Sky Meadows (Figure 5-4) where the XPSWMM water surface elevations is 0.08 feet higher than the 1997 flood indicator at that location. The largest difference between the observed 1997 and modeled 100-year events water surfaces occurs at 745 Colorado Court (Figure 5-3) where the flood indicator is 0.24 feet higher. Given that the survey of the flood indicators was performed two years after the flood event, and that there was a range of estimated peak flows, the XPSWMM water surface elevations are very consistent with and close to the flood indicator elevations. The close fit of the model to the observations for the 100-year event and the 1997 flood are consistent with the general hydraulic expectations for such a wide, low gradient floodplain. That is, flooding patterns during large-magnitude events would not be highly sensitive to minor differences in the flow, topography, or roughness.

In addition to the 1997 field data, FEMA's 2012 study and mapping are also valuable as comparison to the existing conditions 2D 100-year model. The modeled water surface elevation across the site as simulated by the detailed 2D model compare very reasonably to the water surface elevation cross sections from the FEMA 1D model. Similarly, the modeled water depths across the site as simulated by the detailed 2D model are consistent with the FEMA 2012 100-year floodplain boundary (see Figure 4-5, above).

The combination of field based observations from the 1997 flood and the elevation and boundary comparisons with the FEMA maps provide assurance that the 100-year existing conditions simulated for the Project vicinity by the 2D model are representative of real-world conditions.

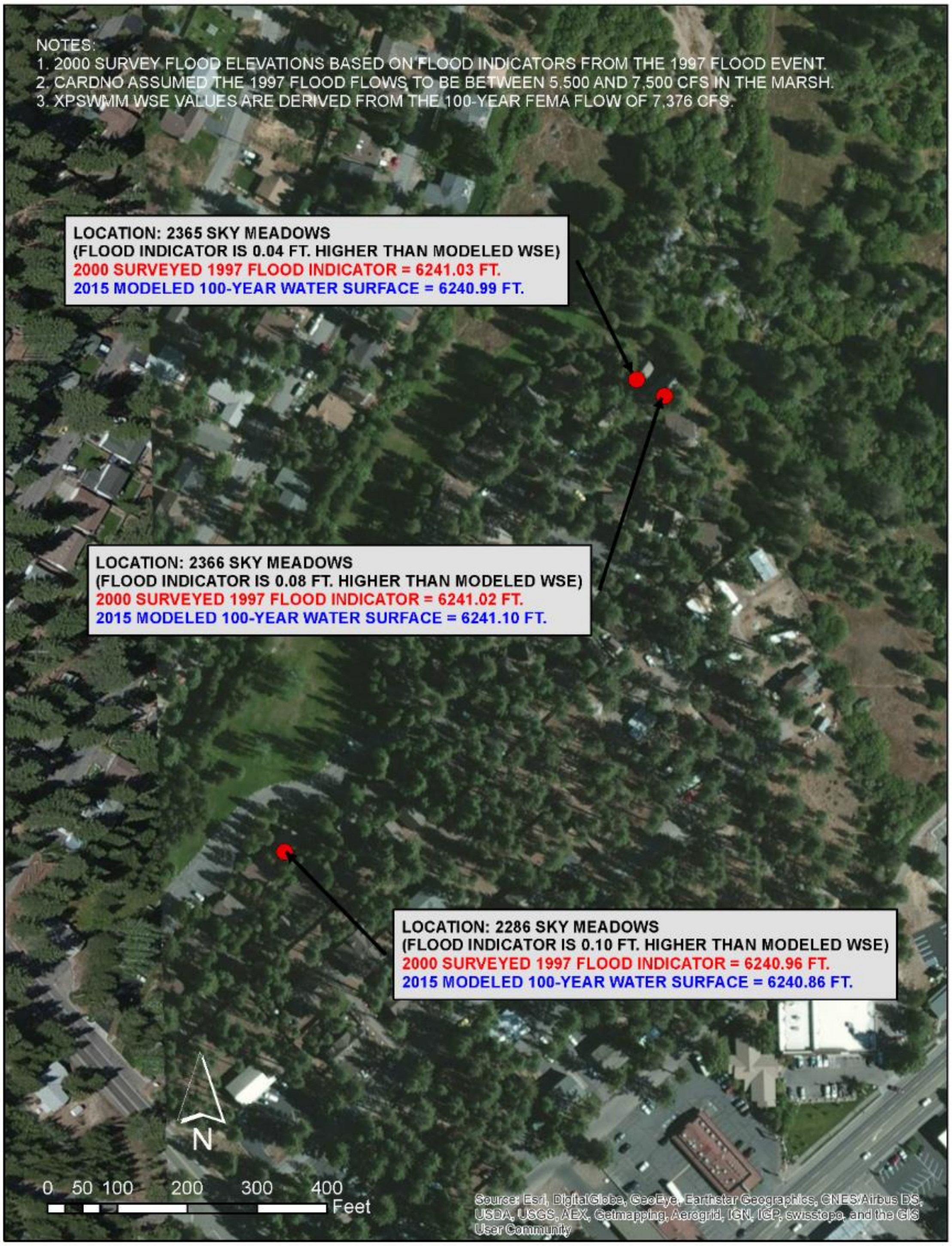
While no quantitative information or surveyed flood elevations at specific locations were available for the 10-year event to use in calibration, the 2D model results match anecdotal information about minor neighborhood flooding and flow paths for events when the Upper Truckee River flow is between 1,000 to 3,500 cfs (see Figure 4-3).

Figure 5-1: Representative 1997 Flood Conditions in Tahoe Island

Figure 5-2: Representative 1997 Flood Conditions in Sky Meadows

Source: Cardno 2015

Figure 5-3: Comparison of 1997 Flood Indicators Surveyed Elevations with 2015 Modeled 100-year Water Surface Elevations: Tahoe Island



Source: Cardno 2015

Figure 5-4: Comparison of 1997 Flood Indicators Surveyed Elevations with 2015 Modeled 100-year Water Surface Elevations: Sky Meadows

6 Preferred Alternative Conditions

The Preferred Alternative condition is simulated using the same model boundary as for the Existing Conditions model (Figure 4-1).

Preferred Alternative Model Input Parameters

Topography

DTM

The topography in the calibrated 2D hydraulic model for existing conditions was modified to represent the topographic conditions associated with the Preferred Alternative (Figure 6-1). The horizontal and vertical datum remained unchanged.

Topographic changes representing the Preferred Alternative that are included in the 2D hydraulic simulations include:

- Pilot channel excavation and the pilot channel confluence re-contouring;
- Removal of reserved fill on the Lower West Side (LWS) wetlands (the ‘islands’ of fill along the existing channel and a portion of the fill along the existing trail;
- Backfill of the existing channel to be abandoned (partial channel fill from the pilot channel downstream to the straightened reach and then complete fill to match the surrounding surface of the LWS);
- Minor channel grade controls and bed modifications at the mouth;
- Reconnection of the Sailing Lagoon to the river;
- Removal of a small fill area at the east end of Barton Beach, and,
- Restoration of dune features between the Sailing Lagoon and Cove East beach.

The above listed topographic changes proposed as part of the Preferred Alternative would all occur on public (State of California) lands.

A few topographic changes proposed as part of the Preferred Alternative would occur on private land and/or require additional agreements or easements that are not certain. While these potential measures would improve flood conveyance and/or capacity, they were not included in the 2D model simulations so that proposed conditions model output would remain conservative. That is, that flood conditions would not worsen as a result of the Project even if the Conservancy could not attain the required easements and agreements for the following:

- Removal of the TKPOA Corporation Yard fill;
- Floodplain lowering within the valley reach downstream of US 50 and upstream of the proposed pilot channel;
- Construction of bank stabilization downstream of US 50; and,
- Installation of through flow culverts in the earthen embankments at US 50;

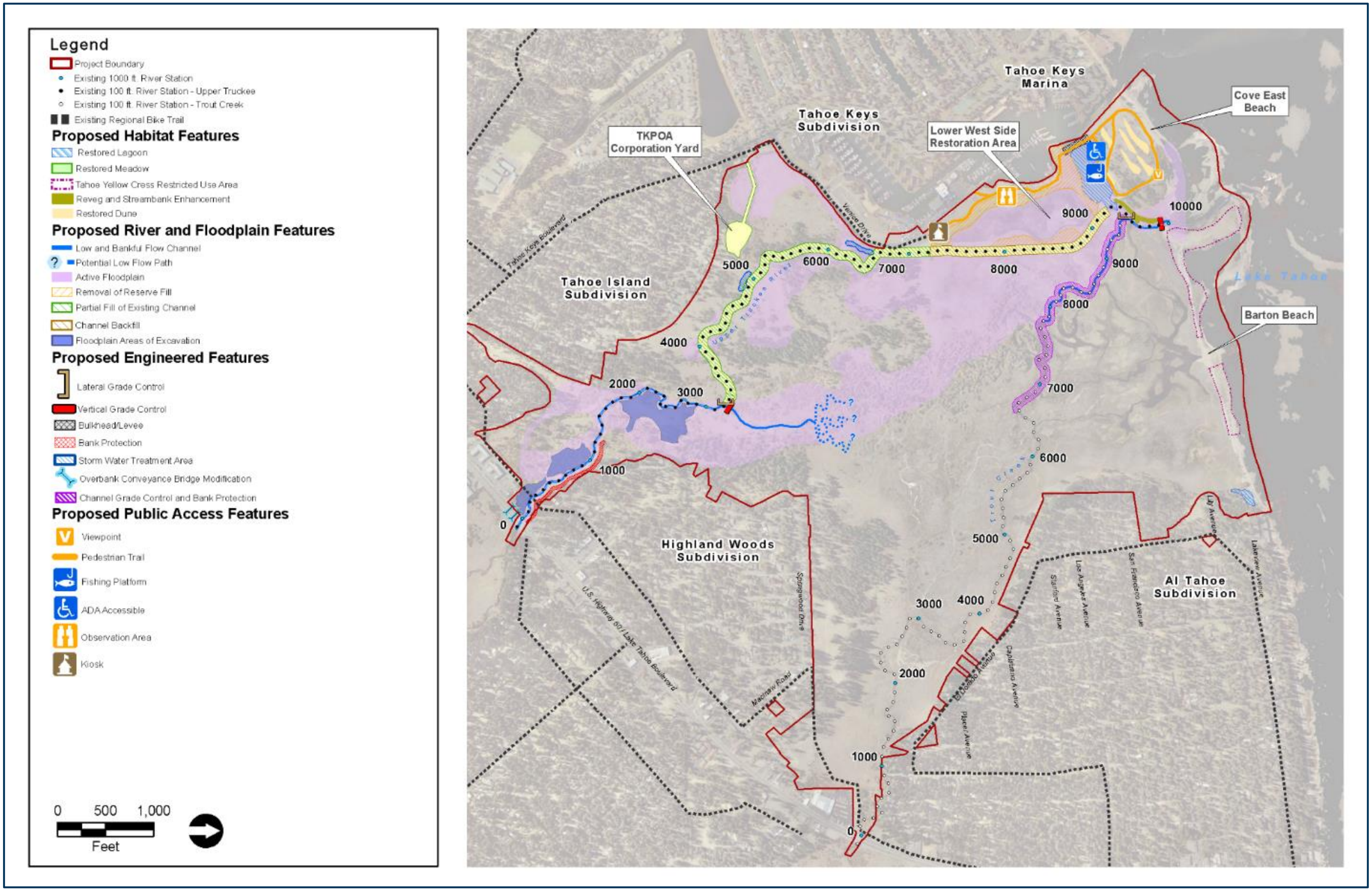


Figure 6-1: Preferred Alternative Conceptual Design Features

Grid Size

The grid size and extents for the proposed condition simulation are that same as for the existing condition (although the Upper Truckee River 'channel' alignment is relocated to follow the pilot channel and remnant channels through the marsh).

Flow constrictions

The flow constrictions for the proposed condition simulation are the same as they are in the existing condition.

Inactive areas

The inactive areas for the proposed condition simulation are the same as they are in the existing condition.

Land use polygons

The land use cover type categories and associated Manning's n values are the same in the proposed condition simulation as they are for the existing condition (Table 4-1). However, some of the land cover type polygons were modified to reflect the direct and indirect changes to vegetation and/or land cover that would result from implementation of the Preferred Alternative (Figure 6-2). For example, willow polygons presently in the location of proposed pilot channel were replaced by channel roughness polygons, and the existing channel to be backfilled was replaced by a combination of grasses with some willow polygons.

Boundary/Flow Conditions

Head boundary

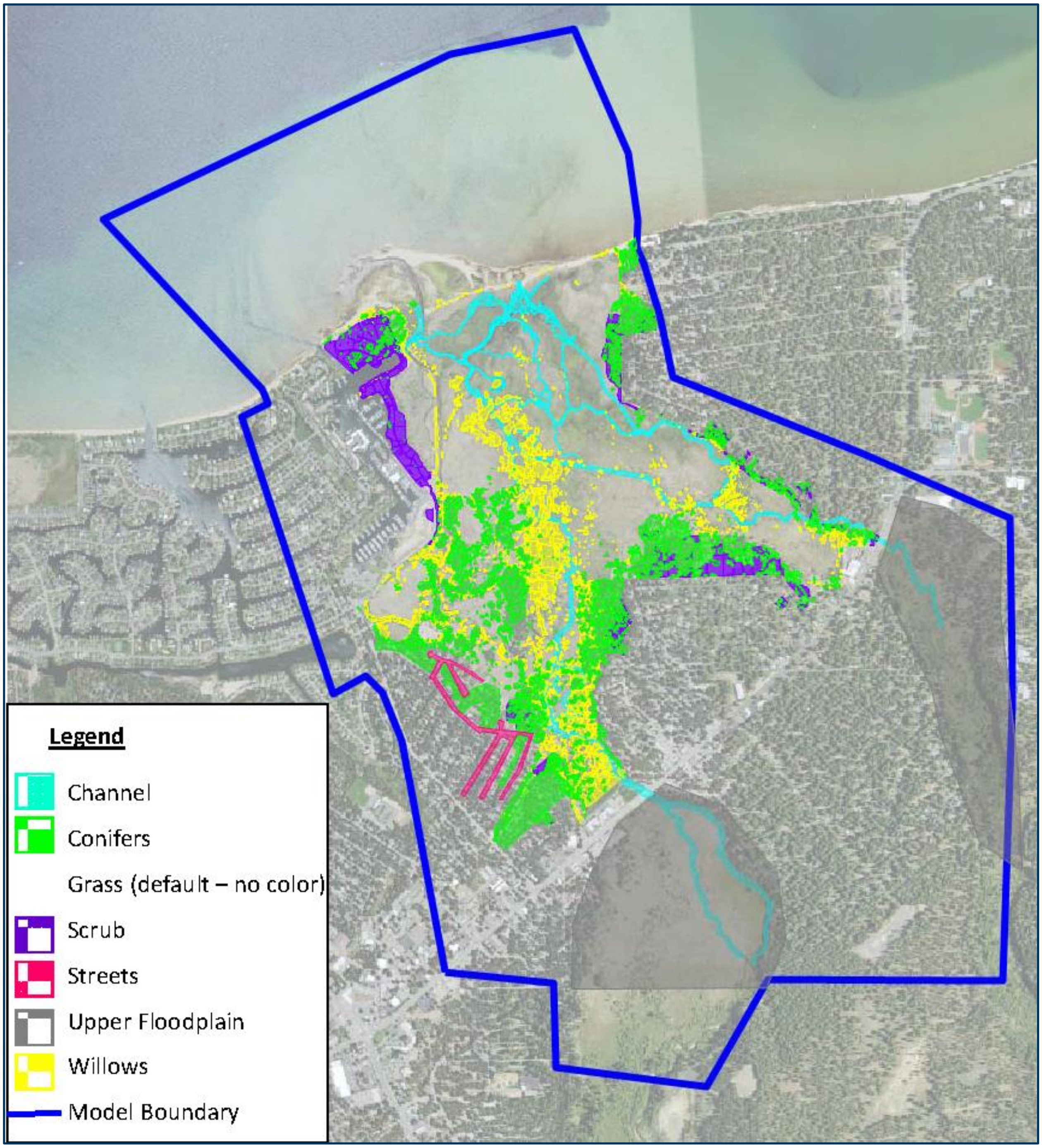
The head boundary conditions in the proposed condition simulation is the same as for the existing condition.

Flow condition

The flows simulated for the proposed condition are the same as for the existing condition.

Simulation

The proposed condition was simulated using a 12-hour steady state flow, as was applied for the existing condition.



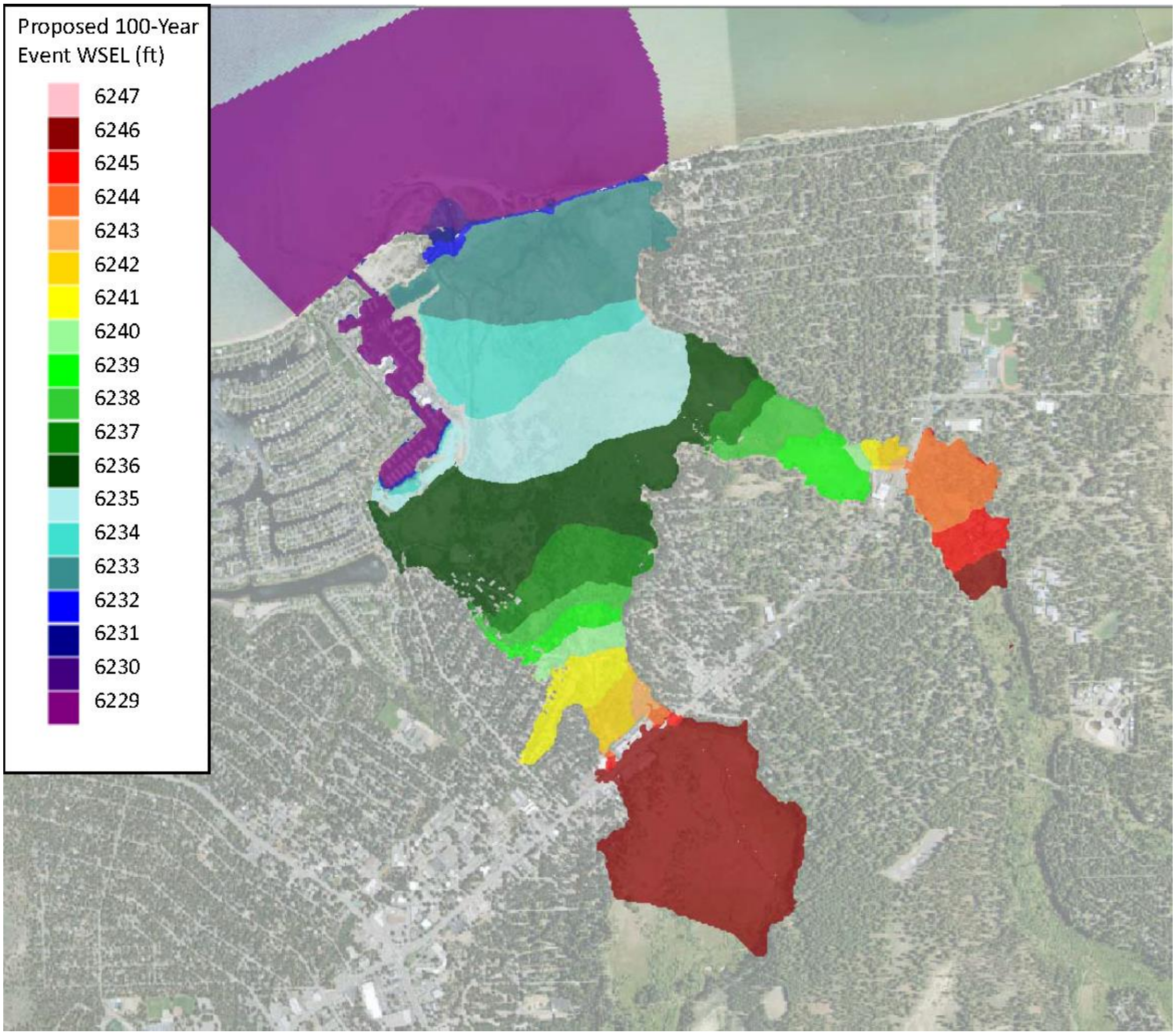
Source: Conservancy 2014

Figure 6-2: Land Use/Cover Types Modified as Roughness Polygons for the Preferred Alternative Condition

Preferred Alternative Model Output: 100-Year Event

Water surface elevations

The simulated water surface elevation (WSELs) for the preferred alternative condition under the 100-year flood event span the same range of elevation from the mouth at the lake (~6229 feet) to the US 50 bridges (~ 6244 feet) and the upstream model boundary (~6247 feet) as for the existing condition (see Figures 6-3 and Figure 4-4). Generally, the water surface shape and slope throughout the modeled area is similar to the existing condition, with similar contours and spacing, as well as absolute elevations.



Source: Cardno 2015

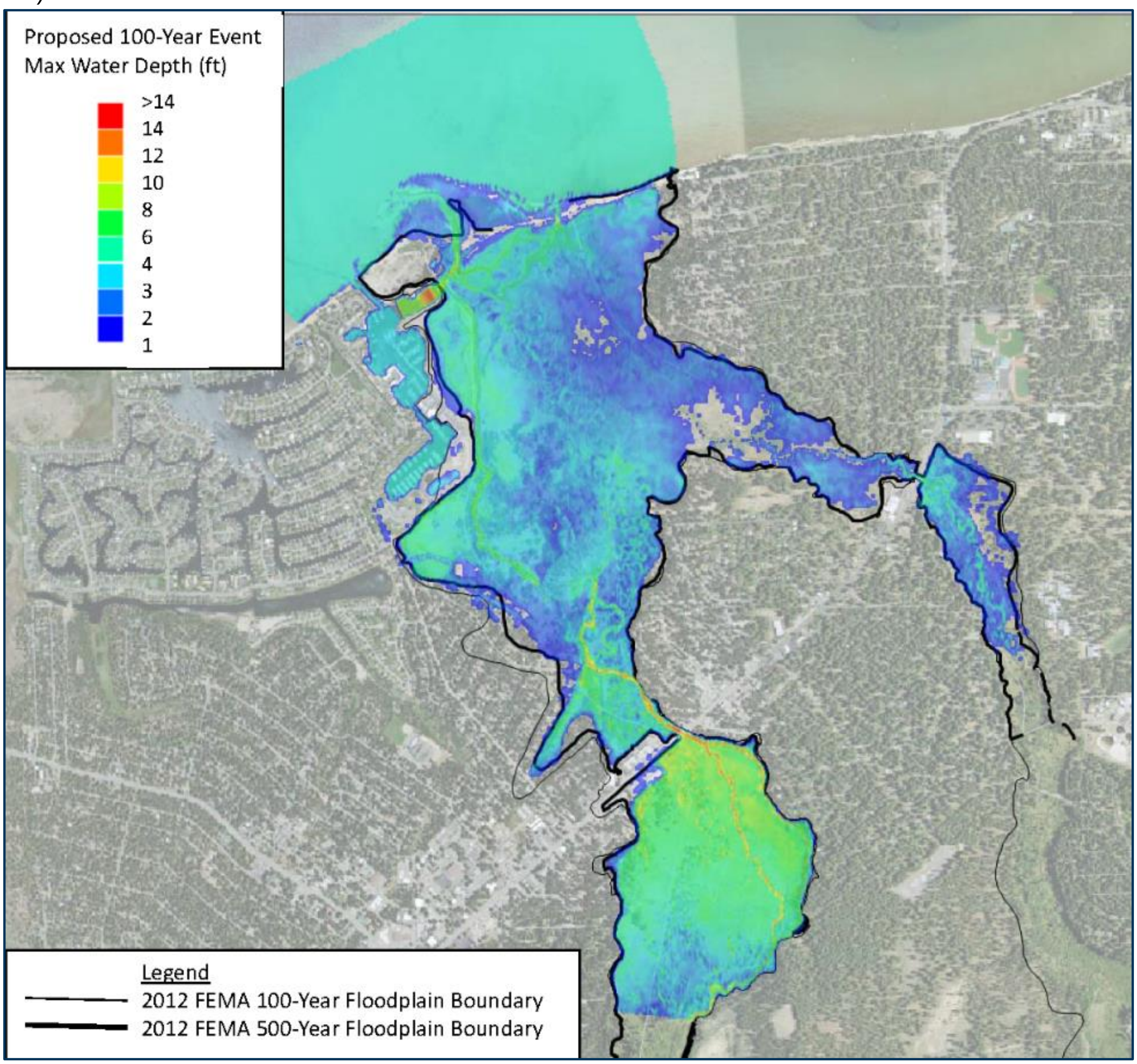
Figure 6-3: Preferred Alternative Condition 100-Year Flood Simulated Water Surface Elevations

Water Depth

The simulated water depths for the Preferred Alternative under the 100-year flood event (Figure 6-4) are very similar to those for the existing conditions (Figure 4-5), spanning the same range of depths and overall pattern, aside from increased diversity of depths in the reconnected lagoon and the elimination of some deep flow along the existing channel segments that will be abandoned. We depict areas simulated to have one or more feet of water depth to focus on active floodplain areas and to be consistent with

FEMA floodplain mapping protocols. The total extent and boundary shape of the 100-year flood water depths is nearly identical to the existing condition and to the 2012 floodplain boundary (see Figures 4-5 and 6-4). Water depths remain greatest in the Sailing Lagoon, and the upstream portions of the Upper Truckee River channel (Figure 6-4).

Modeled 100-year flood water depths are moderately deep (4 to 6 feet) across the upstream valley reach on the Upper Truckee River, in the western corner of the floodplain by the TKPOA yard (by the intersection of Tahoe Keys Boulevard with East Venice Avenue), along the existing channel on the west side third of the Project area, including the LWS wetlands, in the existing lagoon at the confluence of Trout Creek, and along the pilot channel extending northeast towards the middle marsh (Figure 6-4). Water depths are shallow (1 to 2 feet) on the southwest margin of the floodplain [over a slightly larger area by the pilot channel than under existing conditions], in portions of the middle of the marsh east of the pilot channel confluence, and in portions of the Trout Creek corridor and northeast edge of the site (Figure 6-4).



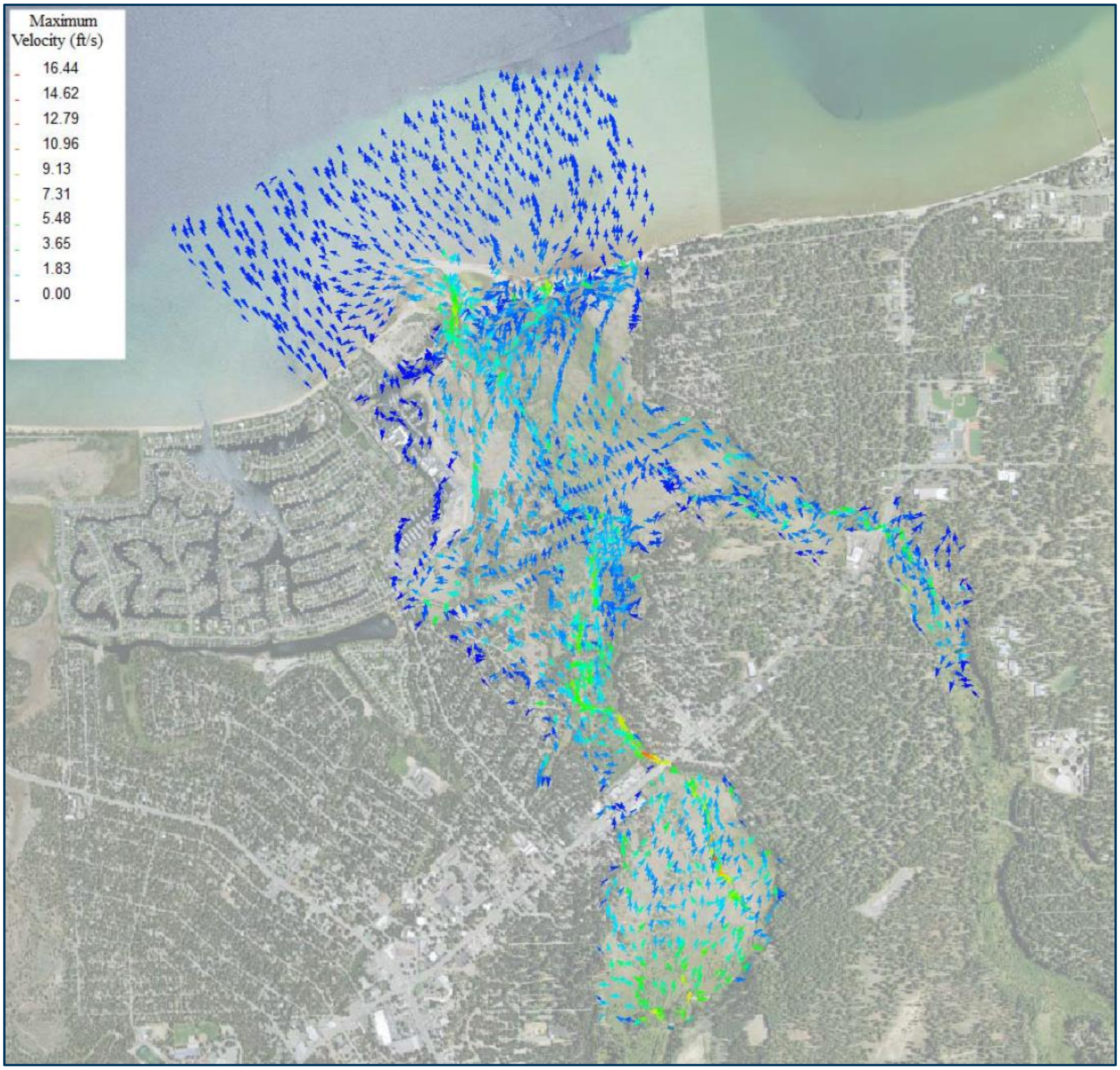
Sources: Cardno 2015 and FEMA 2012.

Figure 6-4: Preferred Alternative Condition 100-Year Flood Simulated Water Depths

As anticipated with the design concept, the 100-year flood water depths are reduced along the backfilled channel, but increased throughout the LWS wetlands and along the pilot channel corridor through the middle of the marsh. These changes are consistent with the intent to reactivate the marsh's remnant channels, restore the channel and floodplain connectivity and to allow the restored LWS wetlands, reconnected Sailing Lagoon and re-activated floodplain terrace into a unified system. The water depths under the Preferred Alternative do not adversely affect existing flood hazards to any of the surrounding developed lands.

Flow Direction and Velocity

The simulated flow directions and velocities for the 100-year event under the Preferred Alternative (Figure 6-5) are similar to those for the existing conditions (Figure 4-6). The maximum velocities within the model boundary are in the channel near and upstream of the US 50 bridge. The backwater eddies around the outer fringes of the study area are similar. Flow directions shift and become more varied along the backfilled channel as it is no longer an organized high flow route. There are expected local velocity increases and routing changes in the excavated pilot channel area, at the connection with the Sailing Lagoon, and at the mouth of the Upper Truckee River and Trout Creek. Additional flow interactions across the western floodplain, LWS and the reconnected Sailing Lagoon are evident, as expected and desired.



Source: Cardno 2015

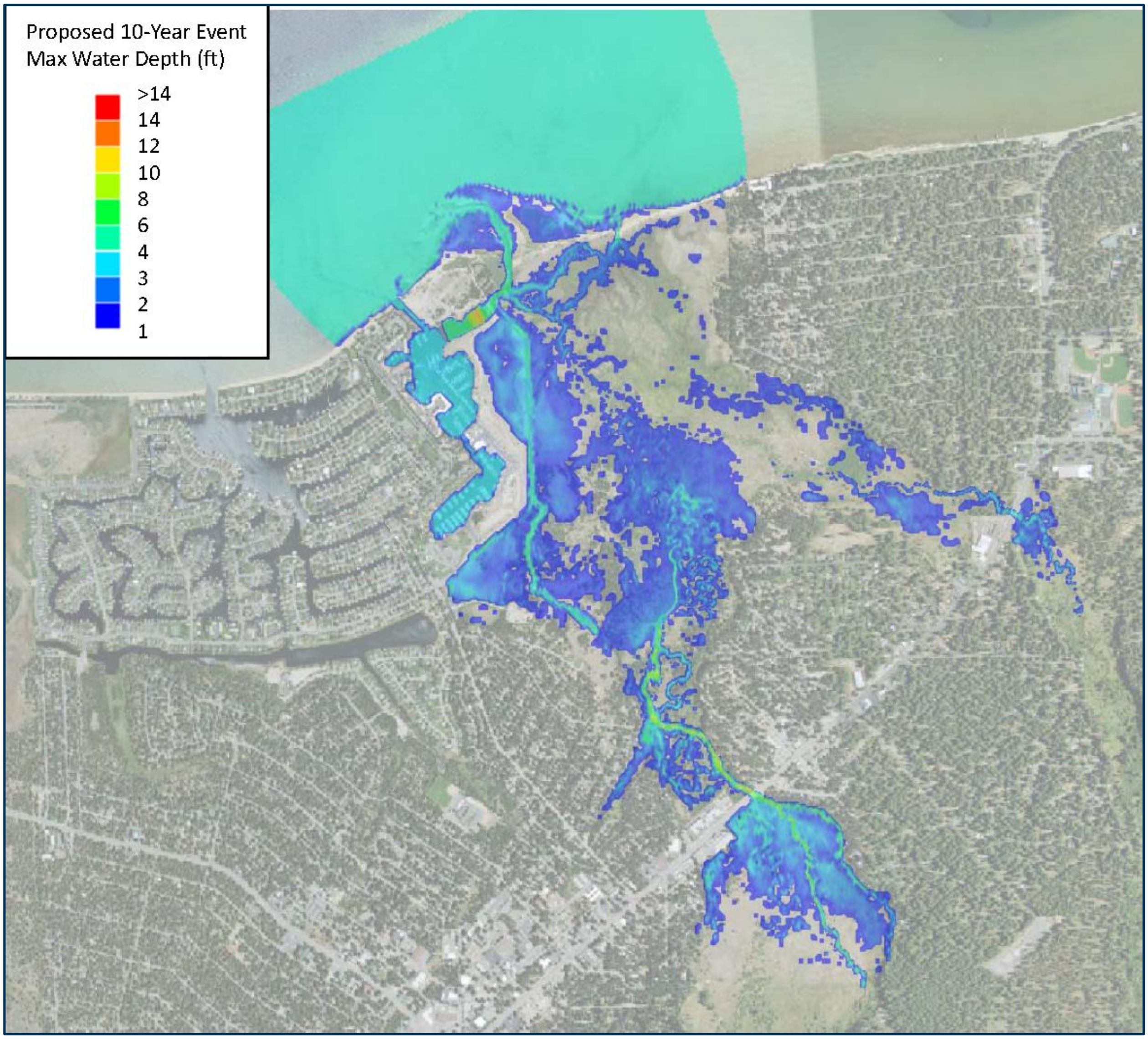
Figure 6-5: Preferred Alternative 100-Year Flood Simulated Flow Directions and Velocities

Preferred Alternative Condition Model Output: 10-Year Event

Water Depth

The simulated water depths for Preferred Alternative condition under the 10-year flood event range up to 10 to 12 feet in a few isolated upstream areas of the Upper Truckee River channel (Figure 6-6). In the reconnected Sailing Lagoon, water depths are more varied than under the existing condition 10-year event, but include small areas up to 12 and 14 feet deep (Figure 4-7).

Modeled 10-year flood water depths for the Preferred Alternative (Figure 6-6) are moderately deep (4 to 6 feet) in the existing secondary channel in the upstream valley reach on the Upper Truckee River and near its confluence with the drainage north of Sky Meadows; in a reduced portion of the corner of the floodplain by the TKPOA yard; in a larger area along the existing channel across the LWS wetlands; in a larger number and extent of remnant channel sections in the middle of the marsh; and, in a corridor along the pilot channel. The areas of the reconnected back beach lagoon, restored LWS floodplain, and middle of the marsh all have depths slightly increased relative to existing conditions under the 10-year event. The area near the pilot channel confluence would have reduced water elevations and depths, and most of the marsh would still have shallow (1 to 2 foot) or very shallow (less than 1 foot) inundation.

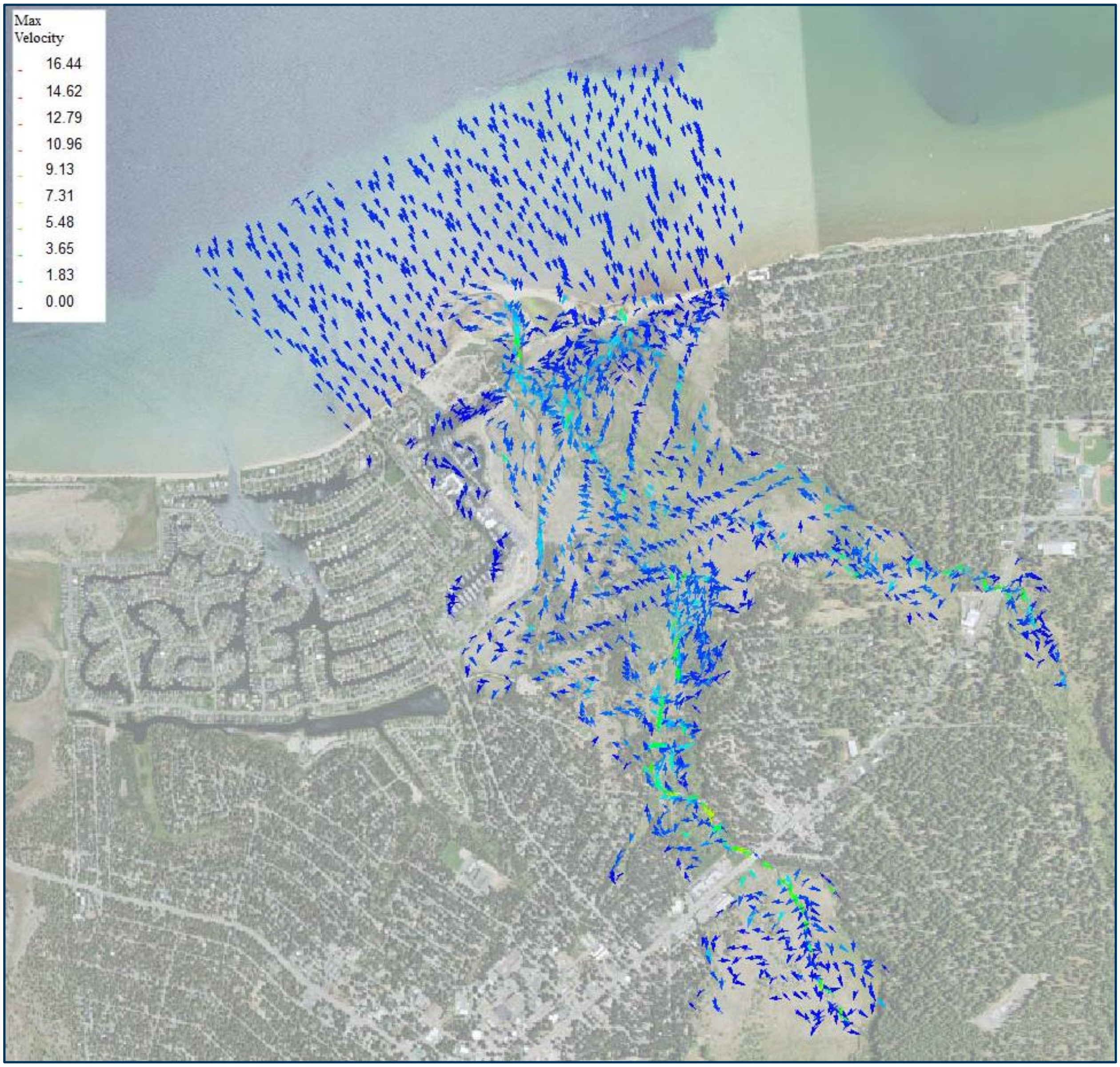


Source: Cardno 2015

Figure 6-6: Preferred Alternative 10-Year Flood Simulated Water Depths

Flow Direction and Velocity

The simulated 10-year flow directions for the Preferred Alternative (Figure 6-7) have a similar spatial pattern to existing conditions (Figure 4-8) upstream of the proposed pilot channel, but differ downstream. The velocities are lowered and flow routing simplified in the west side of the floodplain (along the existing channel alignment) relative to the existing condition. More velocity vectors are located in the reactivated floodplain area between the Upper Truckee River and Trout Creek, but with reduced vector density and magnitudes along portions of the Trout Creek alignment. The velocities and vector patterns across the reconnected LSW wetlands and Sailing Lagoon are slightly reduced in magnitude and more distributed and organized overall, consistent with desired back-beach processes in the lagoon reach.



Source: Cardno 2015

Figure 6-7: Preferred Alternative 10-Year Flood Simulated Flow Direction and Velocities

7 Preferred Alternative Discussion

Existing versus Proposed 100-year Flood Conditions

The modeling of both the existing conditions and the proposed conditions under the Preferred Alternative are at the same level of detail; utilize the most detailed and up-to-date topographic and bathymetric data; calculate results using consistent grid scales; have the same hydrologic inputs, and make the same 2D model simulation assumptions. Comparison of the graphic model results for the Preferred Alternative (Section 6, above) and Existing Conditions (Section 4, above) indicate differences in hydraulic parameters anticipated as a result of implementing the Project's Preferred Alternative. To facilitate a rigorous comparison of proposed 'with Project' versus existing conditions under the 100-year flood event, the 2D modeled water surface elevations for both scenarios are presented below in summary maps. The first summary map (Figure 7-1) presents the simulated 100-year WSELs for the Preferred Alternative as colored polygons (those presented in Figure 6-3, above) with an overlay of the simulated100-year WSEL contour lines for the Existing Condition (originally shown in Figure 4-4, above).

In most areas, the proposed and existing 100-year WSELs display few differences (Figure 7-1). For example, results are similar above and immediately downstream of the US 50 bridges, in the valley reaches along the Upper Truckee River and Trout Creek, and in the western corner of the floodplain (near the intersection of Tahoe Keys Boulevard and East Venice Avenue). The largest shifts in the 100-year WSELs are within the middle of the marsh, along the pilot channel, and at the reconnected lagoon. These small increases in flood water elevations under the 100-year event are associated with desired conditions and ecosystem functions in the Project area, while not resulting in increased flood hazards to surrounding developed lands.

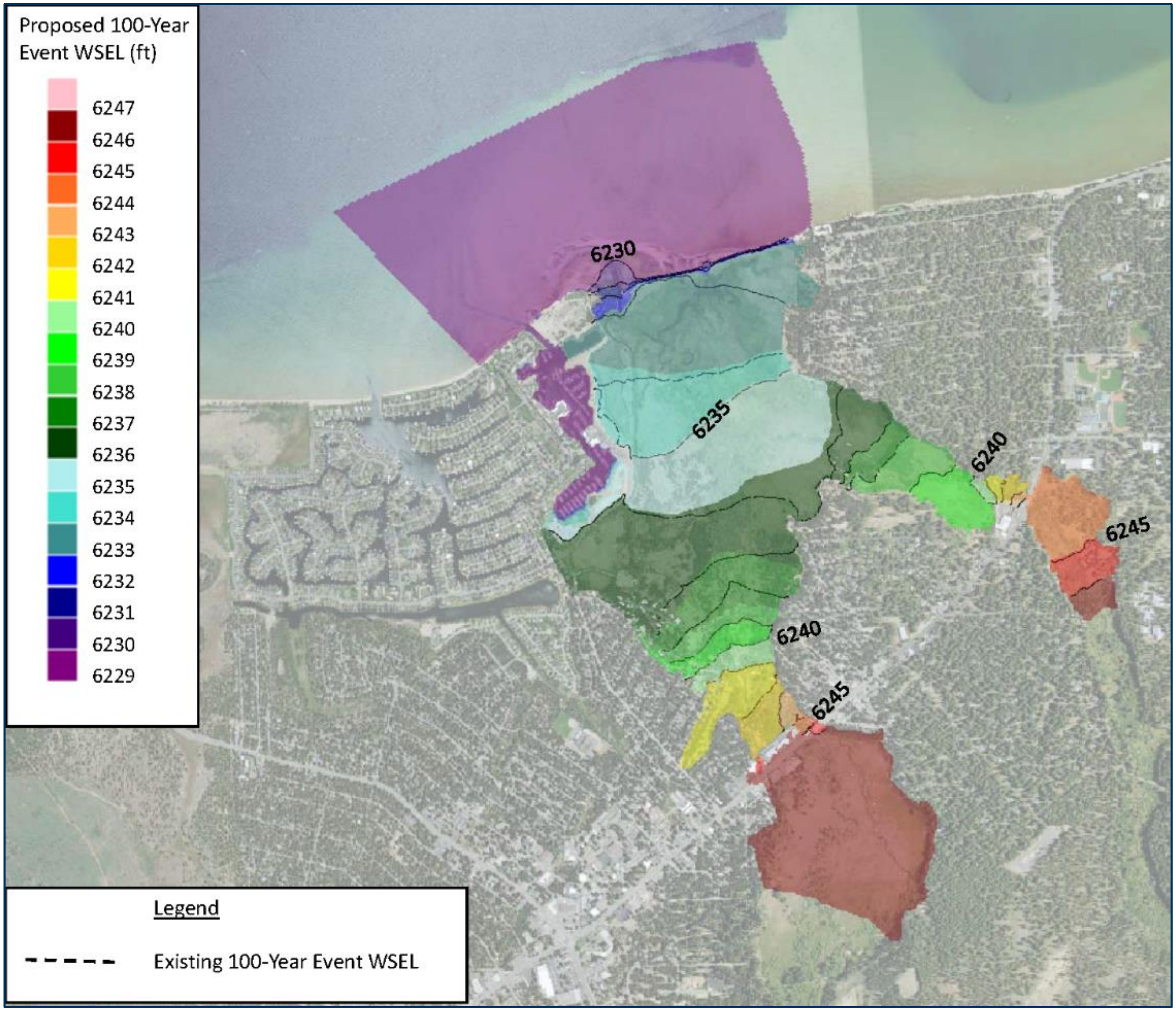
The final two comparative figures (Figures 7-2 and 7-3) depict model output that has been exported from XPSWMM and analyzed in GIS software to identify residual differences in WSELs. A 'positive' residual value represents a higher WSEL under the Preferred Alternative than for the Existing Conditions, and a 'negative' residual represents a lower WSEL under the Preferred Alternative. Therefore, positive and negative residuals may indicate either beneficial or adverse potential changes, depending on their location. The sections below describe the changes to WSELs for the Preferred Alternative in the 100-year flood.

100-year Flow WSEL Changes with the Preferred Alternative

Figure 7-2 is a map of the positive residuals for the 100-year event to assist with screening for adverse flood hazard impacts. There are WSEL increases in the reconnected Sailing Lagoon (2 to 5 feet), at and upstream of the reconfigured mouth (+0.1 to 0.4 feet), and throughout the back-beach lagoon across the marsh (+0.1 to 0.8 feet). Another area of increase is in the middle of the marsh where the pilot channel reconnects to remnant channels (+0.2 to 0.4 feet). All of these increased 100-year WSELs are desired and expected outcomes that occur without producing adverse flooding changes. A few, isolated model grid cells where topography changes rapidly (e.g., from flat floodplain to side slope or portions on the irregular shoreline) have model residuals indicating WSEL increases, but these are considered model noise as they are directly adjacent to grid cells that have residuals indicating WSEL decreases (see Figure 7-3).

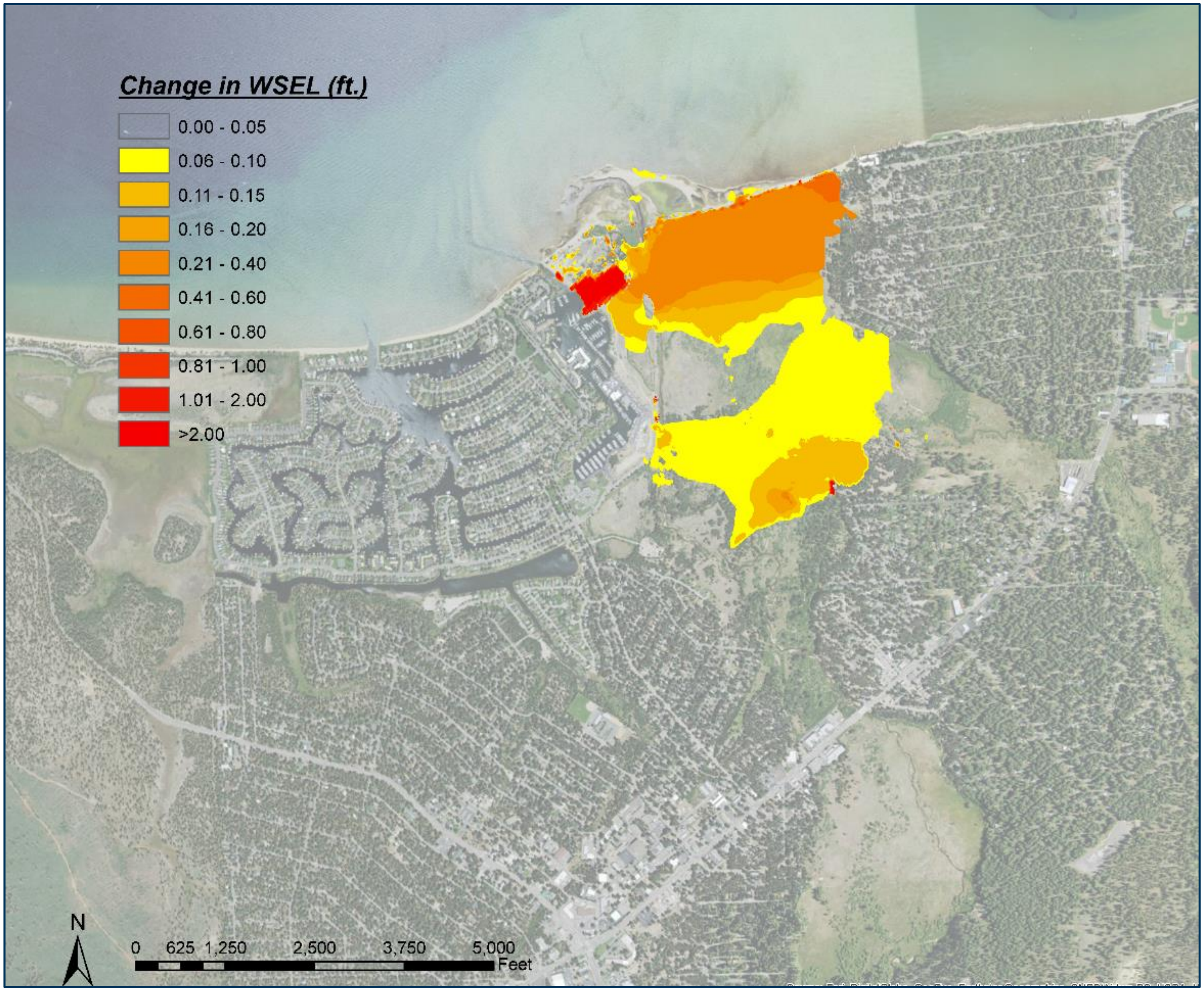
Figure 7-3 is a map of the negative residuals for the 100-year event to assist with screening for possible improvements in hazardous flood levels. A broad area at the downstream end of the valley reach along the Upper Truckee River, including the area modified as the pilot channel, is simulated to have lowered 100-year WSELs (-0.1 to -0.4 feet). A zone of lowered WSELs (-0.06 to -0.2 feet) is simulated on the southwest margin of the 100-year floodplain, along residential areas. The largest decreases are along the LWS (-1 to -5 feet), where fill is being removed and water is allowed to spread across the restored floodplain. WSELs are also lowered downstream of the reconfigured mouth (-.05 to 2 feet).

The changes to the site associated with implementing the Preferred Alternative would; therefore, increase the 100-year water elevations relative to existing conditions at locations and in a manner that are desired and benefit the ecosystem services of the marsh, without expanding the floodplain or increase flood hazards to adjacent developed lands.



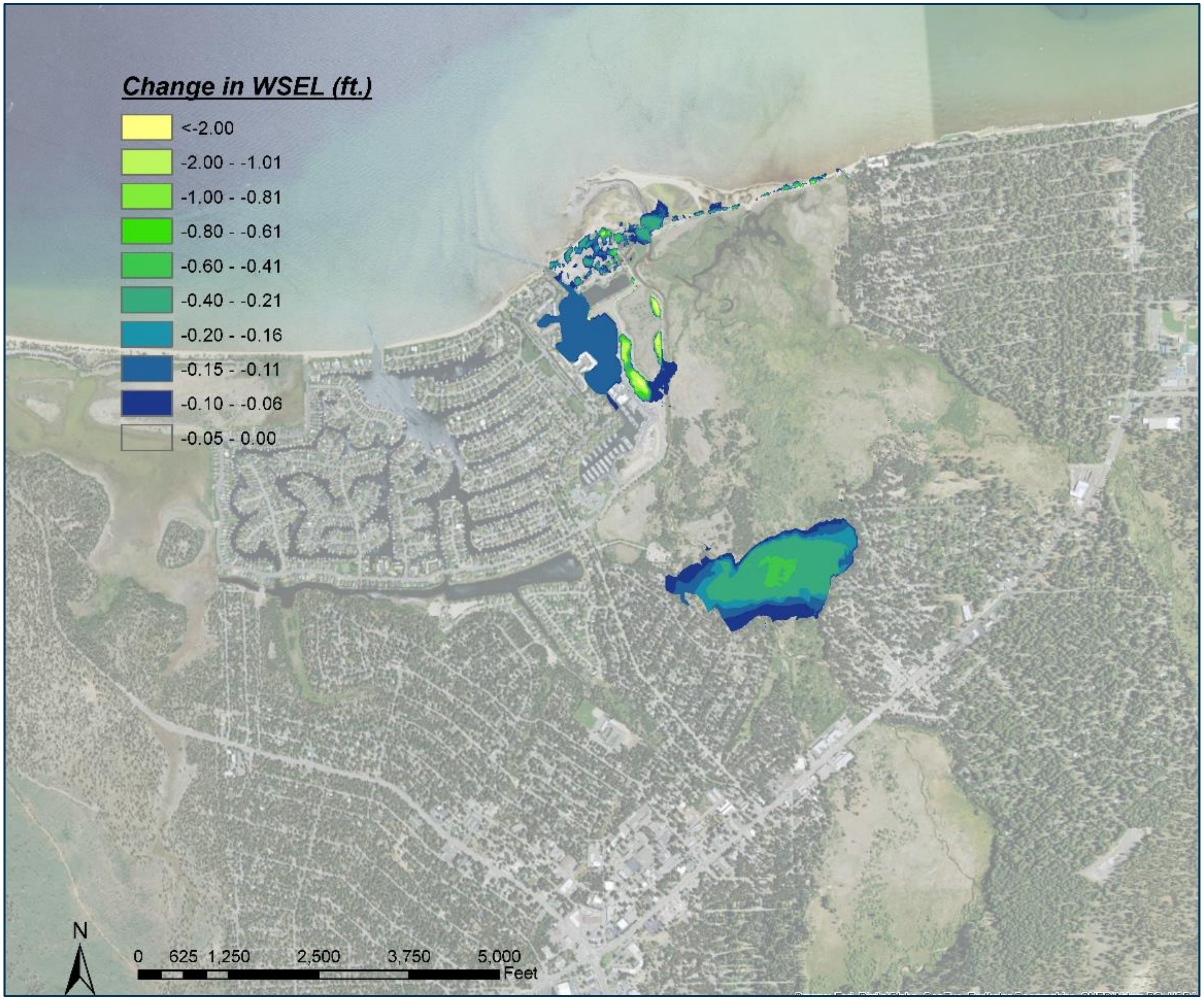
Source: Cardno 2015

Figure 7-1: 100-Year Flood WSELs under the Preferred Alternative and Existing Condition Scenarios



Source: Cardno 2015

Figure 7-2: 100-Year Flood WSEL Increases with Preferred Alternative



Source: Cardno 2015

Figure 7-3: 100-Year Flood WSEL Decreases with Preferred Alternative

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