Deltares USA

Coastal and Riverine Flood Assessment for Alameda County Flood Control District (Phase 2)

Memo describing additional consultancy services



Coastal and Riverine Flood Assessment for Alameda County Flood Control District
Memo describing additional consultancy services (Phase 2)

Authors:
Kees Nederhoff Delteras USA
Rohin Saleh, AquFlows Engineering

Project Manager:
Moses Tsang

Coastal and Riverine Flood Assessment for Alameda County Flood Control District (Phase 2)
Memo describing additional consultancy services

Client	Alameda County Flood Control District
Contact	Kees Nederhoff
Keywords	Coastal modeling

Details	
Version	1.0
Date	January 5, 2024
Project number	1917
Pages	25
Status	concept

Doc. Version	Author	Control	Approval
1.0	Kees Nederhoff	Lauren Schambach	Edwin Welles

Content

Acknowledgments **5**

1 Introduction **6**
1.1 Background 6
1.2 Objective 6

2 SFBD-SWL applications **8**
2.1 Assessing the Risk of Levee Overtopping in the Delta: Extreme Water Levels and Future Sea Level Rise Scenarios 14
2.2 Enhancing Precision in Estimating Extreme Water Levels: Integrating Synthetic Years and Sea Level Rise Adjustments in Hydrodynamic Modeling 8
2.3 Developing a Methodology for Simulating Storm Impacts on Local Watershed Water Levels: A Method Derived for Alameda County 10
2.4 Evaluating the Impact of Wind Stress and Setup on Water Levels in Hydrodynamic Modeling: Insights from the San Francisco Bay Area 12

3 Assessing Hydrodynamic Model Performance in Eden Landing: Resolution Impact and Validation with Topo-Bathymetric Data **17**
3.1 Introduction 17
3.2 Model setup and validation 17

4 Suitability Delft3D-FM for 1D applications **20**
4.1 Analysis of Gradually-Varied Flow Profiles: M1 and M2 Curves in Delft3D Simulations 20
4.2 Evaluating the Precision of Delft3D in Hydrodynamic Simulations: Testing Ground Layer Functions and Bed Friction in Channel Models 21
4.3 Comparative Analysis of San Lorenzo Creek Modeling: HEC-RAS and Delft3D FM Performance Across Varied Flow Conditions 22
4.4 Validating 1D Creek Components in the SFBD-SWL Community Model: A Case Study of Alameda Creek 23

Acknowledgments

This work was funded by Alameda Flood Control and Water Conservation District (District) with the active involvement of Rohin Saleh in model development, calibration, validation scenario development, and alternative evaluations. Gratitude is extended to District support staff Ramses Manalo, Danli Li, and others for providing relevant GIS layers that were used for the model setup. Moreover, we would like to thank the USGS Coastal and Marine Geology Program and in particular Babak Tehranirad, Liv Herdman, Li Erikson, and Patrick Barnard for support in the model development and fruitful conversations.

Disclaimer

The data shared here is offered 'as-is' without any guarantees regarding its accuracy, completeness, or reliability. Moreover, The data are provided on the condition that neither Deltares USA, Alameda Flood Control District, California Department of Water Resources, the U.S. Geological Survey nor the U.S. Government can be held liable for any damages resulting from the authorized or unauthorized use of the data. Any use of the data is at the user's sole risk. For a detailed understanding, one can be referred to https://www.d3d-baydelta.org/download-swl.

1 Introduction

1.1 Background

The San Francisco Bay and Delta (SFBD), recognized as the largest estuary on the United States West Coast, has long been a subject of interest in hydrodynamic and flood controlresearches. Over the past few decades, a variety of numerical models have been developed to explore these aspects. Notable among these are models such as UnTrim, SUNTANS, MIKE 21, SCHISM, RMA2, and Delft3D. While these models have provided valuable insights, most of the time there are some limitations associated with their uses.. Issues such as proprietary restrictions, limited scope for community-driven enhancements, inadequate support+maintenance, and constrained model range have been prevalent. Additionally, most models are not fundamentally optimized for ease of use and some time their extensive simulation times and the consequent demand on computational resources makethem less practical for long-term hindcast studies.

In response to these challenges, a collaborative initiative involving the United States Geological Survey (USGS), National Oceanic and Atmospheric Administration (NOAA), and the Alameda County Flood Control & Water Conservation District, supported by Deltares USA and Deltares Netherlands, led to the development of a new model. This model uniquely connects the San Francisco Bay with the Delta, offering a comprehensive view of the entire system. Delft3D was selected for this new model for its open-source nature, allowing free access to the models, easy modifications and scenario developments, and distributions.

Nederhoff et al. (2021) and Deltares USA (2023) describe the calibration, validation, and application of the developed model of the San Francisco Bay and Delta that can be used as a base model for the computation of still water levels (SWL) in the Bay, its tributaries, and Delta channels. Additionally, the low computational costs enable the accurate hindcasting of SWL over extended periods, crucial for conducting reliable extreme value analysis.

The models and their findings are made publicly accessible on www.d3d-baydelta.org, shared under the Creative Commons License to encourage wider access and collaborative efforts. This model, referred to as the SFBD-SWL, signifies an important advancement in striving for a cohesive strategy in modeling and planning to effectively mitigate the impacts of coastal flooding in the SFBD.

1.2 Objective

This memo outlines a supplementary study (Phase 2) that builds upon the findings presented in the report by Deltares USA (2023).

The objectives are structured as follows:

1. **Application of the SFBD-SWL model to practical questions** (Section 2)
    a. Assessing the Risk of Levee Overtopping in the Delta (Section 2.4)
    b. Investigating stochastic methods to narrow the uncertainty range in extreme value predictions (Section 2.1)
    c. Developing storm schematizations (Section 0)
    d. Assessing the impact of wind setup on water levels (Section 0)
2. **Development and Validation of a local model for Eden Landing** (Section 3). Creation of a localized model that specifically focuses on the hydrodynamic production of tides in the salt marsh ecosystem of Eden Landing.
3. **Evaluating the efficacy of Delft3D for one-dimensional (1D) applications** (Section 4). Assessing the Risk of Levee Overtopping in the Delta (Section 2.4)

a. Analysis of Gradually-Varied Flow Profiles: M1 and M2 Curves in Delft3D Simulations (Section 4.1)
b. Evaluating the Precision of Delft3D in Hydrodynamic Simulations: Testing Bed Friction in Channel Models (Section 4.2)
c. Comparative Analysis of San Lorenzo Creek Modeling: HEC-RAS and Delft3D FM Performance Across Varied Flow Conditions (Section 4.3)
d. Validating 1D Creek Components in the SFBD-SWL Community Model: A Case Study of Alameda Creek (Section 4.4)

Each section of this study is designed to not only leverage the capabilities of the SFBD-SWL model, but also to expand our understanding of specific hydrodynamic phenomena within the San Francisco Bay and Delta region and the underlying model capabilities.

2 Application of the SFBD-SWL

2.1 Enhancing Precision in Estimating Extreme Water Levels: Integrating Synthetic Years and Sea Level Rise Adjustments in Hydrodynamic Modeling

The same 70-year hindcast as used in the previous Section was used to estimate extreme values of water levels and their corresponding return periods plus the statistical uncertainty. This uncertainty can be expressed in a 95% confidence interval which describes the range in which the true return values are likely to fall. When this range is small it gives a high level of assurance about the accuracy of the estimates. When this range is large one should be cautious and ideally account for the ambiguity of extreme water levels. Deltares USA (2023) shows that the uncertainty for annual events is very small (<1 inch), but increases substantially for more rare events. For example, the 95% confidence interval increases to >1 foot (>35 cm) for a return period of 100 years. Ideally, one would be able to reduce this uncertainty with longer numerical simulations or additional statistical techniques. This subsection describes the latter.

The starting point is the same modeling results from the previous subsection. However, to reduce the statistical uncertainty, numerous synthetic years were constructed based on the 70-year historical modeled water levels. In particular, for each time series, we decomposed the SWL into:

1. Constant mean water level;
2. Predictable tidal motions based on the tidal constituents;
3. Stochastic non-tidal residual (NTR). Based on the 70-year historical data, we estimate the possible values the residual water level can have. In Figure 1, we present a range of possible outcomes. As indicated by the higher 5/95% CI (red line in Figure 1), storms generally occur from January through April.

Subsequently, we create a longer-term water level to produce 1000 synthetic years. We randomly apply the historical NTR (with a small phase shift of 7 days) on top of a random tide. This allowed us to perform again a POT/GPD on these 1000 years and compute return values for numerous storm frequencies. Figure 2 presents the results of this analysis. Based on synthetic years, the uncertainty reduced dramatically from 35 cm to 7 cm (14 to 3 inches). Moreover, the reconstructed time series has a 100-year return value of the SWL that is 10 cm or 4 inches *lower* than based on the 70-year-long record. This indicates an *unfavorable* historical combination of tide and NTR resulting in a higher estimate of the extreme water levels.

One additional component that is relevant for these long-term simulations is to account for the historical sea level rise as historical (modeled) events occurred during a lower mean sea level than what is currently applicable. Hence, it is vital to be clear on the year(s) the mean sea level is based on. In this situation, we corrected values to 2020 sea level, similarly to Deltares USA (2023). Notice the difference between the red and blue lines in Figure 2 which show this effect.

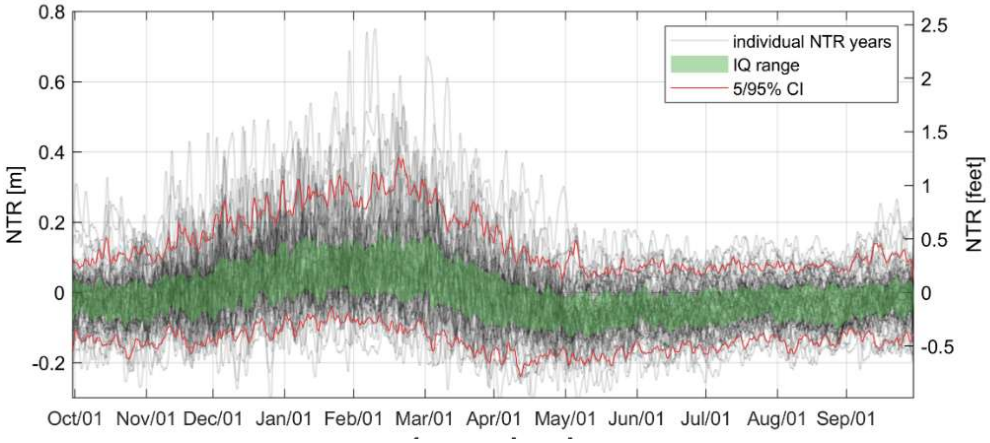


Figure 1. Seasonal variation of stochastic non-tidal residual (NTR) per water year. This figure displays the stochastic NTR as a function of the day, starting from the beginning of the water year (WY). The higher 5/95% confidence interval (CI), shown in red, indicates a greater likelihood of storm events occurring between November and April. This graph is based on 70-year historical data and illustrates the seasonal patterns and variability in NTR

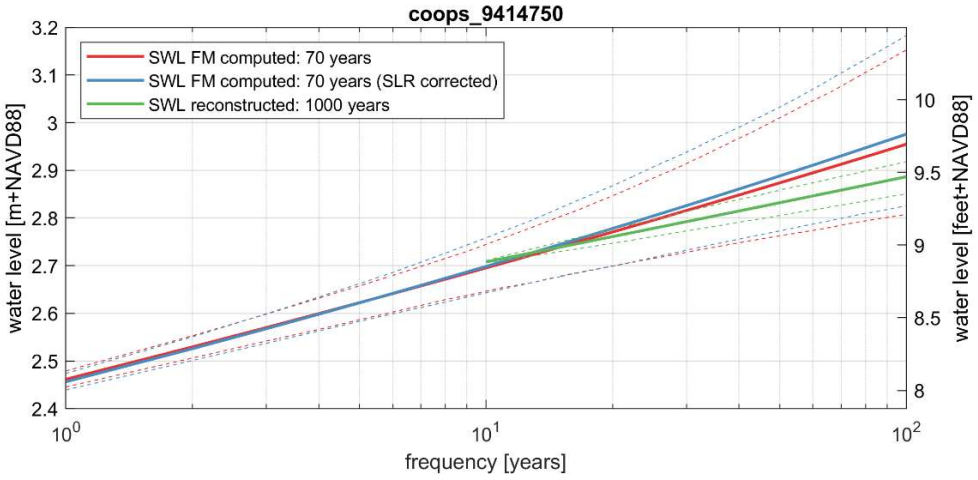


Figure 2. Comparative analysis of extreme water levels at Alameda (NOAA station #9414750). The figure contrasts three different methodologies for predicting extreme water levels. The red line represents the original POT/GPD analysis, the blue line shows the POT/GPD adjusted for sea level rise (SLR) to 2020 levels, and the green line depicts results from a 1000-year synthetic time series. This comparison highlights the dramatic reduction in uncertainty (from 35 cm to 7 cm) and the lower 100-year return value of water level in the synthetic series, indicating a historical overestimation of extreme water levels.

2.2 Developing a Methodology for Simulating Storm Impacts on Local Watershed Water Levels: A Method Derived for Alameda County

To facilitate in-depth analysis of local watersheds, it's crucial to have a method that can accurately apply a time series of water levels for a specified return period and value at downstream boundary locations. This subsection outlines a novel approach crafted for such studies, with a focus on Alameda County (NOAA station #9414750). The methodology leverages the 100 highest simulated water level records and detailed tidal information from this station.

The data enabled us to create two critical representations: a representative tidal cycle (depicted in Figure 3) and a representative non-tidal residual (NTR) profile (shown in Figure 4). Analysis of the tidal data reveals a pronounced semi-diurnal cycle, primarily influenced by the M2 and K1 tidal constituents prevalent in the San Francisco Bay. In contrast, the NTR profile exhibits a distinctive triangular pattern.

Building on these insights, we developed a four-step methodology for simulating storm scenarios and their impact on water levels:

1. **Identification of Extreme Values**: First, we determine the extreme water level for a specific return period. This involves either analyzing historical data or using information from Deltares USA (2023) that is available here at https://www.d3d-baydelta.org/download-swl.
2. **Establishment of Mean Sea Level and Ratios**: We then determine the Mean Sea Level (MSL) and the ratio of tidal influence to NTR. This step is crucial for understanding the relative impact of tidal movements versus NTR factors.
3. **Construction of Time Series for Tidal and NTR Signals**: The next phase involves computing distinct time series for both the tidal cycle and the triangular NTR signal.
4. **Computation of Water Levels**: Finally, we calculate the still water levels by summing the MSL, tidal cycle, and NTR contributions.

This methodology provides a robust framework for simulating and understanding the dynamics of water levels in local watersheds, particularly in the context of extreme weather events. By combining detailed tidal analysis with NTR patterns, we can offer more robust predictions of downstream boundary conditions for flood risk management and mitigation planning.

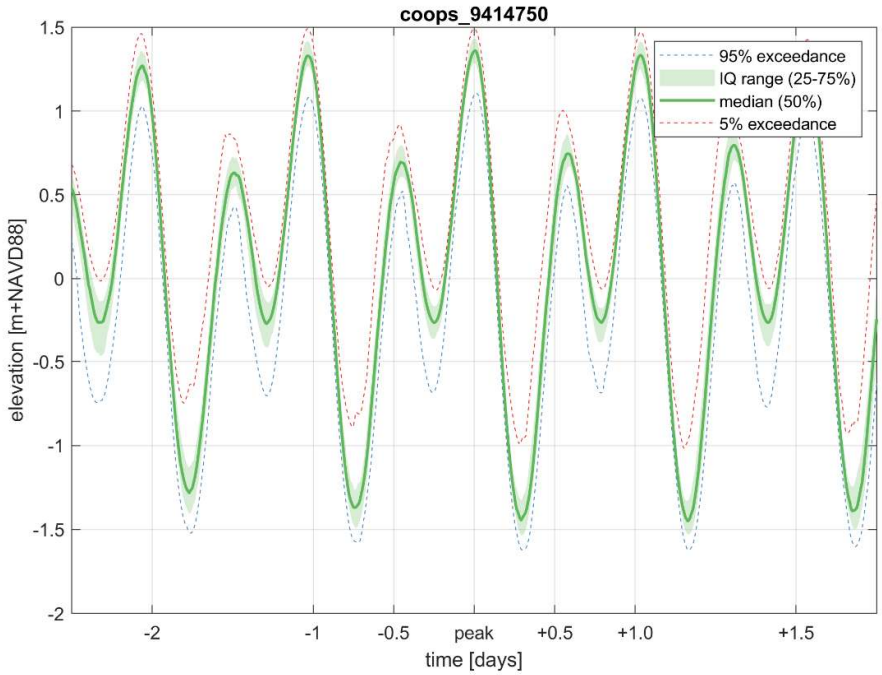


Figure 3. Illustration of representative tidal water levels at Alameda (NOAA station #9414750). This figure showcases a representative tidal cycle, highlighting the semi-diurnal pattern predominantly influenced by the M2 and K1 tidal constituents in the San Francisco Bay.

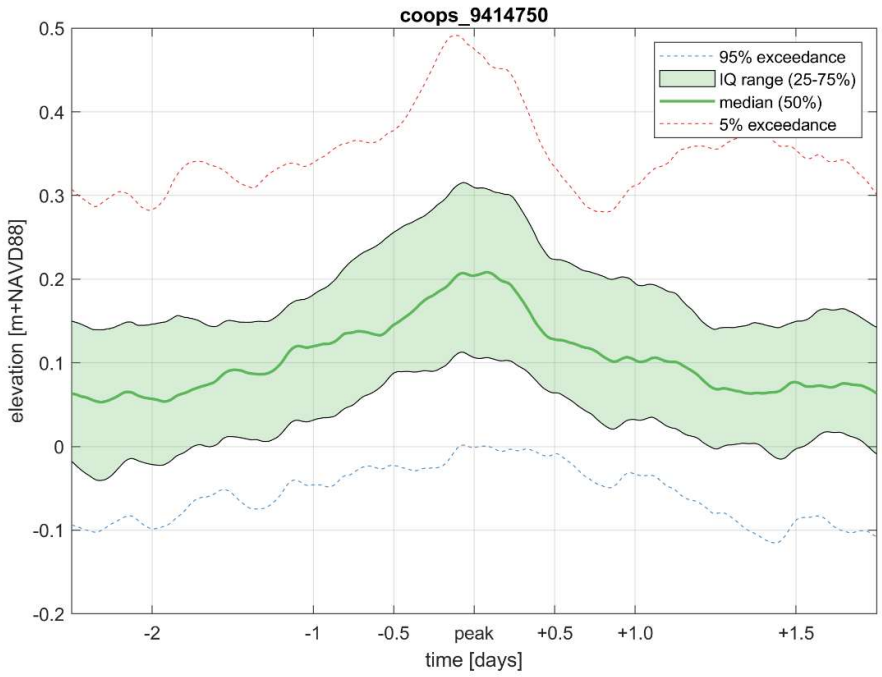


Figure 4. Profile of representative non-tidal residuals (NTR) at Alameda (NOAA station #9414750). This figure presents a representative NTR profile, characterized by its distinctive triangular pattern

2.3 Evaluating the Impact of Wind Stress and Setup on Water Levels in Hydrodynamic Modeling: Insights from the San Francisco Bay Area

Wind stress is a key factor in understanding the dynamics of large water bodies like oceans, seas, estuaries, and lakes. It refers to the shear stress exerted by the wind on the water's surface. Wind setup refers to the displacement of water due to wind blowing across the water body's surface. This translation from wind speed to stress is quantified using a drag coefficient, which accounts for air density and wind speed, representing the momentum exchange between air and sea.

Nederhoff et al. (2021) and Deltares USA (2023) have adopted the empirical relationship proposed by Vatvani et al. (2012) for calculating the drag coefficient in their Delft3D modeling, though numerous other formulations exist in the literature. This subsection delves into the significant role of wind setup by experimenting with variations in the drag coefficient. Specifically, we compared maximum water levels during the ten most significant wind events on record under scenarios of no wind drag and with double the drag values suggested by Vatvani et al. (2012). This approach offers a conservative assessment of the uncertainty inherent in wind-driven setup (see Figure 5 for a comparison of the effect).

Wind speeds in the San Francisco Bay are generally modest, especially when compared to hurricane-prone regions. According to the ERA5 reanalysis data (Hersbach et al., 2020), typical yearly wind speeds reach around 10 m/s, with 100-year events potentially hitting 14 m/s (equivalent to Beaufort scale 6). However, given the coarse resolution of this data, these estimates are likely lower than actual observed values. In the San Francisco Bay, prevailing winds predominantly originate from the southwest and southeast. Southwest winds lead to a general setup across the Bay, while southeast winds create setup in the North Bay and a setdown (lower water levels) in the South Bay. A validation study by Nederhoff et al. (2021) at Alameda (station #9414750) revealed an RMSE of 1.15 m/s for wind speed magnitude, indicating greater discrepancies in wind direction than in magnitude, with RMSE values of 2.16 and 2.42 m/s for eastward and northward wind speeds, respectively.

Modeling of the largest recorded wind event in December 1982 showed that the absence of wind-driven drag could result in water levels being up to 10 cm lower while running simulations with double the drag could increase levels by a similar margin (Figure 5). Across the ten largest wind events, the variation in water levels ranged from 5 to 15 cm (Figure 6), depending on whether the model included a wind-driven setup or applied double the drag. Additionally, Nederhoff et al. (2021) concluded that the influence of wind on extreme water level return values is minimal compared to other factors such as tides and sea level anomalies.

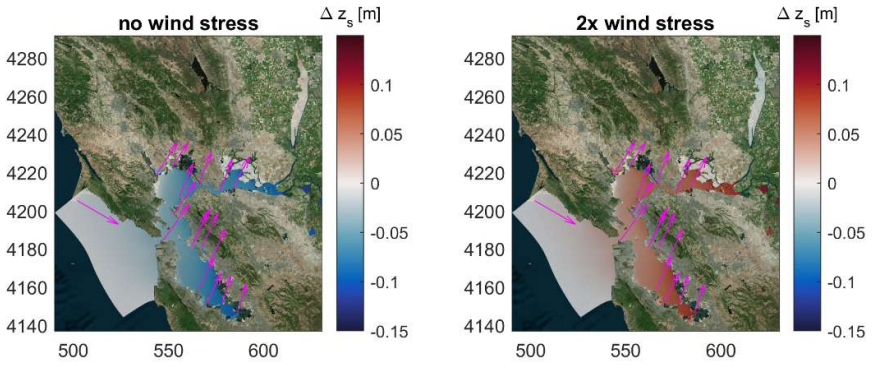


Figure 5. Impact of wind stress on water levels during the largest wind event in the ERA5 record. This figure demonstrates the difference in water level simulations conducted without wind stress (zero drag) and with double the standard drag coefficient, as per Vatvani et al. (2012). Blue colors represent areas where the absence of wind stress leads to lower water levels, while red colors indicate areas with higher water levels due to increased drag

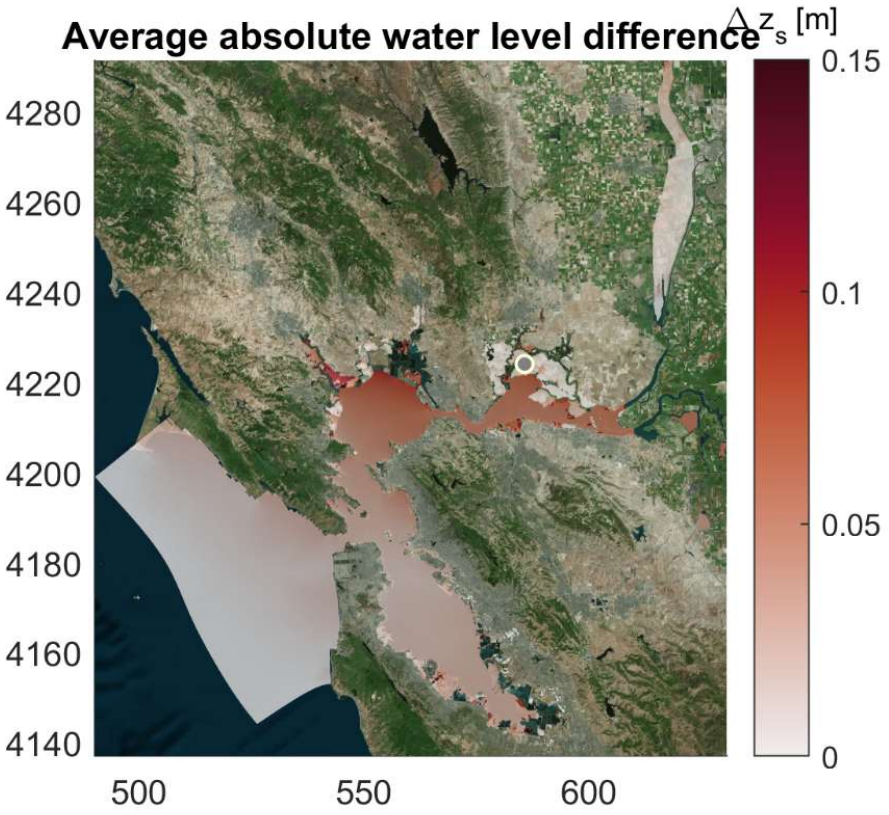
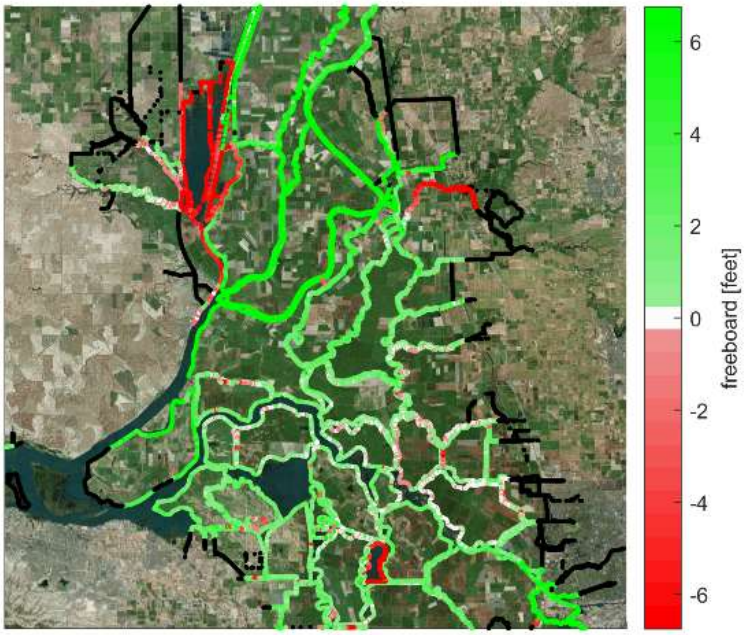


Figure 6. Comparative analysis of water level differences for the five highest wind events. This figure presents the average absolute differences in water levels across the five highest wind events recorded, comparing scenarios with no wind-driven setup and those with double the standard drag coefficient. The graph offers insights into the variability of water level responses to different wind stress scenarios, highlighting the range (5 to 15 cm) of potential water level fluctuations due to wind-driven forces.

2.4 Assessing the Risk of Levee Overtopping in the Delta: Extreme Water Levels and Future Sea Level Rise Scenarios

No single storm is responsible for past extreme water levels levels across the entire San Francisco Bay region. The combination of events that produce a one-in-100-year (1% annual chance) flood at one location in the Bay may be quite different than the events that have produced a 100-year flood elsewhere. Deltares USA (2023) presents extreme water level estimates based on the peak-over-threshold (POT) Generalized Pareto distribution (GPD). The POT/GPD makes better use of the available modeled data than methods used by other studies (e.g. DHI, 2013). With this method, it was possible to accurately estimate the return period for extremes across the Bay for rare events (100-year) as well as more frequent events (e.g. yearly extremes). Results from a 70-year hindcast (see Nederhoff et al., 2021) were presented only for San Franciso Bay, however, values were also computed in the San Francisco Delta. The height of extreme water levels in the San Francisco Delta is especially important to compare to levee heights to detect potential overtopping which can result in inundation of large areas.



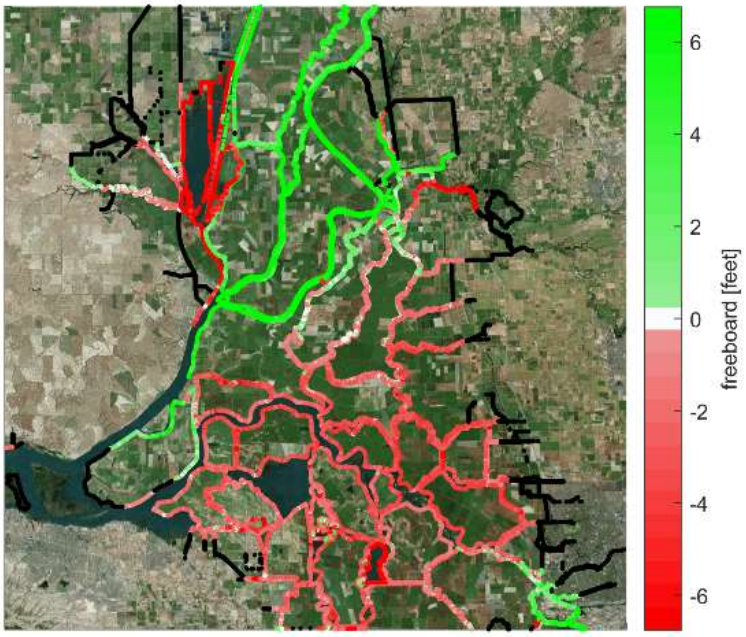


Figure 7. Analysis of levees in the San Francisco Delta under different sea level scenarios. This figure illustrates the projected extreme water levels (100-year) on Delta levees. The top panel (A) shows the relative freeboard with the current sea level, where green indicates a positive freeboard (levee exceeds the 100-year) and red indicates a negative freeboard (risk of levee overtopping). The bottom panel (B) depicts the scenario with a 4.8-foot sea level rise, highlighting the increased risk of overtopping and inundation due to sea level rise.

presents the results of the extreme value analysis based on results from Deltares USA (2023) compared to the levee height across the Delta. Levee positions were based on the Department of Water Resources (DWR) database for centerlines for Delta levees[1]. The relative freeboard is shown for both the current sea level (panel A) and a future sea level scenario of 4.8 feet (panel B). Green means a positive freeboard in which the levee height is higher than the 100-year water level as computed by Delft3D. Red means a negative freeboard which means the levee will get overtopped resulting in inundation. Model results indicate that in the current situation, the majority of the levees are generally higher than the 100-year water level. However, with sea level rise levees would start to get overtopped.

This preliminary analysis shows the strength of one continuous hydrodynamic model that connects the marine-driven Bay with the fluvial-driven Delta. Sea level rise is going to affect both areas and numerical models can help understand where and when tipping points will emerge.

[1] https://atlas-dwr.opendata.arcgis.com/datasets/df57b2bdb7954cad8c89210738cfa658_0

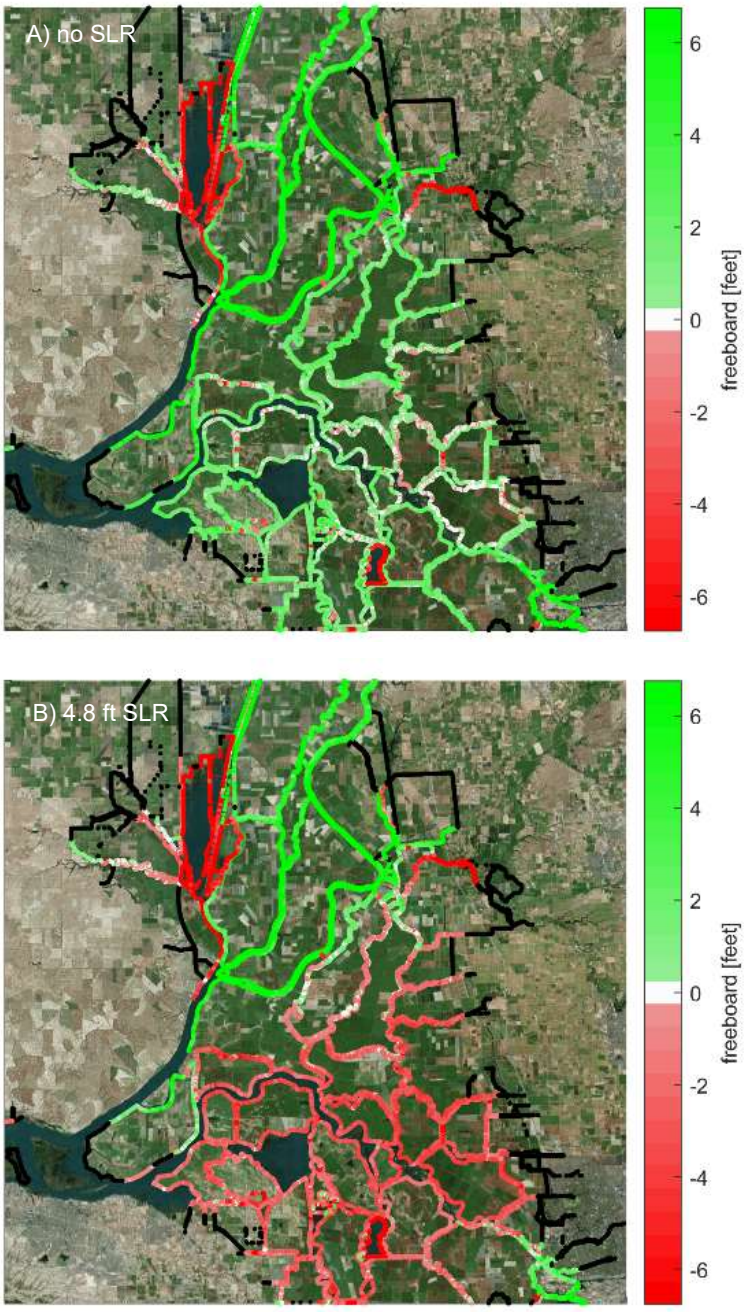
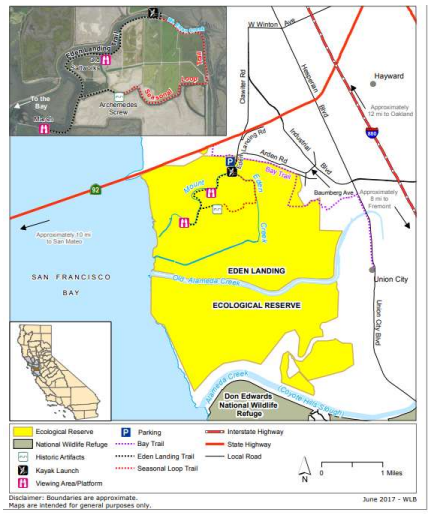


Figure 7. Analysis of levees in the San Francisco Delta under different sea level scenarios. This figure illustrates the projected extreme water levels (100-year) on Delta levees. The top panel (A) shows the relative freeboard with the current sea level, where green indicates a positive freeboard (levee exceeds the 100-year) and red indicates a negative freeboard (risk of levee overtopping). The bottom panel (B) depicts the scenario with a 4.8-foot sea level rise, highlighting the increased risk of overtopping and inundation due to sea level rise.

3 Assessing Hydrodynamic Model Performance in Eden Landing: Impact of Grid Resolution and Validation with Topo-Bathymetric Data

3.1 Introduction

Eden Landing Ecological Reserve, located near Hayward in the San Francisco Bay Area, is a vital hub for ecological restoration and wildlife conservation. Spanning approximately 6,400 acres, it forms a key component of the South Bay Salt Pond Restoration Project. Historically used for salt production, the reserve has undergone major transformations in recent years to restore tidal marshes, mudflats, and transitional habitats. These ecosystems provide essential feeding and resting grounds for migratory birds, support diverse aquatic communities, and enhance regional ecological resilience.



The main objective of this study is to evaluate how tidal dynamics influence restoration outcomes at Eden Landing and to provide quantitative insight that can inform ongoing and future design decisions. Specifically, we aim to (1) use high-resolution LiDAR and field observations of water levels to characterize hydrodynamic behavior within restored salt ponds and adjacent marshes, and (2) apply a Delft3D model to simulate tidal circulation, connectivity, and water exchange across the reserve.

Figure 8. Map of the Eden Landing Ecological Reserve Salt Marsh Area. This figure highlights the area of interest within the Eden Landing Ecological Reserve, focusing on the salt marsh region. The map, provided by the California Department of Fish and Wildlife, outlines the geographical extent and key features of the reserve, which plays a critical role in the South Bay Salt Pond Restoration Project and serves as an essential habitat for migratory birds and diverse aquatic life.

3.2 Model setup and validation

In this study, a series of model schematizations were developed using Delft3D FM, featuring variable resolutions of 2, 5, 10, and 20 meters to capture the complex hydrodynamics of the area. The model's bathymetry was constructed, combining high-resolution 1x1 meter topo-bathymetric data provided by the Alameda Flood Control District with bathymetric information from USGS sources for the broader San Francisco Bay region.

We conducted a comparison of observed water levels at five observation locations within Eden against the model's predictions (illustrated in Figure 9). The downstream boundary conditions for the model were derived from the regional Delft3D FM model of the San Francisco Bay and Delta, as discussed in the works of Nederhoff et al. (2021) and Deltares USA (2023). Notably, all model parameters were maintained at their default settings, and no calibration processes were undertaken.

The model results, particularly at observation point 5, revealed insights about the influence of resolution on the accurate reproduction of tidal propagation through the main channel (as demonstrated in Figure 10). It was observed that a resolution of 10 meters was generally adequate for the main channel; however, an optimal resolution of 5 meters (equating to approximately 5 points

per significant feature) would be ideal. It's important to note that the model exhibited limitations in accurately replicating low water levels, which is likely attributable to limitations in the topo-bathymetric data obtained through LiDAR. This aspect underscores the need for high-quality, precise topo-bathymetric data in developing robust and accurate hydrodynamic models, particularly for complex estuarine environments like the Eden Landing Ecological Reserve.



Figure 9. Topo-bathymetric map of the Eden Landing Study Area including the observation locations.

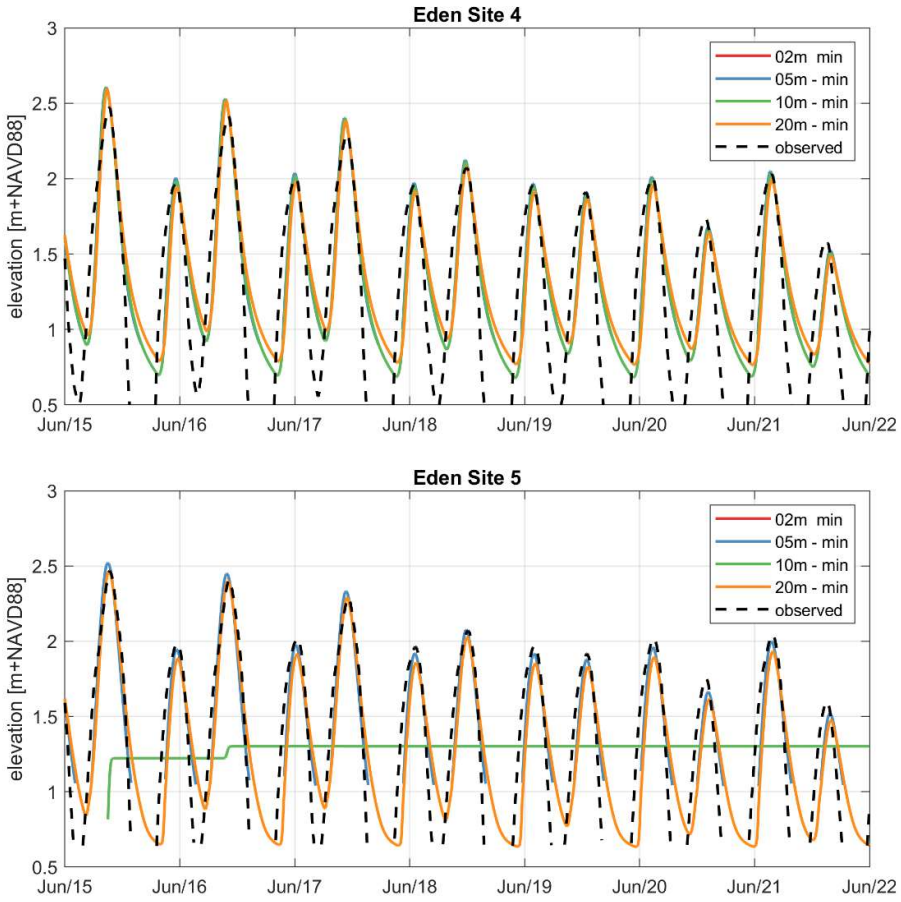


Figure 10. Comparison of observed (black line) and modeled water levels at Eden Landin (colors). These time series graphs compare the actual observed water levels at various observation points (upper panel site4 and bottom panel site 5) within Eden Landing against the predictions of the Delft3D FM model. The graph illustrates the model's performance in replicating tidal propagation and highlights the impact of spatial resolution (ranging from 2 to 20 meters) on the accuracy of the model.

4 Suitability Delft3D-FM for 1D applications

This section focuses on the suitability of Delft3D-FM for 1D applications. In particular, several tests were performed to compare with analytical expressions (Subsection 4.1 and 0), other models (Subsection 4.3), and observational data (Subsection 0). The goal was to gain confidence in the 1D capability of Delft3D FM.

4.1 Analysis of Gradually-Varied Flow Profiles: M1 and M2 Curves in Delft3D Simulations

Gradually-varied flow (GVF) is characterized by steady, non-uniform movement in channels where water surface elevation changes gradually. Common instances of GVF include the backwater effect caused by obstacles like dams or weirs in rivers, and the drawdown occurring at sudden channel drops. Key to understanding these phenomena are two primary backwater curves, often referred to as the Belanger Curves, specifically the M1 and M2 profiles. In our study, both these backwater profiles were successfully simulated using the Delft3D software in 1D (Figure 11). The accurate reproduction of these distinct flow profiles within Delft3D validates the model's capability to simulate the fundamental physics of gradually varied flow.

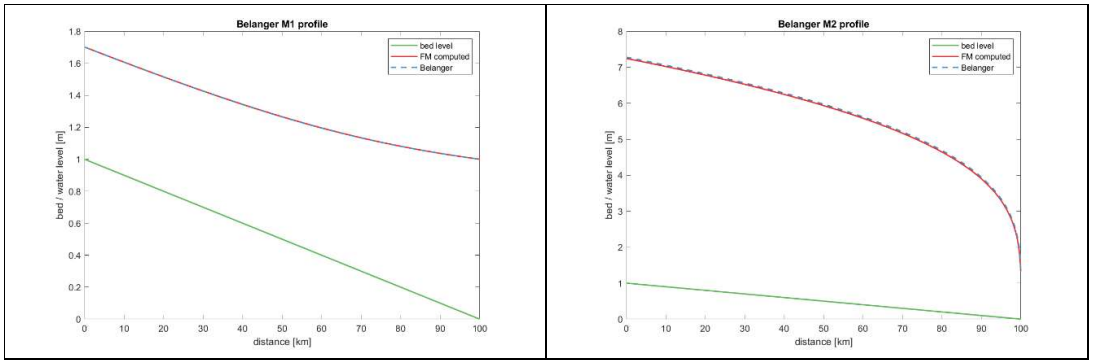


Figure 11. Belanger Profiles as simulated by Delft3D FM 1D. This figure depicts the successfully simulated M1 and M2 backwater curves (Belanger Profiles) using the Delft3D software in a 1D mode.

4.2 Evaluating the Precision of Delft3D in Hydrodynamic Simulations: Testing Bed Friction in Channel Models

This subsection presents an evaluation of Delft3D capabilities, focusing on testing function in 1D pipes and assessing the bed friction term in both 1D and 2D channel models. We employed various 1D profiles and channels of similar dimensions to analyze these aspects. The model setup was standardized with uniform pressure gradients, achieved by setting water levels at both ends of the channels to match the bed slope of 10^-3. A constant Chezy coefficient of 60.0 was applied throughout for simplicity. In our test setup, the water level at the left boundary was 2.5 meters and 1.5 meters at the right, with the boundaries spaced 1000 meters apart. In terms of channel configurations, we tested six scenarios in Figure 12.

For the 2D channel (2D_10_conv), the depth-averaged velocity was closely matched to theoretical calculations of $U = C\sqrt{Ri} = 3\ (m/s)$, $C = 60\ (\sqrt{m}/s) R = 2.5\ (m)$, $i = 0.001$ (-). The same precision was observed in the 1D channel (1D_10_conv) with identical width and rectangular conveyance. Both channels employed the conveyance approach, assuming a vertical logarithmic flow profile with a hydraulic radius equal to the local water depth, applicable for wide channels.

The 'lumped' bed friction approach, where the hydraulic radius is assumed constant across the entire profile, was applied to the other channels and was tested across different channel configurations, both open and closed, with varying widths and profiles. The observed velocities in these channels closely aligned with theoretical predictions, demonstrating the model's accuracy.

- Specifically, in the third channel (1D_10_lump), using the lumped approach, the hydraulic radius was calculated as R=A/P, with P=W+2H totaling 15 meters, resulting in R being approximately 1.666 meters. The computed profile averaged velocity of ~2.50 m/s matched the theoretical value.
- The fourth channel (1D_2_lump) featured an open, rectangular profile with a width of 2 meters. Here, the hydraulic radius was 0.57 meters, and the computed velocity of ~1.60 m/s was in line with the expected value.
- For the fifth channel (1D_2_2_lump), with a rectangular profile and specified height of 2 meters, a hydraulic radius of 0.5 meters was used. The resulting velocity, ~1.34 m/s, matched the theoretical prediction.
- In the sixth channel, a closed pipe (1D_2_pipe1) with a diameter of 2 meters, the hydraulic radius was 0.5 meters. The computed velocity, ~1.34 m/s, again demonstrated the model's high level of precision.

These results showcase the correct implementation of Delft3D when either using the conveyance or the lumped bed friction approach in various channel scenarios, underlining the model's capability to accurately simulate complex hydraulic conditions.

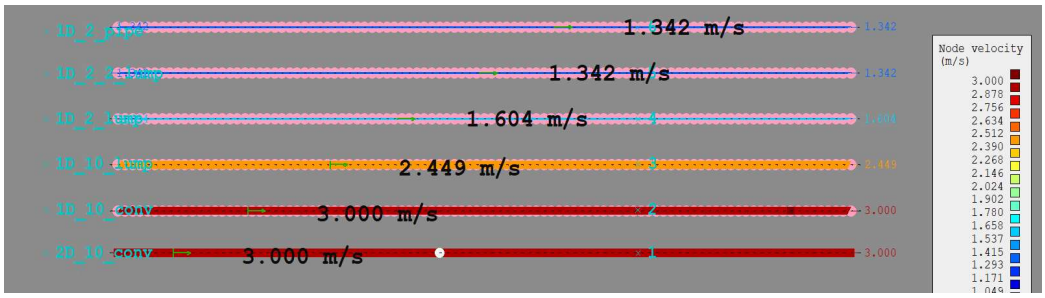


Figure 12. Channel configurations and flow profiles as simulated by Delft3D FM. This figure illustrates the outcomes of various channel scenarios tested in Delft3D FM, focusing on the application of both conveyance and lumped bed friction approaches. It includes simulations of 1D pipes and 2D channel models under different configurations and bed friction terms, demonstrating the model's precision in replicating theoretical velocity profiles in hydrodynamic simulations.

4.3 Comparative Analysis of San Lorenzo Creek Modeling: HEC-RAS and Delft3D FM Performance Across Varied Flow Conditions

The San Lorenzo Creek, flowing through Hayward, California into the San Francisco Bay, has been modeled by the Alameda Flood Control District using the HEC-RAS software for numerous years. In a comparative study, the existing HEC-RAS model of the creek was translated into a Delft3D FM model. This conversion allowed for the re-evaluation of the creek's behavior under various flow conditions, ranging from low to high discharge rates, with the Delft3D FM model relying entirely on the data and parameters from the original HEC-RAS model. The model had a numerical resolution of 1 meter.

Figure 13 illustrates the comparison of the backwater curves calculated by both HEC-RAS and Delft3D-FM. For lower discharges, such as 500 and 1000 cubic feet per second (cfs), the two models yielded similar results, typically displaying the M1 backwater profile with minimal discrepancies. However, as the discharge rates increased to higher levels, e.g. for 10,000 and 17,000 cfs, the differences between the models became more evident. Notably, the backwater curve closer to the San Francisco Bay exhibited a rounder shape in the Delft3D-FM model compared to the sharper curve in the HEC-RAS model. Furthermore, while both models identified a hydraulic jump at a distance of 7000 feet from the Bay, the jump around 3000 feet from the Bay was more pronounced in the HEC-RAS model. This comparison highlights that the model typically produces similar results but differences can be found.

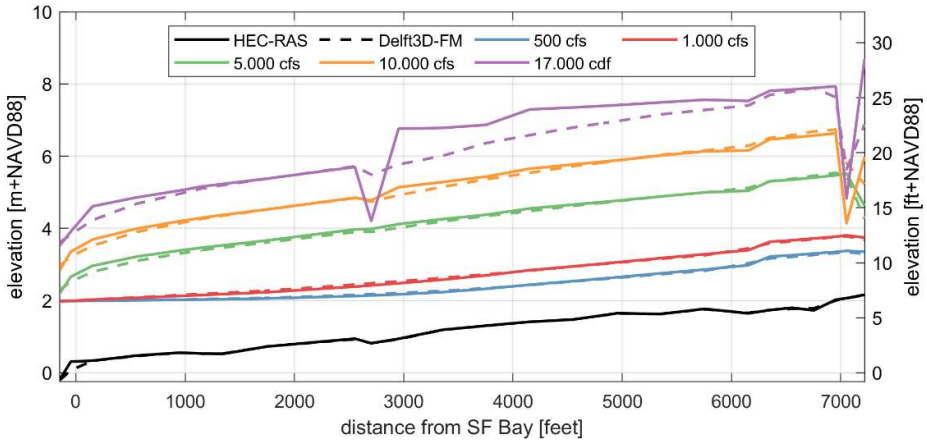


Figure 13. Comparative analysis of backwater curves for San Lorenzo Creek by HEC-RAS and Delft3D FM. The figure shows the computed backwater curves for San Lorenzo Creek as modeled by both HEC-RAS (solid line) and Delft3D FM (dashed line) under various discharge rates (represented by different colors).

4.4 Validating 1D Creek Components in the SFBD-SWL Community Model: A Case Study of Alameda Creek

The SFBD-SWL community model encompasses 1D creek representations within the tributaries of the San Francisco Bay and Delta. Previous studies by Nederhoff et al. (2021) and Deltares USA (2023) primarily focused on the large-scale hydrodynamics of the Bay, thus not delving into the validation of these 1D creek components. This section aims to fill that gap by presenting a validation of the 1D model within Alameda Creek (illustrated in Figure 14). The model simulations were forced by station-averaged daily observed discharge data from USGS gauges #1180500 and #1117900. We then compared the Delft3D FM model simulated gauge height again at both USGS stations.

Figure 15 displays the time series of water level elevations at these observation points. The model successfully captures the peak water levels at both stations, although a slight bias is evident in the simulations. Notably, at station #1118070, the model predicted several peaks that were not observed in reality. This discrepancy is likely due to the boundary conditions used in the model. The Delft3D model utilizes daily-observed discharge data upstream as its primary input and does not account for pluvial effects or urban drainage systems, which could explain the mismatches in water level peaks.

This validation exercise underscores the model's ability to accurately simulate key hydrodynamic features in 1D creek components, despite some limitations in capturing all aspects of the creek's behavior due to the nature of the input data and the scope of the model's design.

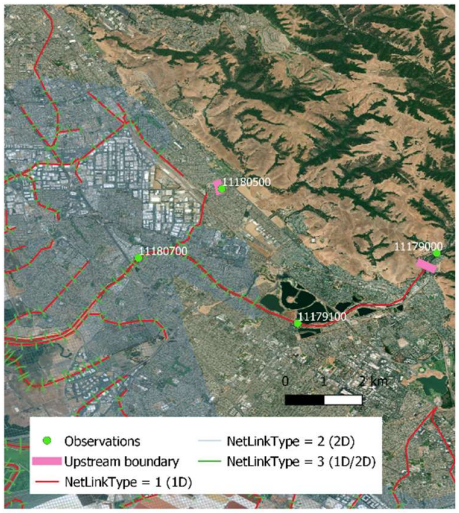


Figure 14. Area of interest in Alameda Creek for the validation of the community model for 1D creeks in the tributaries of the Bay.

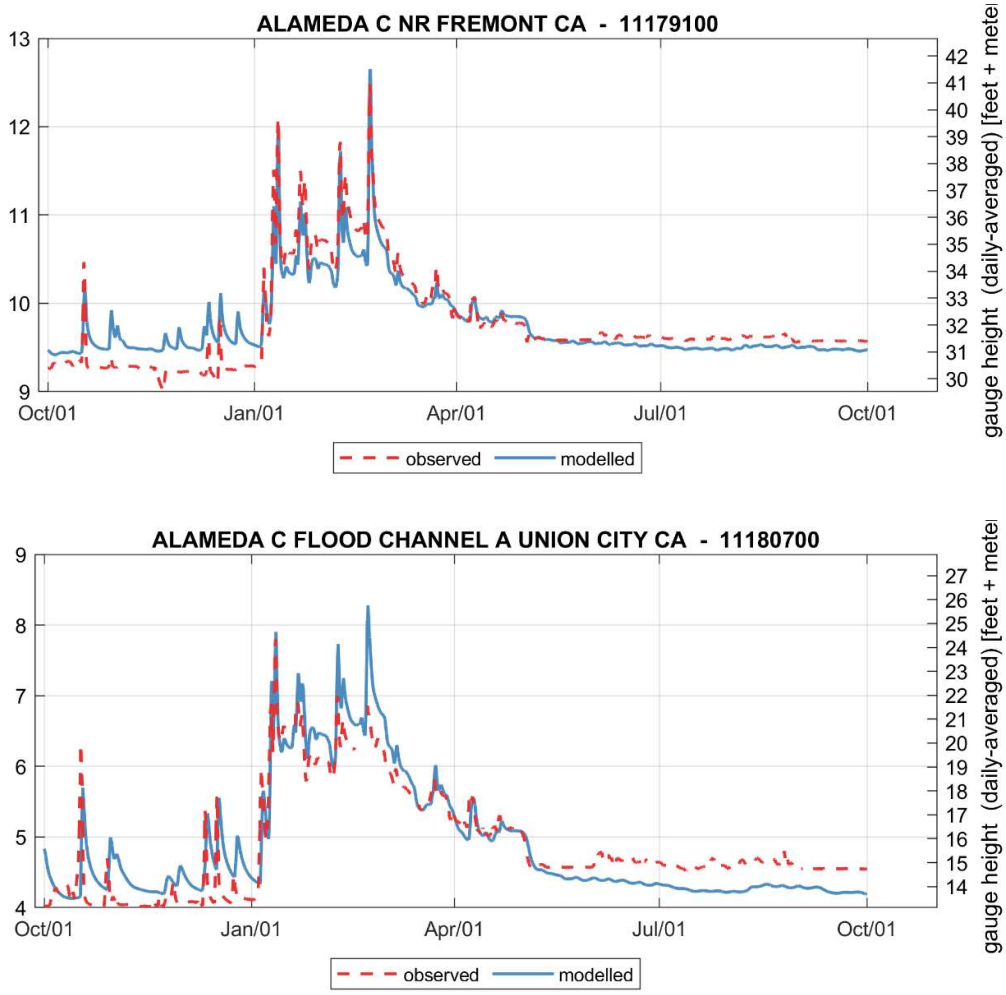


Figure 15. Water Level Elevations at USGS Station #1179100 (upper panel) and #1180700 (bottom panel): Observed vs. Modeled. This time series graph compares the observed water level elevations (dashed red line) with those predicted by the Delft3D FM model (blue line) at the USGS station

5 References

Deltares USA. (2023) Coastal and Riverine Flood Assessment for Alameda County Flood Control District. Report: Delft3D FM and SWAN Model Development and Application for Derivation of Extremes across the San Francisco Bay.

DHI. (2013). Regional Coastal Hazard Modeling Study for South San Francisco Bay.

Hersbach, H., Bell, B., Berrisford, P., Hirahara, S., Horányi, A., Muñoz-Sabater, J., Nicolas, J., Peubey, C., Radu, R., Schepers, D., Simmons, A., Soci, C., Abdalla, S., Abellan, X., Balsamo, G., Bechtold, P., Biavati, G., Bidlot, J., Bonavita, M., … Thépaut, J. N. (2020). The ERA5 global reanalysis. Quarterly Journal of the Royal Meteorological Society, March, 1–51. https://doi.org/10.1002/qj.3803

Nederhoff, K., Saleh, R., Tehranirad, B., Herdman, L., Erikson, L., Barnard, P. L., & van der Wegen, M. (2021). Drivers of extreme water levels in a large, urban, high-energy coastal estuary – A case study of the San Francisco Bay. Coastal Engineering, 170, 103984. https://doi.org/10.1016/j.coastaleng.2021.103984

Vatvani, D., Zweers, N. C., Ormondt, M. Van, Smale, A. J., Vries, H. De, Makin, V. K., & Bilt, D. (2012). Storm surge and wave simulations in the Gulf of Mexico using a consistent drag relation for atmospheric and storm surge models. 2399–2410. https://doi.org/10.5194/nhess-12-2399-2012