MAY 2025

DLIS Risk Reduction Analysis

Reporting Year 2023-2024

Assessing the Impact of Delta Levee Improvements on Flood Risk, Public Safety, and State Interests

This report explains how recent levee improvements reduce flood risks and protect lives, property, and critical resources in the Delta

Delta Stewardship Council

A CALIFORNIA STATE AGENCY

Table of Contents

Introduction

The purpose of this report is to assess and quantify the change in the likelihood of levee failure, loss of life, property, and other state interests resulting from Sacramento-San Joaquin Delta (Delta) levee improvements carried out during the reporting year of 2023-2024.

Summary of Findings

While several Delta levee improvement projects were authorized in reporting year 2023–24, only one project — the Bethel Island levee upgrades — was completed and available for analysis during this reporting period.

The project focused on improving approximately two and a half miles of levee to meet the higher Bulletin 192-82 standard, strengthening flood protection and enhancing habitat along critical sections of the island. With a $9.6 million investment, the improvements addressed levee stability, seepage management, and habitat enhancement, reflecting important steps toward meeting both flood

risk reduction and environmental goals under the Delta Levees Special Flood Control Projects program.

The key metrics from this analysis are summarized below. For a detailed breakdown of the results, including actual values and percent changes, please refer to the Metrics Summary Table provided in the Project Analysis section of this report:

- Expected annual damage decreased by $24,527 (0.4%)
- Expected annual fatalities declined slightly by 0.001 (0.4%)
- Probability of levee failure dropped by 0.2%

Background

Levees in the Delta play a crucial role in reducing flood risks to people, property, natural resources, and infrastructure systems of statewide importance to all Californians. A levee failure, such as a breach, could lead to devastating floods, potentially causing injury or loss of life, significant damage to property and infrastructure, disruption of water supply, and harm to environmental resources.

The Sacramento-San Joaquin Delta Reform Act of 2009 (Wat. Code, § 85000 et seq.; Delta Reform Act) tasked the Delta Stewardship Council (Council), in consultation with the Central Valley Flood Protection Board, to recommend priorities for discretionary State investments in Delta levees to reduce flood risks while supporting the coequal goals of water supply reliability and Delta ecosystem restoration. (Wat. Code, § 85306.) In collaboration with various agencies and the public, the Council has formulated the Delta Levees Investment Strategy (Cal. Code Regs., tit. 23, § 5012; DLIS) to prioritize State investments in the Delta's levee system.

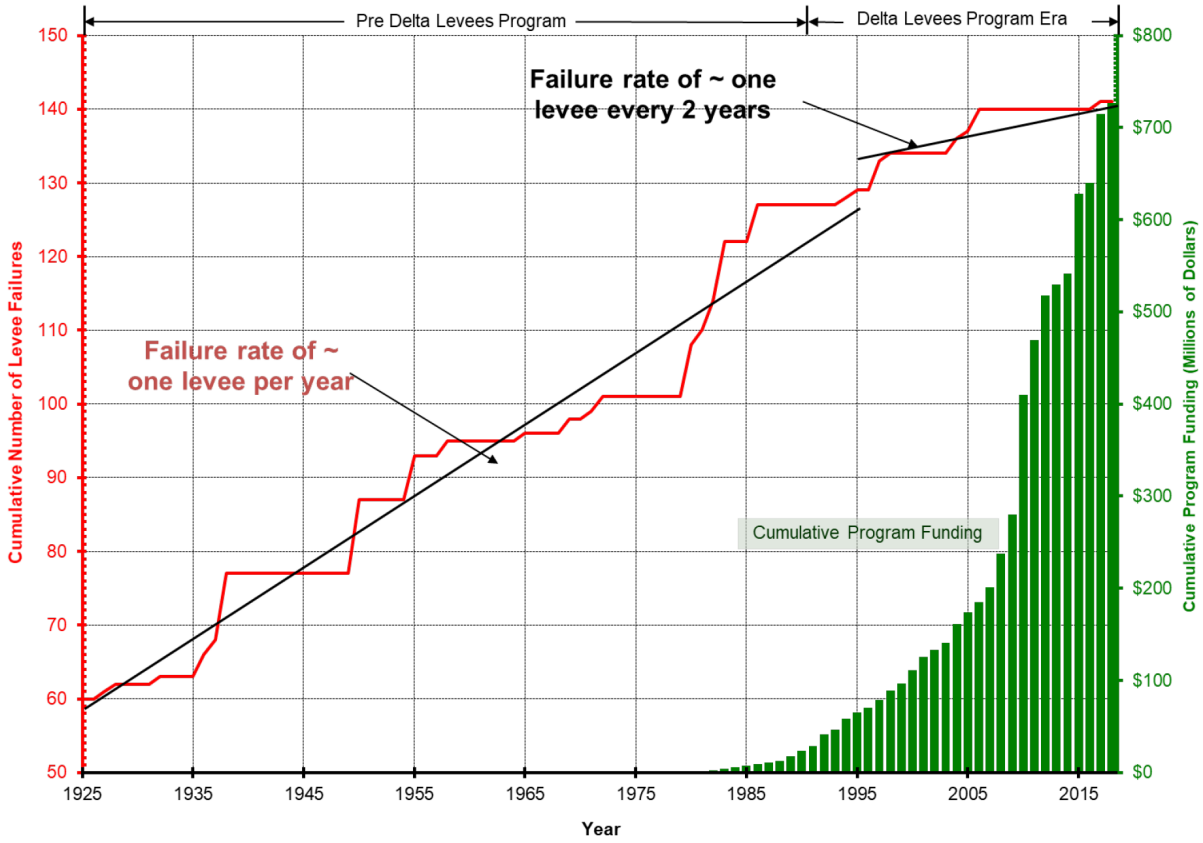
The Role of Funding in Reducing Flood Risk

The Delta is the heart of the State’s water supply network, and home to legacy communities, prime farmland, transportation corridors and a critical ecosystem. It is safeguarded by an extensive network of over 1,100 miles of levees that preserve its unique agricultural landscape and cultural heritage. These levees face constant challenges from the forces of river flows, tides, and wind waves, distinguishing

them from typical river levees that are primarily stressed during flood events. Built predominantly over 150 years ago using materials available at the time, many of these levees rest on a foundation of low strength and stability, including organic peat soil and alluvial sands. This type of construction, coupled with threats, such as subsidence, climate change, and sea level rise, places the levees at risk. Climate change is expected to compound these challenges with more precipitation falling as rain rather than snow, increasing flood risks, and altering reservoir management needs. Additionally, sea level rise places added pressure on the levee systems, underscoring the importance of continuous funding for levee strengthening and maintenance.

Despite legislative efforts to address these concerns, funding for the maintenance and improvement of the Delta's levee system remains a significant challenge for both local agencies and the state. Historical data demonstrates a direct relationship between the level of funding allocated to levee maintenance and improvements, and the frequency of levee failures in the Delta. Prior to the Delta Levees Maintenance Subventions Program, the area experienced an average of one levee failure per year. However, with increased investment through the program, the rate of failures has been cut by half, highlighting the effectiveness of sustained financial support in reducing incidents and enhancing levee resilience. This trend underscores the critical need for ongoing and increased funding to ensure the long-term sustainability and safety of Delta levee infrastructure.

The chart below provided by the Department of Water Resources (DWR) demonstrates how funding for the Delta Levees Maintenance Subventions Program correlates with a marked decrease in levee failures, illustrating fewer failures following program initiation and cumulative financial investment. This underscores the critical link between funding and levee integrity, suggesting that consistent and sufficient financial support is pivotal for bolstering levee resilience, enhancing performance, and safeguarding the Delta against the risks of infrastructure failure.



Delta Levees Investment Strategy

DLIS established a transparent strategy for prioritizing State-funded levee investments in the Delta. In alignment with Water Code section 85305, subdivision (a), the project aided the Council by developing an analytical framework to assess flood risks to State interests for each Delta island or tract. Risk is defined as the probability of a flood event multiplied by the consequences of that event. State interests were defined by the Council to be:

- Human life
- Property
- Water Supply Reliability
- The Delta's Ecosystem
- Delta as Place – represented by Legacy Towns, State Highways and Prime Agricultural Land.

If an island or tract has a high probability of flooding, but minimal State interests then the Risk posed from flooding is low. Conversely if the levee system is

protecting a population center, the risk could be high, even if expected flooding is infrequent.

DLIS-Decision Support Tool

DLIS introduced a Decision Support Tool (DST) to help the Council and stakeholders explore flood risk outcomes across different timeframes and scenarios, ultimately guiding the development of a prioritized list of islands for levee investments to mitigate flood risks. The DST employs a comprehensive approach to evaluate the potential consequences of levee failure and flooding. By leveraging detailed data analysis and interactive visualizations, the DST supports the Council in formulating effective strategies for levee investments aimed at reducing these risks.

The DST facilitates strategic planning through a four-step process.

1) It assimilates and displays information regarding assets at risk throughout the Delta, laying the groundwork for a thorough risk assessment.
2) Following this, the tool estimates the probability of flooding and assesses the associated risks to various Delta assets, including lives, property, water supply, and habitat. This probabilistic analysis is crucial for understanding the magnitude and scope of potential impacts.

DLIS Regulation

DLIS categorizes Delta islands and tracts based on risk-based priorities (very-high, high, or other) to guide the allocation of discretionary funds for levee improvements by DWR. DLIS regulation (Cal. Code Regs., tit. 23, § 5012.) directs State funding to levee improvement projects where they can most effectively protect state interests. Additionally, DLIS requires DWR to annually report its funding decisions, detailing the rationale behind them, especially when funding decisions vary from established priorities. This reporting ensures transparency and accountability, focusing investments on safeguarding critical state interests even when short-term priorities shift.

3) The third step involves providing interactive visualizations, which play a pivotal role in supporting the Council's deliberations on prioritizing high-risk islands based on the weighted risks.
4) Lastly, the DST assimilates results from analyses of different levee investment scenarios, demonstrating how these investments could mitigate the identified risks, while facilitating understanding and tradeoffs for the given scenarios.

The DST uses risk models that draw upon extensive databases to predict the likelihood of flooding resulting from levee breaches, whether caused by water overtopping or seismic events. By calculating flood probability as a function of levee fragility—which is influenced by factors like river stage heights and ground acceleration—the DST offers a robust framework for understanding and managing flood risk.

The DST uses various metrics to assess risks to people, assets, water supply reliability, the Delta ecosystem, and the Delta as a place. These metrics consider both the probability and consequences of flooding, utilizing hazard recurrence curves and fragility curves to inform the analysis.

Expected Annual Fatalities (EAF):

EAF provides insight into the average annual number of flood-related fatalities expected in the Delta region across different flood scenarios. It considers the differential impact of flood levels on fatalities, calculating EAF for each island by multiplying the annual probability of flooding by estimated fatalities at potential flood levels. Overall, EAF offers a comprehensive assessment of flood-related mortality risks in the region.

Expected Annual Damages (EAD)

EAD evaluates the average annual monetary value of damages expected due to flooding in the Delta region's infrastructure and assets. It focuses on direct losses to residential and commercial properties, transportation systems, agricultural facilities, and more. Despite its usefulness, EAD may not capture all indirect consequences, but it serves as a foundational metric for understanding flood impacts.

Risk to the Delta Ecosystem:

Risk to the Delta ecosystem is evaluated by assessing the expected flooding of leveed habitats, including natural communities, conservation areas, and seasonal floodplains. This metric calculates the expected flooding of high-value non-tidal habitat for each island, considering the annual probability of flooding multiplied by the area of existing and potential high-value habitat.

Delta as a Place:

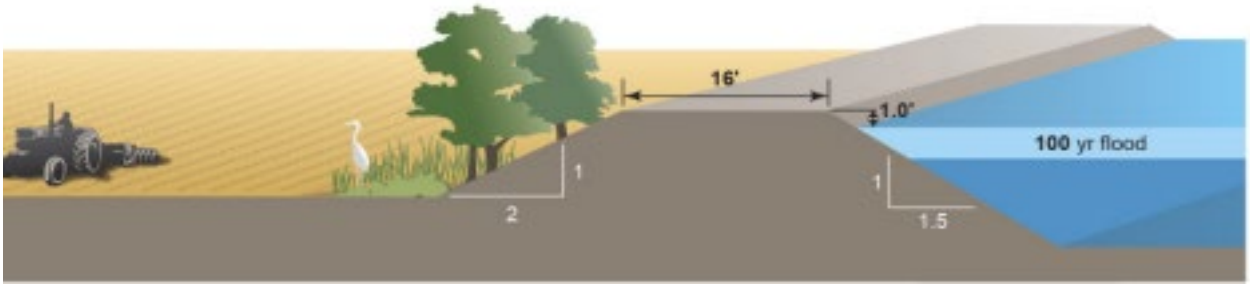
Metrics for the Delta as a place identify legacy towns, prime farmland, and roadways that could be damaged or disrupted by floods. Roadways include only those of interest to the State, such as county, state, and federal highways that cross the legal Delta, along with scenic Highway 160, which is also a state highway. These metrics represent the historical, cultural, and agricultural values in the Delta, providing insights into the potential impact of flooding on these important areas.

Levee Standards

Over time, various standards have been established for rural or agricultural Delta levees, detailing levee geometry and maintenance requirements. These standards include federal regulations, such as title 33 of the Code of Federal Regulations, part 208, section 208.10, and the US Army Corps of Engineers' Rehabilitation and Inspection Program under Public Law 84-99 (Delta-Specific, Pub. L. No. 84-99). Notable among these standards are:

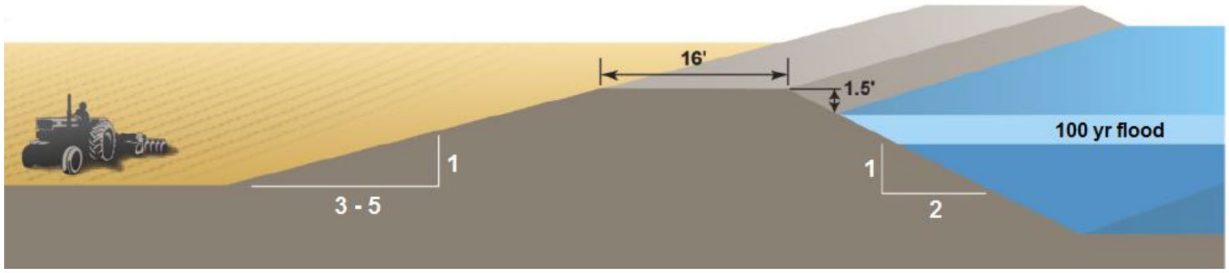
Hazard Mitigation Plan (HMP)

Widely utilized in the Delta since the 1986 flood, the HMP standard specifies a levee crest width of at least 16 feet, a waterside slope of 1.5 horizontal to 1.0 vertical (1.5H:1V), landside slope of 2H:1V or less, and a minimum of 1 foot of freeboard above the 100-year flood stage.



Delta-Specific, Public Law Number 84-99 (PL 84-99)

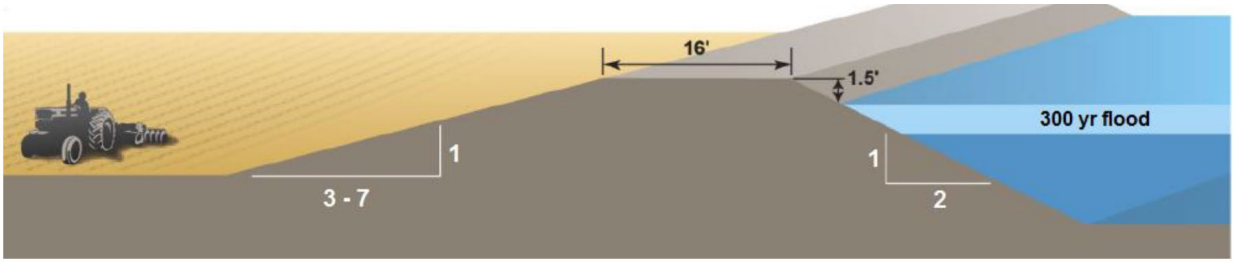
Most Delta levees target achieving the PL 84-99 standard, which offers enhanced flood protection compared to the HMP standard. PL 84-99 guidelines prescribe levee side slopes of 3H:1V to 5H:1V landside and 2H:1V waterside, along with increasing freeboard to 1.5 feet above the one-percent annual chance (100-year flood) water level. However, this is still below FEMA accreditation requirements. Notably, PL 84-99 includes a provision for flatter landside levee slopes compared to the DWR Bulletin 192-82 standard, particularly on organic soil foundations.



DWR Bulletin 192-82

Developed for major central Delta islands safeguarding significant State interests, Bulletin 192-82 levee guidance is suitable where tides play a crucial role in determining design flood elevations. This standard aligns with PL 84-99 guidelines in many aspects, except that the design water level corresponds to a 0.33-percent (1 in 300) annual chance of occurrence. Under Bulletin 192-82 standards, freeboard for levees is maintained above the 300-year flood frequency elevation, as provided

by the USACE.



In the Delta, there is a minimal difference between the 100-year and 300-year water surface elevations, typically about 6 inches in most cases. It should be noted that the design water surface elevations are derived from the US Army Corps of Engineers' 1992 Special Study.

Impacts of Levee Improvements

Within the scope of DWR's various funding programs, including the Delta Levees Special Flood Control Projects Program, efforts are underway to fortify the Delta's levee infrastructure. A total of 21 levee improvement projects have been approved and allocated funding for reporting year 2023-2024. As detailed in Table 2A of the DWR's annual report to the Council on February 2025, these initiatives are dedicated to enhancing the levee systems to bolster flood protection and support ecosystem restoration. Out of the 21 funded projects, only one is completed as of February 2025.

The reduction in levee fragility was quantified using the DST for the only project that was completed in reporting year 2023-2024. Metrics, such as EAD and EAF, were compared for conditions both before and after the project, isolating the effects of enhanced flood protection measures. All variables remained constant except for the levee fragility, ensuring that observed changes could be directly attributed to the completed project. It should be noted that, although the DST is capable of projecting future impacts, this particular analysis was conducted based on the conditions in 2020.

Below is a detailed summary of the levee improvement project completed in reporting year 2023-2024, highlighting DLIS priorities, associated costs, state interests, and projected outcomes including annual damage, fatalities, and levee

failure probabilities for each island or tract. Please note that DWR's report documented 21 additional projects currently in construction during the reporting period. Once the construction projects are complete, and reported to the Council, Council staff will update the DST with the levee improvements and analyze the expected reduction in risk. Levee construction projects may take several years to complete – the Council can expect to see the completed projects documented in future DLIS reports.

Project Analysis

Bethel Island (DLIS Priority: Very High)

Bethel Island has an 11.5-mile levee system managed by the Bethel Island Municipal Improvement District (BIMID). These levees are crucial for protecting the island's residents, agriculture, water quality, and natural habitats from flood risks. All the levees comply with FEMA's Hazard Mitigation Plan (HMP) design standards, offering a basic level of flood protection. However, over this reporting period a segment of approximately two and a half miles, as part of the Northwest Levee Improvement Project and Marina Levee Improvement Project (project), was upgraded to meet the Bulletin 192-82 standard.

The project enhanced the existing levees along approximately a two and a half-mile segment, spanning stations 0+00 to 130+00. This project involved raising the levees to meet Bulletin 192-82 standards while enhancing waterside and landside habitat. By achieving the higher standard, the levees are better equipped to anticipate challenges such as sea level rise, while still ensuring protection against floods exceeding a 100-year event. Completed in 2023 with a budget of $9.6 million, the project represents a crucial step in bolstering the resilience of Bethel Island's levee system.

Key improvements made through the project include:

- **Levee Modification:** The project involved fill placement to improve the levee to Bulletin 192-82 standards.
- **Seepage Management:** Improvement of existing levee toe drains to capture seepage and improve levee stability.

- **Habitat Creation:** Creation of Shade Riverine Aquatic habitat and Lowland habitats with native plant species to enhance the Delta ecosystem.

The Delta Levees Special Flood Control Projects Program was created to address flooding on the eight western Delta Islands and was later expanded in 1997 to the entire Delta. The program also requires net long-term habitat improvement (Wat. Code, §12311). The project improved approximately two and a half miles on the levees on Bethel Island to Bulletin 192-82 standards and improved approximately two miles of existing levee toe drains to improve levee stability. The project also provided habitat enhancement through the creation of 3,400 linear feet of Shaded Riverine Aquatic habitat and 4,600 linear feet of lowland habitats with native plant species.

Metrics Summary Table

Bethel Island DST Metrics	Pre-Project	Post-Project	Net Change ($ and %)
Expected Annual Damage ($/yr.)	$6,058,743	$6,034,216	-$24,527 (-0.4%)
Expected Annual Fatalities	0.233	0.232	0 (-0.4%)
Probability of Levee Failure	4.36%	4.35%	-0.20%
Expected Annual Flooded Leveed Habitat (acres/yr.)	15.1	15.0	-0.1 (-0.2%)
Expected Annual Damage, Delta as Place ($/yr.)	$168,125	$167,469	-$656 (-0.4%)

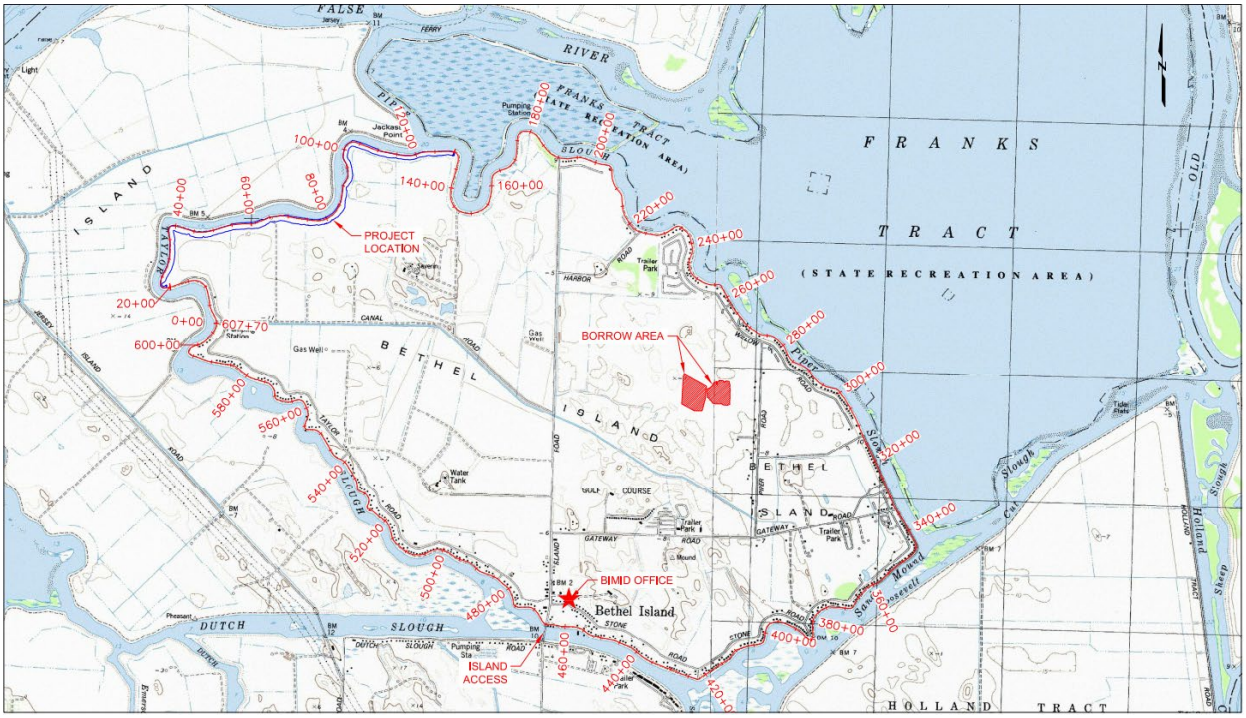
Interpreting the Results

While these numbers indicate incremental improvements, it's important to clarify that the overall risk profile for Bethel Island remains largely unchanged. The improvements did not "move the needle" in a meaningful way when measured across the entire island system. This is not unexpected, as upgrading just a portion of a larger levee network often delivers limited systemwide benefits — but it remains a critical part of the broader, long-term effort to improve flood resilience in the Delta.

It's also important to note that the current analysis methodology focuses primarily on changes in levee crest elevation as the main factor influencing risk reduction. As

a result, other valuable improvements — such as seepage management, stability berms, widening the levee base to accommodate future sea level rise, or providing a wide two-lane road for emergency response — are not fully captured in the quantitative metrics reported here. While these elements significantly enhance the overall performance and resilience of the levee system, their benefits are not reflected in the calculated risk reductions and should be considered when evaluating the full value of the improvement projects.

Figure showing Bethel Island levee stations



References

1. DWR's 2023-2024 Annual Report to the Delta Stewardship Council on Investments in the Delta Levees, March 2025.
2. Northwest Levee Improvements Project (BI-17-1.2-SP As-Builts PART 1)
3. Marina Levee Improvement Project (BI-17-1.2-SP As-Builts PART 2)
4. Amendment No. 1 PFA BI-17-1.1-SP, Department of Water Resources, June 2021

Appendix A
Estimated Risk Reduction

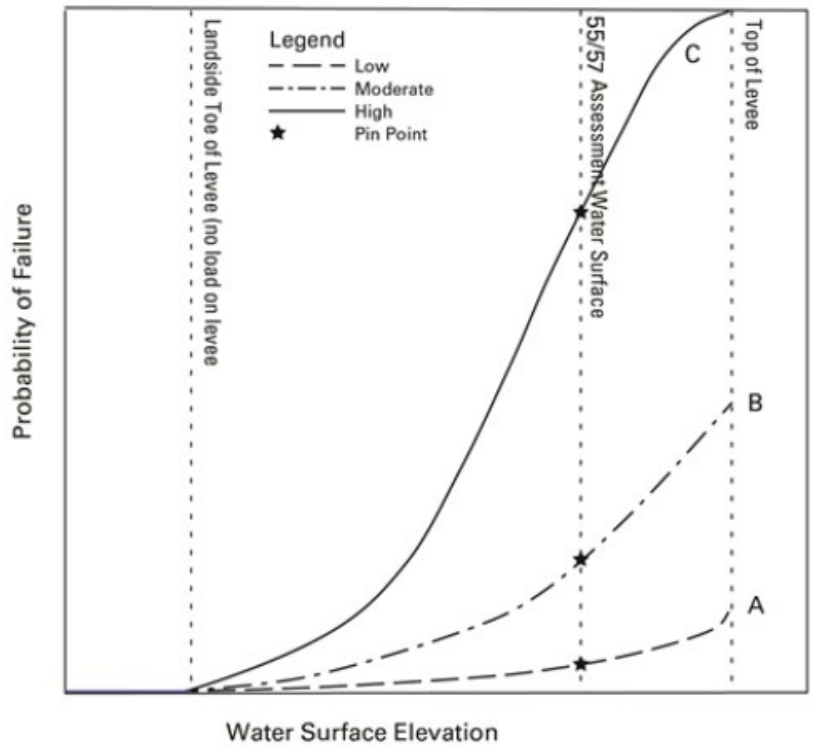
The following section provides an overview of updates to the DST levee fragility methodology, explaining how these changes shape the risk estimates presented in this report and where important limitations remain.

In response to comments received during DLIS rulemaking process, the Council refined the levee fragility methodology used by the DST. The revised methodology aimed for a consistent and accurate comparison of levee systems throughout the Delta. Central to this revision was the adoption of an alternative shape for the levee fragility curves, departing from the traditional S-shaped curve utilized in the 2016 DLIS assessment. This updated curve is notably flatter, a change based on extensive consultations with Delta levee district engineers. The rationale behind this modification was to accurately reflect the current conditions of Delta levees, informed by the lower-risk category from the 2012 Central Valley Flood Protection Plan (CVFPP) fragility curves.

Previously, the standard curve shape used in the 2016 DLIS closely resembled the high-risk category of the 2012 CVFPP's fragility curves (Curve C in Figure below), characterized by its S-shape. This shape has now been replaced with one that aligns with the low-risk category from the same plan (Curve A in the Figure below), marking a significant shift in how levee fragility is conceptualized. Notably, Curve A indicates a mere 0.5 percent probability of failure at the Adjusted Water Surface Elevation (AWSE), in stark contrast to the 85 percent failure probability associated with the high-risk Curve C. This adjustment suggests that, under the revised methodology, the risk of levee failure remains relatively low as water levels rise, with a significant risk materializing only in overtopping conditions.

This change in curve shape is supported by historical observations and recent improvements to Delta levees. Historically, Delta levees have withstood frequent high-water events such as floods, tides, and storm surges over the past century. However, it should be noted that substantial enhancements have been made to these structures in the last 30 years, including flatter back slopes, broader and

flatter crests, the addition of rock revetments, and stability berms in many areas. These upgrades have effectively diminished the occurrence of levee failures in recent decades, contrasting with the more frequent failures observed over the previous century. The adoption of the flatter fragility curve thus reflects both a more accurate representation of current levee resilience in the Delta and a methodological improvement in assessing levee fragility across the region.



The revised methodology for assessing levee fragility across the Delta, while innovative, brings to light several concerns regarding its assumptions and comprehensiveness. A critical downside of this approach lies in its implicit assumption that all levees are in optimal condition, neglecting to account for variations in levee integrity due to maintenance efforts or structural improvements. This oversight means that the tool does not differentiate between the resilience of newly upgraded levees and those that are older, treating both as equally vulnerable despite the evident superior performance of the newer structures. For instance, according to the current methodology, a newly constructed setback levee on Bethel Island would be perceived to offer the same level of flood protection as its predecessor, suggesting an unchanged levee fragility curve regardless of the enhancements made.

While this methodology is simple and consistent, it fails in capturing the nuances of levee improvements. For example, the practice of averaging levee crest elevations across an entire island fails to reflect localized enhancements accurately. If a section of a levee adjacent to a legacy town is raised, this improvement is diluted when averaged over the length of the island's levee, thereby minimizing the perceived impact of the upgrade. Similarly, the addition of stability berms or the implementation of measures to reduce seepage—such as the construction of cutoff walls—are overlooked by the tool, which operates under the assumption that all levees are uniformly robust.

It should be noted that the DST methodology does not account for modifications that enhance levee stability, but do not increase levee crest elevation such as the flattening of landside or waterside slopes through the addition of fill. These changes improve the levee's stability while providing a more solid base for future levee crest raises, which allows for adaptation for changing hydrology and rising sea levels. In the DST's current framework, only direct raises to the levee crest are recognized as significant improvements and used in the risk reduction calculations.