Performance Measure 4.12: Subsidence Reversal for Tidal Reconnection

Performance Measure (PM) Component Attributes

Type: Outcome Performance Measure

Delta Plan Description

Subsidence reversal activities at appropriate elevations to prevent net loss of opportunities to restore tidal wetlands in the Delta and Suisun Marsh.

Expectation

Preventing long-term net loss of land at intertidal elevations in the Delta and Suisun Marsh from impacts of sea level rise and subsidence.

Metric

Acres of land with subsidence reversal activity in the Delta and Suisun Marsh on islands with large areas of land capable of reaching intertidal elevations suitable for potential future restoration by 2100. Reported annually.

Baseline

Set as zero in 2008.

Target

By 2030, 3,500 acres in the Delta and 3,000 acres in Suisun Marsh with subsidence reversal activities on islands with large areas of land capable of reaching intertidal elevations (Map 1).

Basis for Selection

General Purpose:

California will experience sea-level rise over the next century. The Ocean Protection Council's sea-level rise guidance estimates that sea-level rise (SLR) in San Francisco could range from 1.6 to10.2 ft. by 2100 (OPC 2018). Anticipated sea-level rise will increase pressure on already stressed Delta ecosystems (DSC 2018). In addition to sea-level rise, the land in the Delta is subsiding due to microbial oxidation and most of the central Delta is already below sea-level (Deverel et al 2016). The result of this process is that much of the Delta is at subtidal elevations and as a result would offer limited ecological value if reconnected to the stream (Durand 2017). Only a thin band of land is at appropriate elevations suitable for tidal restoration through hydrologic reconnection (DSC 2019) and that band is getting smaller as the landscape subsides and sea-level rises. Hence, the potential for future tidal restoration is being lost.

Furthermore, many of the existing areas suitable for wetland restoration are already being targeted for restoration as a part of the eco-restore program. Finding areas suitable for tidal wetlands restoration will become increasingly difficult. Many of the most suitable areas are already having projects planned and other areas in the Delta are becoming incapable of supporting intertidal restoration due to sea-level rise and subsidence. One way to preserve the potential for future intertidal restoration on the landscape is subsidence reversal.

If the subsidence reversal activities are located at appropriate elevations, the accumulated land can counteract effects of sea level rise and subsidence, and increase or maintain its elevation. Preventing the loss of land will also preserve the opportunity for the land to be restored for tidal reconnection. This performance measure aims to prevent net loss of future opportunities to restore tidal wetlands at elevations suitable for such restoration. Subsidence reversal activities must be initiated by 2030 and be ongoing to continue to 2100 in order to prevent the land loss due to sea level rise and potential subsidence.

A 50^{th} percentile outcome elevation model accounting for 2.6 ft. of SLR (OPC 2018, see methods section below) **indicates that 3,500 acres of land at intertidal elevation in the legal Delta and** 3,000 acres in Suisun Marsh **can be lost in a ten year period. By initiating** subsidence reversal activities on 3,500 acres in the Delta and on 3,000 acres in the Suisun Marsh, the loss of land at intertidal elevation can be prevented and subsequently the opportunities for future tidal reconnection and restoration can be maintained. This can be done while supporting native species.

<u>Relationship to PM 5.2 Carbon Sequestration</u>

Ecosystem benefits are not the only reason to do subsidence reversal. Managed wetlands operated for subsidence reversal sequester carbon in the organic material they accrete. This decreases carbon emissions for organic soils by creating an anaerobic environment that prevents microbial oxidation. Delta Plan performance measure 5.2 (PM 5.2 – “Carbon Sequestration”) tracks acres of these projects across the entire Delta and Suisun Marsh with a target of 30,000 acres by 2030. This performance measure is different from PM 5.2 – “Carbon Sequestration” because instead of tracking acres of managed wetlands for subsidence reversal, it only tracks acres of subsidence reversal located in places at shallow subtidal elevation as such land has a reasonable chance of achieving intertidal elevations through subsidence reversal before 2100. Unfortunately, the carbon sequestration benefits in these areas are diminished so it is unlikely that carbon markets will incentivize projects in these areas. They likely will not occur without conscious efforts to place them for ecological benefits.

Implementing subsidence reversal activities would help counteract the effects of subsidence and sea-level rise and support habitat connectivity. Much of the subtidal

Delta areas is not at high enough elevation to reach intertidal elevations by 2100 with applied ongoing subsidence reversal activities (Map 1). Previous and current subsidence reversal projects have primarily targeted deeply subsided areas. This measure aims at those Delta islands with large enough areas (1,235 acres) at subtidal elevations. These areas (Map 1) have the potential to reach intertidal elevations by 2100 if subsidence reversal activities are ongoing.

Linkage to Delta Reform Act and the Coequal Goals

Delta Reform Act:

The loss of land elevation is a major stressor on the system that makes restoration of the Delta more difficult. The Delta Reform Act of 2009 (DRA) defines a number of strategies for restoring a healthy Delta ecosystem. Achieving the target in this performance measure would support the following strategies:

- **"Restore large areas of interconnected habitats within the Delta and its watershed by 2100." (WAT § 85302(e)(1)).** Due to sea-level rise and subsidence on land at current intertidal elevation, habitat reconnection potential is being lost. In the ten-year period (2020 to 2030) of modeled elevation change (see methods section below), 3,500 acres were lost in the legal Delta and 3,000 acres were lost in Suisun Marsh. Applying subsidence reversal activities on the same amount of land will prevent the net loss of opportunities to restore tidal wetlands due to the subsidence and sea-level rise.
- **"Restore Delta flows and channels to support a healthy estuary and other ecosystems." (WAT § 85302(e)(4)).** The Delta geometry has been radically simplified from the complex channel systems that were common in the pre-reclamation Delta (SFEI-ASC 2016). With large-scale wetland restoration, the formation of complex dendritic channels is possible. This measure tracks projects that could create new spaces for restoring those geomorphic formations. Those new spaces would offset the loss of elevation occurring elsewhere.
- **"Restore habitat necessary to avoid a net loss of migratory bird habitat and, where feasible, increase migratory bird habitat to promote viable populations of migratory birds." (WAT § 85302(e)(6))**. Both managed wetlands for subsidence reversal and reconnected wetlands from potential future reconnection provide habitat for migratory bird species (Shuford and Dybala 2017, Shuford et al 2019).

In addition to defining strategies for restoring a healthy Delta, the DRA also mandates that the Delta Plan include measures promoting specified characteristics of a healthy Delta (WAT § 85302(c)). Achieving the target in this performance measure would promote the following characteristics of a healthy Delta identified in the DRA:

- **"Viable populations of native resident and migratory species." (WAT § 85302(c)(1)).** Prior to reclamation, native and migratory species thrived in a dynamically inundated tidal marsh system (SFEI-ASC 2016). In the last 150 years more than 95% of wetlands in the Delta have been lost; those wetlands are habitat for many native species (SFEI-ASC 2016). Without opportunities on the landscape to restore lost tidal wetlands, it will be difficult to support viable populations of native resident and migratory species. PM 4.16 – “Acres of Natural Communities Restored” identifies tens of thousands of acres of natural wetlands as a target for restoration. Achieving that goal will require significant space on the landscape. Meeting the target of this measure would help ensure that the Delta landscape maintains opportunities for natural wetland restoration as opposed to losing more opportunity to sea-level rise and subsidence.

- **“Diverse and biologically appropriate habitats and ecosystem processes.” (WAT § 85302(c)(3)).** The pre-reclamation Delta was characterized by a diverse series of seasonally inundated tidal wetlands that provided heterogeneity through diverse fluvial and geomorphic patterns (SFEI-ASC 2016). Restoring these processes will require space on the landscape that is not deeply subtidal. The intertidal space is being lost to subsidence and sea-level rise.
- **“Reduced threats and stresses on the Delta ecosystem.” (WAT § 85302(c)(3)).** Land loss is a stress on the ecosystem. Deeply subsided island offer less potential habitat value than those of intertidal elevations (Durand 2017).
- **“Conditions conducive to meeting or exceeding the goals in existing species recovery plans and, state and federal goals with respect to doubling salmon populations.” (WAT § 85302(c)(5)).** A review of recovery plans indicates that the Delta and Suisun Marsh will require tens of thousands of acres of tidally connected wetlands (see the datasheet for PM 4.16 – “Acres of Natural Communities Restored”). Loss of land at appropriate elevations prohibits restoration and connectivity of habitats.

<u>Delta Plan Core Strategy:</u>

Protect land for restoration and safeguard against land loss

Methods

Baseline Methods

The baseline from the digital elevation model (DEM) of the Delta and Suisun Marsh is set at 2008 because most of the DEM data was gathered in between 2007-2008.

Target and Analysis Methods

<u>Acres of intertidal land lost by 2030:</u>

The target of 3,500 acres in the Delta and 3,000 acres in Suisun Marsh was calculated using a formula (described in appendix 1) for ten years of elevation change occurring as a result of subsidence and sea-level rise. 3,500 acres in the Delta and 3,000 acres in Suisun Marsh are the amount of acres that are currently at intertidal elevation that will no longer be at intertidal after a decade due to subsidence and SLR in the Delta. These acres are lost opportunity for future tidal wetland restoration that cannot be recovered without active management.

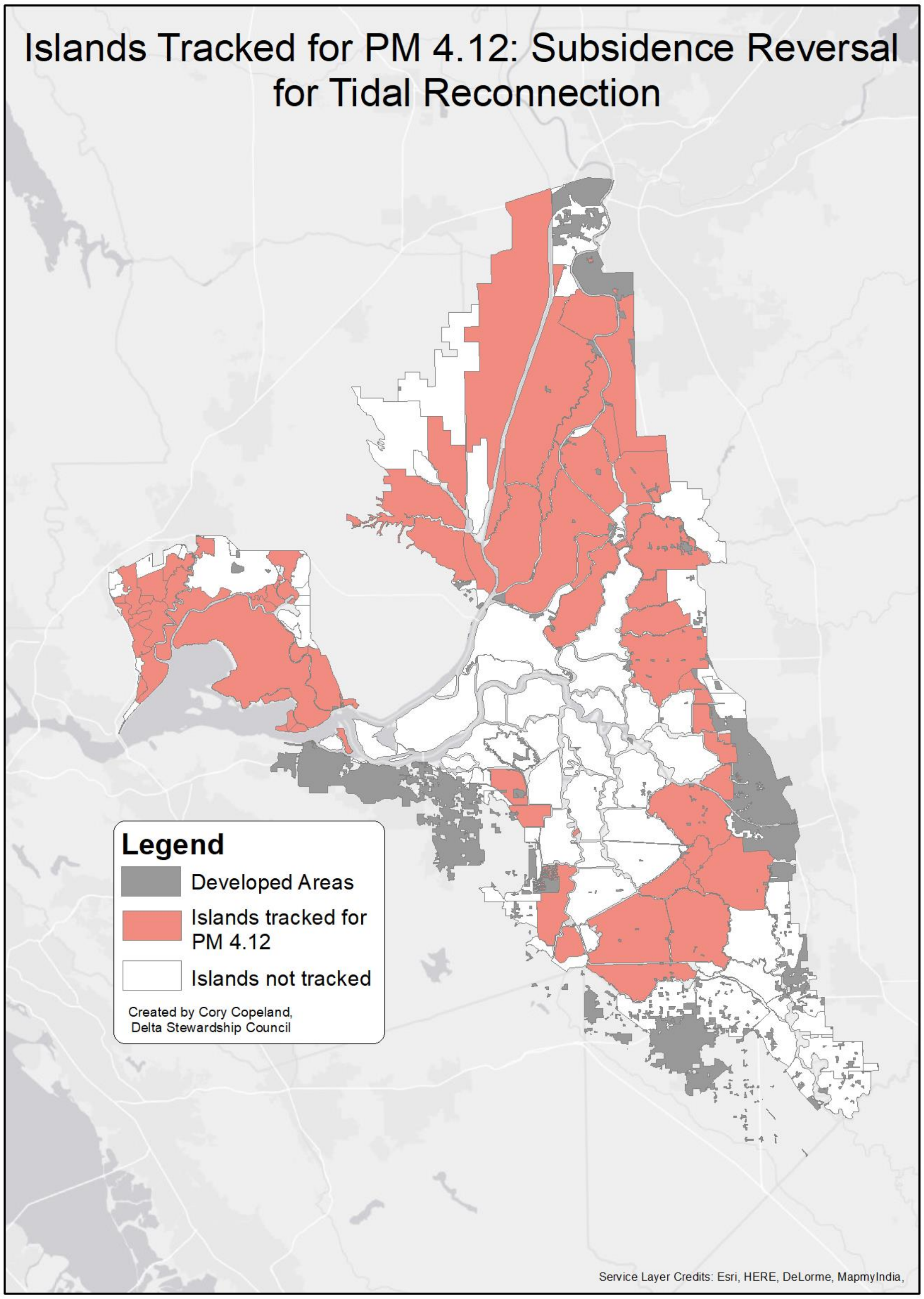
If 3,500 acres of subsidence reversal are placed in the Delta and 3,000 acres in Suisun Marsh by 2030, then ten years of lost potential will be addressed within 10 years.

A target date of 2030 reduces uncertainty and allow for adaptive management of subsidence reversal targets through routine Council processes. Subsidence reversal technology in the Delta is nascent. Setting a decadal target is prudent with few projects on the landscape exploring subsidence reversal techniques in the Delta and none in Suisun Marsh. Ten years is long enough for more projects to be developed and implemented and for the Council and implementing agencies to review lessons from the projects as a part of adaptive management processes. Additionally, a target of 2030 makes this measure consistent with the existing Delta Plan target for PM 5.2's carbon sequestration projects.

Identifying islands with large areas of land capable of reaching intertidal elevations suitable for potential future restoration by 2100

The Delta and Suisun Marsh islands were analyzed to determine which islands contain significant opportunities for the subsidence reversal activities to reach to intertidal elevations. Subsidence reversal in other areas provide important benefits to the system (and will continue to be tracked as a part of Delta Plan PM 5.2). Deeply subsided areas are unlikely to reach intertidal within the 2100 planning horizon for the Delta Plan given by the Delta Reform Act of 2009 (see: WAT § 85302(e)(1) for 2100 restoration planning horizon). For each island in the Delta and Suisun Marsh, we estimated the amount of elevation that could potentially be gained through subsidence reversal. We then looked island by island to count the number of acres that could reach intertidal elevations that may be suitable for future tidal restoration.

We included any island with at least 50% of its area in that could reach intertidal elevations that may be suitable for future tidal restoration or 1,235 acres of potential intertidal area after subsidence reversal. This 50% threshold was used because islands that have a large portion of area suitable for this purpose would need the least amount of new infrastructure for a project. Islands with only a small portion of land capable of reaching intertidal elevations may need to build new infrastructure to target those areas (e.g. levees or drainage for areas not a part of the project). The 1,235 acre threshold was selected because it is the minimum area needed for complex intertidal channel systems to develop in a wetland complex (SFEI-ASC 2016) and would therefore allow for large scale intertidal wetland restoration. This 1,235 acre threshold is also used in the Delta Plan Appendix 2 to determine if a tidal wetland project is large-scale. This measure will track acres of subsidence reversal only within those islands. An island list (Appendix 2) and map (Map 1) were manually corrected to exclude islands that included large acreage but little connectivity to support channel formation such as Brannan-Andrus.



Map 1: Areas Where Subsidence Reversal Activities Ongoing from 2030 to 2100 Can Produce Intertidal Elevations by 2100

Data Sources

Primary Data Sources

Data sources will ultimately vary, but the following data sources serve as starting point for tracking the metric and providing background for reporting the measure:

1. The Delta Stewardship Council covered actions website. Projects of this nature are likely to meet the definition of a covered action and will likely need to establish consistency with the Delta Plan before implementation. The project description should describe the area of the project.
    a. Update frequency: As covered actions are submitted.
2. Department of Water Resources (DWR). DWR is the lead role in implementing subsidence reversal projects through their West Delta Program. Initially data will be collected by DWR until other organizations, landowners, and stakeholders begin implementing subsidence reversal projects.
    a. Update frequency: on a project by project basis
3. CA Wetland Protocol Group. Consists of multiple organizations and/or agencies (e.g., SSJDC, DFW, SMUD, MWD, and Coastal Conservancy).
    a. Update frequency: as needed.
4. California Department of Fish and Wildlife Wetlands Restoration for Greenhouse Gas Reduction Program. Uses Cap-and-Trade money to fund greenhouse gas emissions. Delta wetlands are a potential future target for this program.
    a. Update frequency: through funding cycles usually annual or shorter.

Alternative Data Sources

Alternative data sources will be used if the primary data sources become unavailable or insufficient. Alternative data sources can be used concurrently with the primary data sources as a reference or supplemental information. For this measure, the alternative data sources focus on project implementation that could technically occur independent of the state interests described above, but is unlikely to.

1. UC Davis and UC Berkeley Research. The University of California, Berkeley monitors greenhouse gas fluxes on rice and wetlands, and baseline (typical farming practices). The University of California, Davis is researching carbon stock and agronomy and economics for rice.

    a. Update frequency*:* As reported.

Process

Data Collection

1. Every year, Council staff will survey the identified online data sources.

2. If necessary, Council staff will contact the responsible agencies for clarifications on project status.
3. Data will then be compiled and be used to compare to previous years.

Reporting

Every year, Council staff will update the status of this performance measure by:

1. Review the location of the projects to see if they are on an Island in the Delta or Suisun Marsh (Map 1 or Appendix 2) with large areas of land capable of reaching intertidal elevations suitable for potential future restoration by 2100. Those outside of these Islands are not included in this metric, though they may be included in the reporting of PM 5.2 Carbon Sequestration.
2. Display the annual acreage of projects showing a comparison over time as projects become implemented.
3. Where possible, include a map of the Delta with the locations displayed on it.

Additional Notes

For this performance measure, there is no single data source. Instead, it will require staff to stay aware of projects put in place in the Delta. It is possible that staff will be aware of these projects through Delta Plan covered actions. Based on reporting of PM 5.2 the following sources are places that have in the past that have been involved with subsidence reversal projects. Currently there are no projects implemented at an appropriate elevation so these data sources describe places that may implement or track future projects. Data sources will ultimately vary, but the following data sources serve as starting point for tracking the metric and providing background for reporting the measure. These sources will be tracked at least annually on a recurring basis, but may be updated more frequently as staff become aware of projects. Any subsidence reversal project implement by a state or local agency in the Delta is likely to come to our attention well before implementation through the early consultation for the Council's covered actions process for determining consistency with the Delta Plan. However, staff will check the following sources for information on projects

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Appendix 1: Detailed Methods

2020-2030 Elevation Change Formula

The formula below is the set of intertidal elevations that meet the condition of being within the difference between current intertidal elevation and intertidal elevation 10 years from now (See figure 1 for an illustrated explanation of the methods). These methods are applied to a 200m cell size raster grid covering the legal Delta and Suisun Marsh.

$IT = (IT1 \cup IT10) - IT10$

The acreage area of ***IT*** is an estimate of the number of acres at intertidal elevations today that will not be intertidal after 10 years.

The intertidal zone for the first year (***IT_1***) is defined using the following formula:

$IT1 = MHHW > E < MLLW$

Where ***E*** is elevation at each pixel in the Wang and Ateljevich (2012) Delta and Suisun Marsh DEM (Tolentino 2017) which was aggregated up to $200m^2$.

MLLW is tidal datum for mean lower low water levels (Ecosystem Amendment Appendix 1).

MHHW is tidal datum for mean lower low water levels (Ecosystem Amendment Appendix 1).

The intertidal zone (***IT_{10}***) for the tenth year is defined using the following formula-

$IT10 = MHHW > E - \Delta SLR + \Delta ES > MLLW$

ΔSLR Expected sea-level rise. This analysis assumes linear sea-level rise of 2.6 feet by 2100 predicted Golden Gate sea-level rise for 50^{th} percentile in RCP 8.5 emission scenario. Only sea-level rise over the next 10 years was taken into account.

ΔES is the change in elevation from subsidence within 10 years. For each pixel in the DEM the rate of change is given by the subsidence rates estimated in Deverel et al. (2016) based on organic soil composition.

The target for acres was calculated by comparing intertidal zone at IT_1 to IT_{10}. The area of the Intertidal zones that was in IT_1 but not IT_{10} was calculated. In the legal Delta that area was about 3,500 acres. In Suisun Marsh, the area was about 3,000 acres.

<u>Target Methods – Locations where ongoing subsidence reversal activities can reach intertidal elevations by 2100:</u>

The subsidence reversal zone was calculated using the following formula (see Appendix 2 for and illustration of the methods), assuming a beginning date of 2020 and end of 2100. The formula produces the band of elevation where ongoing subsidence reversal techniques would accrete land to reach intertidal elevations and prevent the net loss of opportunities to restore tidal wetlands to benefit the ecosystem. This analysis assumes that subsidence reversal activity would be halted once the landscape reaches intertidal elevations.

This was calculated using this given equation:

$SRT = (MLLW > E) \cup (E - \Delta SLR + \Delta E)$

SRT is the subsidence reversal target zone. It is areas at intertidal elevation by 2100 given subsidence reversal is used during that period to increase elevations.

Where ***E*** is elevation based on an update to the Wang and Ateljevich (2012) Delta and Suisun Marsh DEM (Tolentino 2017) which was aggregated up to $200m^2$.

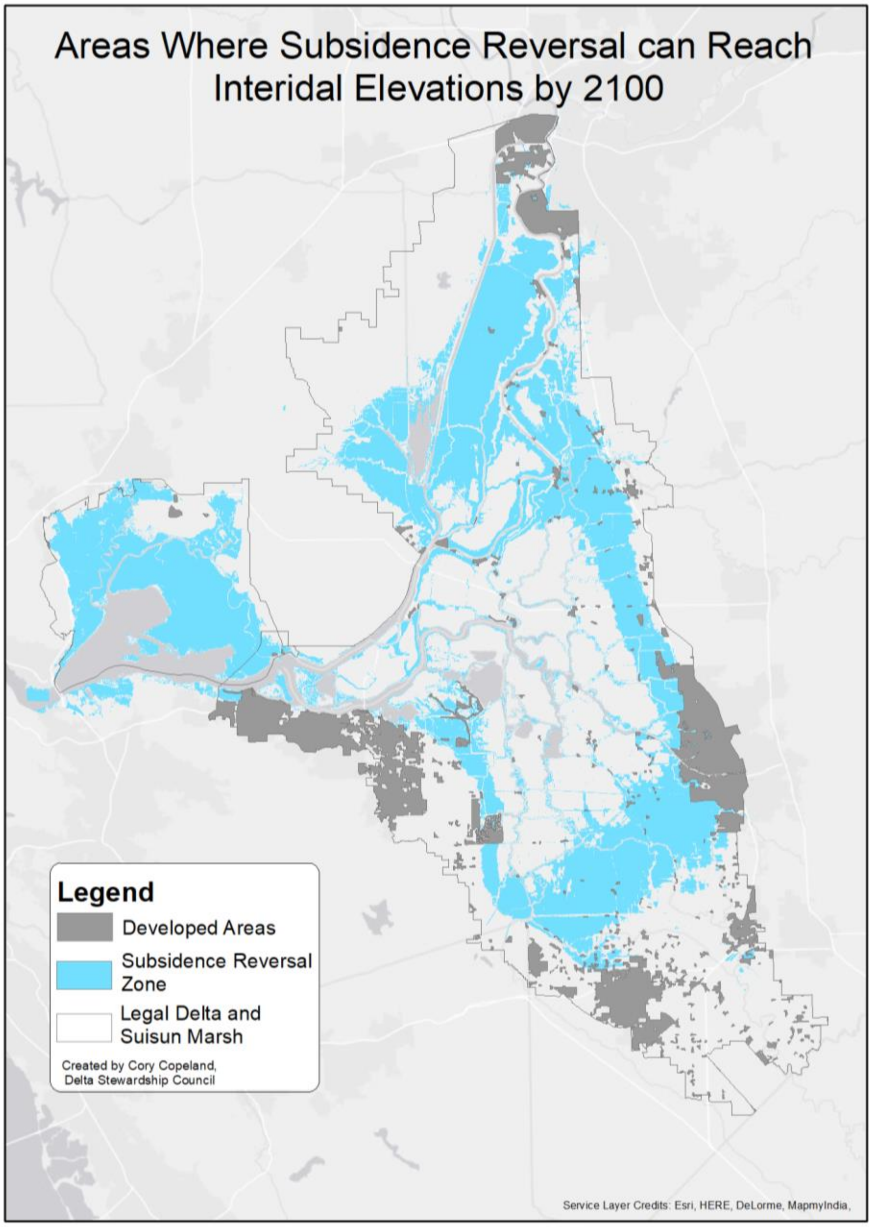
MLLW is tidal datum for mean lower low water levels (Ecosystem Amendment Appendix 1).

MHHW is tidal datum for mean lower low water levels (Ecosystem Amendment Appendix 1).

ΔSLR Expected sea-level rise. This analysis assumes sea-level rise of 2.6 feet by 2100 predicted Golden Gate sea-level rise for 50th percentile in RCP 8.5 emission scenario.

ΔE is the change in elevation from subsidence reversal by 2100. The mapped band is based on rates of sediment accretion of 4 cm/year from Miller et al 2008.

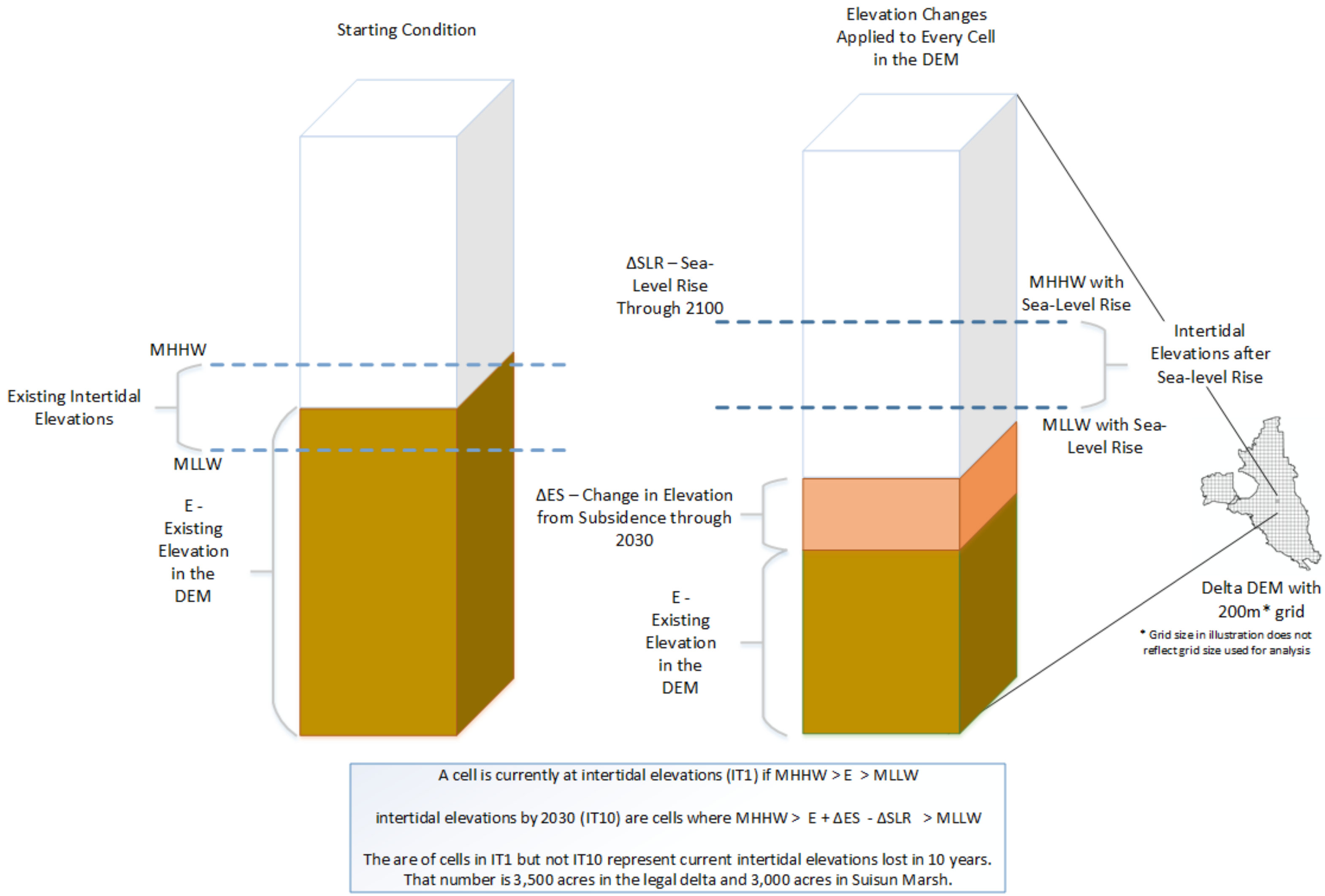
Using this method calculated the area capable of being restored to intertidal by 2100 was calculated. That area is shown below in Map 1.



Map 1: Areas Where Subsidence Reversal Activities Ongoing from 2030 to 2100 Can Produce Intertidal Elevations by 2100

This map shows all the areas in the Delta which are presently at intertidal elevation and shallow subtidal. If subsidence reversal activities are implemented by 2030 in these locations, and these activities continue to accrete the land elevation, these areas will increase and maintain the intertidal elevation by 2100. The year 2100 serves as a conservative cutoff. Although there are uncertainties, if the best available science indicates an area cannot reach intertidal by at least 2100, assuming the conservative assumptions built into the model, then the land is likely too deeply subsided to achieve intertidal elevations through subsidence reversal alone. Developed areas are shown on the map for illustrative purposes.

<u>Figure 1 - Conceptual diagram of target acreage methods</u>: estimated area of intertidal elevation to be lost by 2030 due to sea level rise and land subsidence



<u>Figure 2 - Conceptual diagram of areas targeted for subsidence reversal activities</u>: subsidence reversal zone - to prevent a net loss of opportunities for future (2100) tidal wetland restoration

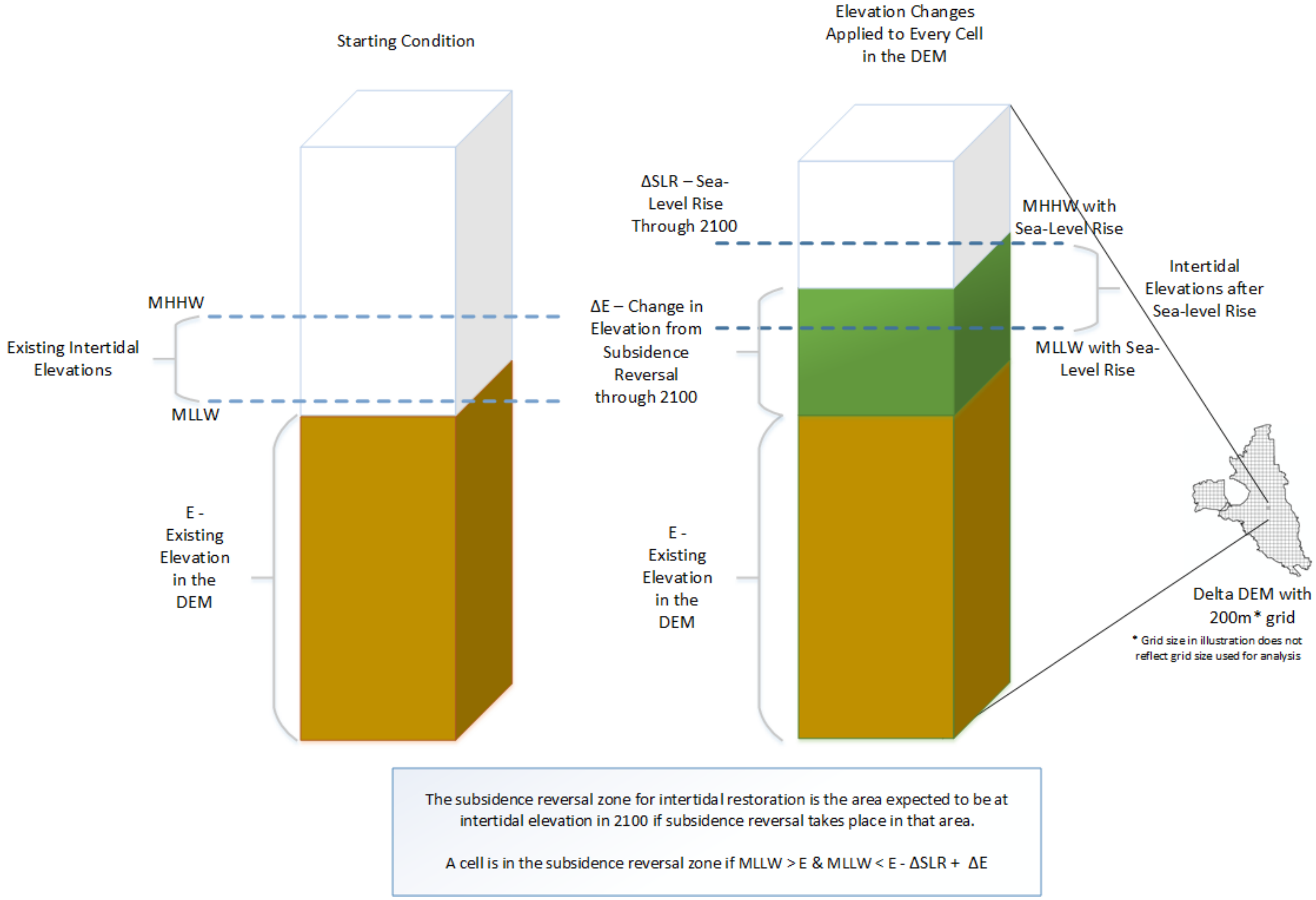


Diagram annotation: The subsidence reversal zone is the area at current subtidal elevation (?) that is expected to reach intertidal elevations if subsidence reversal practices are initiated by 2030 and continue to 2100. This area will then become available for tidal wetland restoration in 2100 ameliorating for the expected land loss due to sea level rise and subsidence.

Appendix 2: Islands at an appropriate elevation

List of Islands at an appropriate elevation to reach elevations that would support potential intertidal restoration by 2100:

DREXLER POCKET

HONKER LAKE TRACT

BRACK TRACT

GRAND ISLAND

TERMINOUS TRACT

MERRITT ISLAND

TYLER ISLAND

PEARSON DISTRICT

SUTTER ISLAND

SHIN KEE TRACT

BISHOP TRACT

LITTLE EGBERT TRACT

EHRHEARDT CLUB

RYER ISLAND

UPPER ANDRUS ISLAND

DEAD HORSE ISLAND

FAY ISLAND

FABIAN TRACT

SHIMA TRACT

SMITH TRACT (LINCOLN VILLAGE)

BYRON TRACT

LISBON DISTRICT

CACHE HAAS AREA

RIO BLANCO TRACT

DREXLER TRACT

WRIGHT-ELMWOOD TRACT

NEW HOPE TRACT

CANAL RANCH TRACT

HOTCHKISS TRACT

WINTER ISLAND

ATLAS TRACT

EGBERT TRACT

NETHERLANDS

PROSPECT ISLAND

GLANVILLE

MCCORMACK-WILLIAMSON TRACT

MAINTENANCE AREA 9

DLIS-11

DLIS-20 (YOLO BYPASS)

CHIPPS ISLAND

MEIN'S LANDING

DLIS-26 (MORROW ISLAND)

DLIS-63 (GRIZZLY ISLAND AREA)

DLIS-48

SUNRISE CLUB

DLIS-52

HONKER BAY

DLIS-62

DLIS-40

DLIS-41 (JOICE ISLAND AREA)

CHIPPS ISLAND SOUTH

DLIS-55

DLIS-47	DLIS-32	MIDDLE ROBERTS ISLAND
DLIS-46	DLIS-33	LOWER ROBERTS ISLAND
DLIS-30	DLIS-44 (HILL SLOUGH UNIT)	VEALE TRACT
DLIS-36	DLIS-37 (CHADBOURNE AREA)	HASTINGS TRACT
DLIS-25	DLIS-5	
DLIS-28	DLIS-49	Island IDs are those used in the Delta Levee Investment Strategy (DLIS).
DLIS-29	DLIS-50	
DLIS-39	UNION ISLAND EAST	
DLIS-31 (GARABALDI UNIT)	UNION ISLAND WEST	

Please contact Scott.Navarro@deltacouncil.ca.gov if you have questions regarding accessibility.