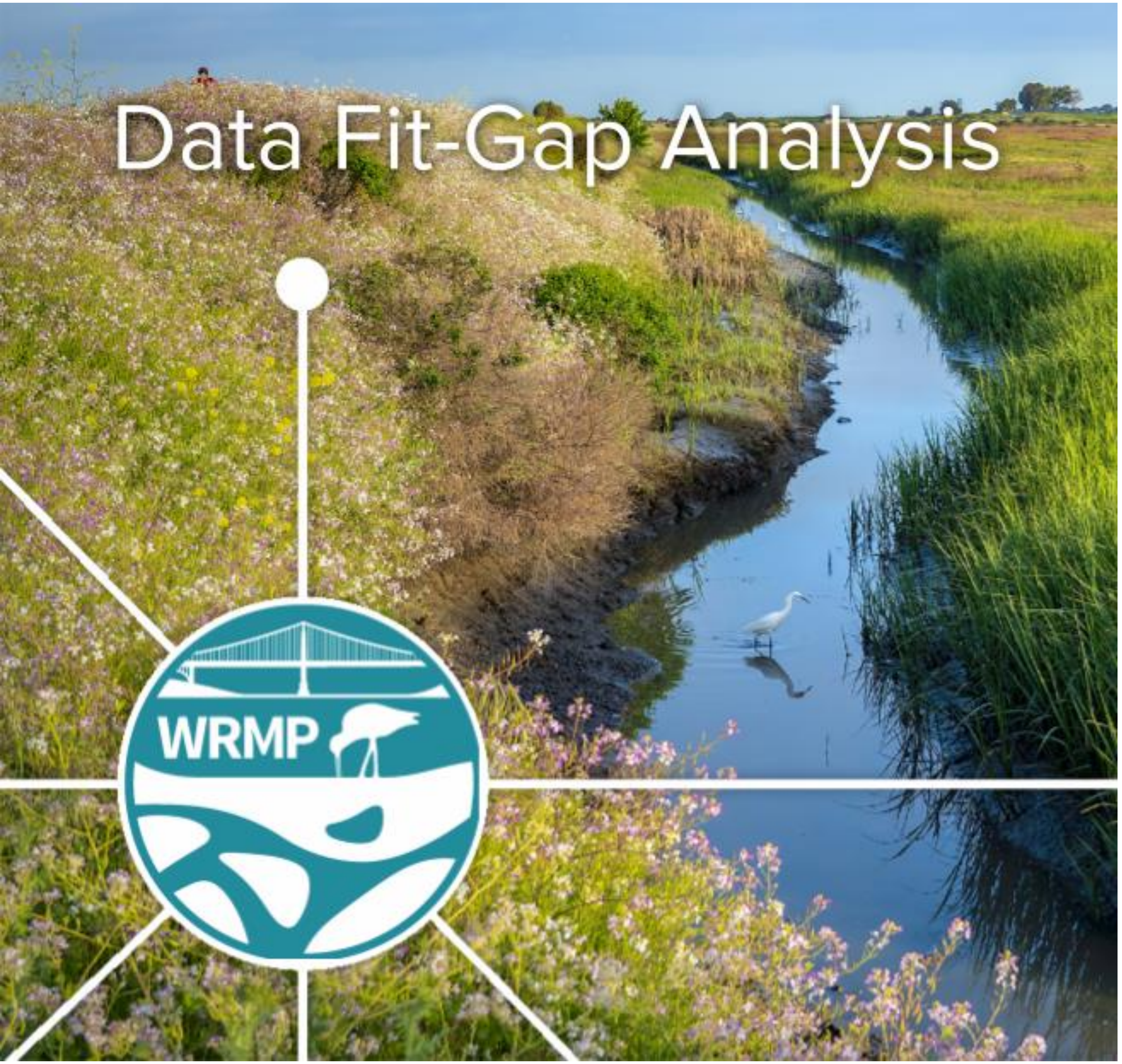
Data Fit-Gap Analysis



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In active collaboration with committees representing the San Francisco Estuary Wetlands Regional Monitoring Program

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Data Fit-Gap Analysis

Initial Publication, September 2021

OVERVIEW

This document describes the data needs for the indicators associated with the San Francisco Estuary Wetlands Regional Monitoring Program (WRMP), evaluating those data needs against the availability, quality, resolution, scope, and format of current datasets. Through this work, the document will measure what is needed for program effectiveness against what is practically achievable, given current resources.

The production of this document and the related efforts to document data management processes for the WRMP are funded by a USEPA Wetland Program Development grant, awarded to the San Francisco Estuary Partnership (SFEP) in partnership with the San Francisco Estuary Institute - Aquatic Science Center (SFEI-ASC), San Francisco Bay National Estuarine Research Reserve (NERR), and the San Francisco Bay Joint Venture (SFBJV). The approach described in this document adheres to the terms of the USEPA-funded project, as influenced by ongoing engagement with the committees of the WRMP.

PURPOSE

The results of the Fit-Gap Analysis featured in this document are intended to inform the process for designing the data collection, processing, quality control, visualization, and distribution measures required of an appropriate data management system to serve the needs of the emerging Wetlands Regional Monitoring Program.

Key stakeholders can review the materials in this document to assess program priorities in light of anticipated costs and processing time/effort associated with the full lifecycle of data management.

Decisions made in light of this information would ideally reflect a host of factors captured in this document, including the WRMP's science priorities, data availability, and practical business process considerations. The decisions regarding the viability of data sources will, in turn, influence a range of subsequent products ranging from the drafting of Standard Operating Procedures (SOPs) to Quality Assurance Program Plans (QAPPs). In fact, the data management system itself, a broad endeavor that entails data collection, processing, and distribution, will follow from Steering Committee decisions. As such, this document is designed to focus deliberations conducted among the diverse program stakeholders on the highest priority and most cost-effective courses of action.

In part, the document identifies datasets critical to the successful evaluation of programmatic scientific objectives. It is therefore important for this document to uphold program principles of collaboration, transparency, and sustainability. Such principles are key to the successful and credible sharing of commonly managed data.

PRINCIPLES

Informing the process for conducting this Fit-Gap Analysis are the principles for the WRMP as articulated in its Program Plan:

- Collaboration among institutions: The WRMP will work across institutions and organizations to achieve program goals.
- Legitimacy through transparency: The WRMP will function through a fair, deliberative and transparent process.
- Long-term ownership and sustainability: We intend that the WRMP, once established, will be long-lasting and sustainable.
- Program will adapt over time based on management needs and science: The WRMP is rooted in an adaptive management model. As new science emerges, the program can adapt [its methods and technology] through adjustment of management questions.

These are the principles most salient to data management as conducted by a program operating in the public interest. In particular, as we evaluate data sources according to set criteria, we will also do so through the lens of these program principles. The clear emphases on collaboration, transparency, sustainability, and adaptation over time bear a strong influence over the selection of data sources that might foster these principles.

METHODOLOGY / PROCESS

Motivations for our Approach

After determining the priority indicators to form the focus of the data management-related efforts, the team worked on the materials to meet the needs of the Fit-Gap Analysis. (See Priority Indicators below.) Because the Fit-Gap Analysis lays the groundwork for so much to follow — the Indicator Calculation document, the program's standard operating procedures, and all the details that will populate the Data Management Plan — the team sought to adhere to the program principles in the sequential and iterative development of the materials, primarily to ensure that the TAC had plenty of opportunity to furnish materials, expertise, and discuss the Fit-Gap Analysis as it was developed. We did not wish to imply a *fait accompli* for the determination of datasets most suitable for given indicators, or even foreordain the criteria by which datasets would be selected and evaluated. Rather, our method was to solicit information from the TAC, in recognition of their scientific and technical expertise, and then share the synthesis at every step of development. In this way, we could foster high levels of collaboration, transparency, sustainability, and adaptation to new ideas.

The Process

Over the course of a 12-month period, the Data Management team conducted a cycle of presenting tasks to the TAC, conducting surveys on specific topics, then sharing with the TAC the results of those surveys. The sequence of information gathering was as follows:

1. **Criteria Parameter Development**: Beginning by defining the minimum criteria for inclusion of datasets, the team assembled the potential criteria and presented them to the TAC, in close consultation with the TAC co-chairs.
2. **Criteria by Indicator Development**: The team then facilitated the enumerated criteria per indicator for the terms solicited by the TAC in the first consultation.
3. **Dataset List**: Then the team assembled the datasets that met the minimum criteria, as solicited from the TAC.
4. **Gap Evaluation**: Evaluating the datasets against the minimum criteria and Indicator objectives, the team offered an opportunity for the TAC to review some of the key mismatches, deficiencies, and potential conflicts in the relationship between datasets and indicators.

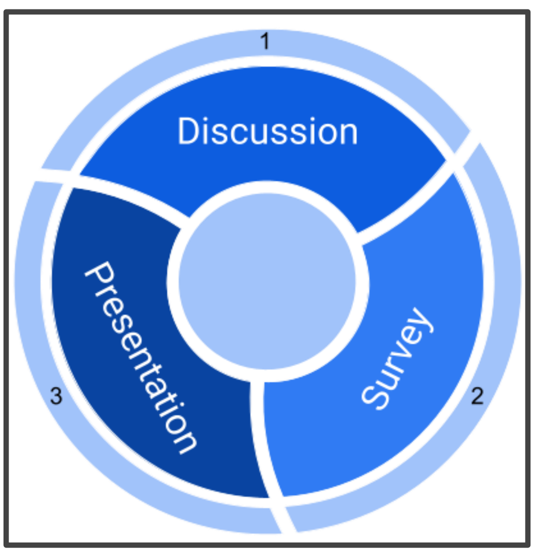
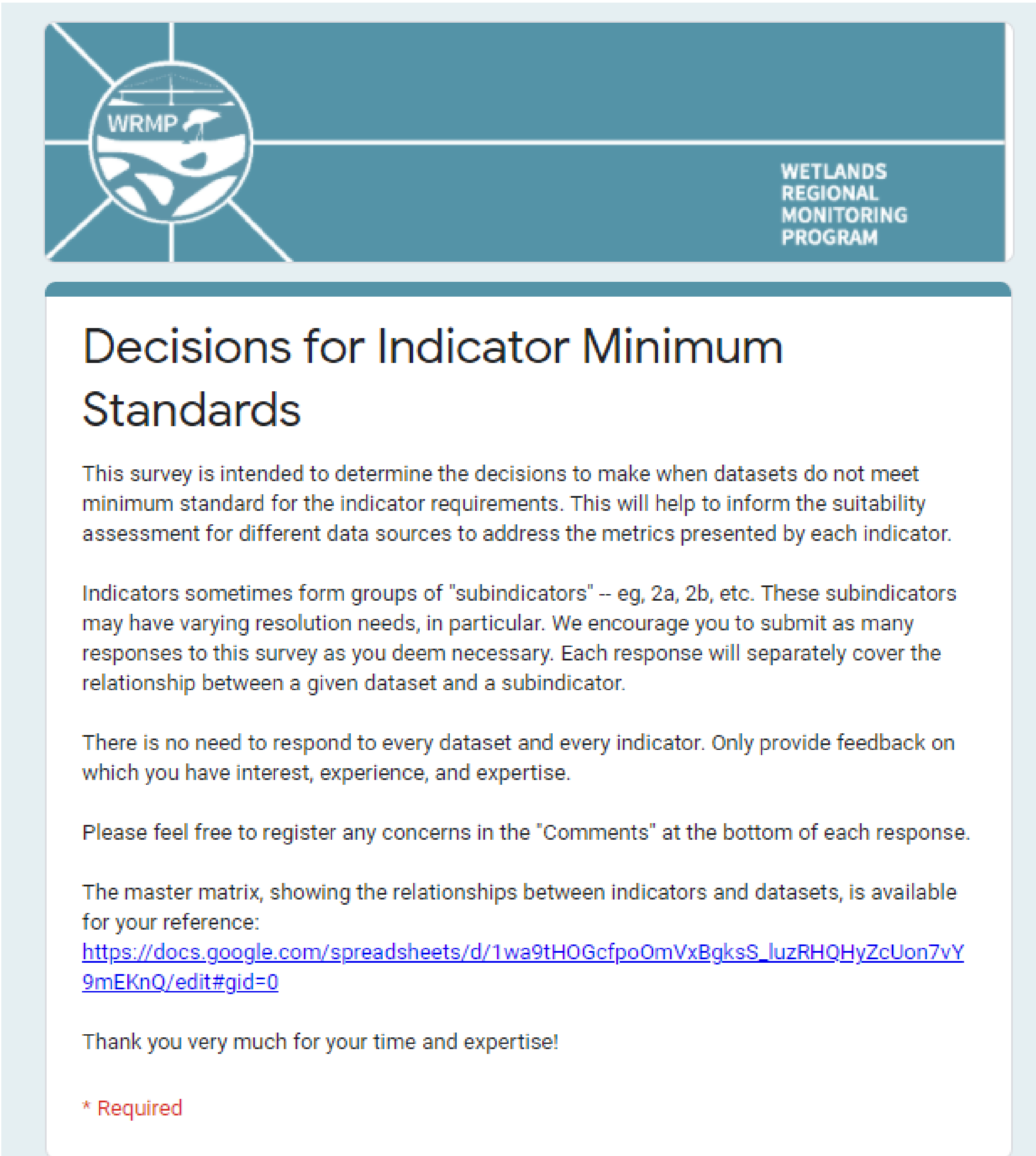


Figure 1. Diagram illustrating the sequence to foster participation, precise and accurate feedback, and iterative progress

Our process — discussion, survey, presentation — was designed as a way to maximize opportunities for participation (Figure 1). Response rates to the surveys (typically seven or fewer of the twenty-two potential TAC members), however, indicate that the majority of TAC members were not motivated to participate in the feedback cycle. This outcome is to be expected, however, as the majority of TAC members, whose time and efforts are uncompensated, participate in meetings but refrain from conducting a significant amount of work beyond those in-meeting hours due to time constraints.



Decisions for Indicator Minimum Standards

This survey is intended to determine the decisions to make when datasets do not meet minimum standard for the indicator requirements. This will help to inform the suitability assessment for different data sources to address the metrics presented by each indicator.

Indicators sometimes form groups of "subindicators" -- eg, 2a, 2b, etc. These subindicators may have varying resolution needs, in particular. We encourage you to submit as many responses to this survey as you deem necessary. Each response will separately cover the relationship between a given dataset and a subindicator.

There is no need to respond to every dataset and every indicator. Only provide feedback on which you have interest, experience, and expertise.

Please feel free to register any concerns in the "Comments" at the bottom of each response.

The master matrix, showing the relationships between indicators and datasets, is available for your reference: https://docs.google.com/spreadsheets/d/1wa9tHOGcfpoOmVxBgksS_luzRHQHyZcUon7vY9mEKnQ/edit#gid=0

Thank you very much for your time and expertise!

* Required

Figure 2. The team used Google Forms to survey the TAC and assemble their responses. This example pertains to Survey #4: Decisions for Indicator Minimum Standards.

GEOGRAPHIC SCOPE

The geographic range of this analysis, in alignment with the primary focus of the WRMP itself, is the region constituting the Baylands of the San Francisco Bay Area. The Wetlands Regional Monitoring Program Plan describes the geographic range in the following terms:

> The geographic scope of the WRMP encompasses the "complete" tidal marsh ecosystem, as defined by BEHGU. The complete tidal marsh ecosystem includes subtidal areas to a depth of 12 ft below local Mean Lower Low Water (zero tide height), tidal flats, fully tidal and muted tidal marshes, and adjoining estuarine-terrestrial and estuarine-fluvial transition zones. The scope does not currently include managed marshes, such as duck clubs in Suisun Marsh, or diked non-tidal marshes within the historical limits of the San Francisco baylands (Goals Project, 2015). The WRMP recognizes that the complete tidal marsh ecosystem includes the entire intertidal zone, the estuarine-terrestrial transition zone, and the subtidal zone to the maximum depth of rooted submergent vegetation and surface wave effects on benthic sediment resuspension. The boundaries of these zones are inexact in nature. Any assessment of distribution, abundance, diversity, or condition of tidal marshes should consider the complete tidal marsh ecosystem. However, unless stated otherwise, the term tidal marsh pertains to the intertidal portion of the ecosystem that supports rooted, vascular vegetation.[1]

Areas adjacent to the Baylands — such as the open waters of the Bay and the uplands of the associated watersheds — will not be excluded from consideration, but the criteria for fit-gap evaluation will, at present, focus on a narrow range of geography that is of primary concern for tidal wetland restoration.

This approach hews closely to Management Question #1 and Science Priority #1 as expressed in the WRMP Program Plan: "Where are the region's tidal marsh ecosystems, including tidal marsh restoration projects, and what net changes in ecosystem area and condition are occurring?"[2]

STAKEHOLDERS

Internal

The Technical Advisory Committee (TAC) will provide primary review and insight regarding the content of the report. The TAC, in their expertise regarding the subject matter, can offer specific information regarding the indicators, the data associated with each, and the range of data quality and availability.

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[1] https://www.sfestuary.org/wp-content/uploads/2020/03/WRMP-Program-Plan_Final_Web2_New.pdf
[2] https://www.sfestuary.org/wp-content/uploads/2020/03/WRMP-Program-Plan_Final_Web2_New.pdf

The Steering Committee will review the document and make key decisions, as required, about the allocation of resources for data management, in discussion with the WRMP implementation project leads, who must advise on the viability of approaches, given the project scope and resource limitations.

External

Elements from the Fit-Gap Analysis, if not the document in its entirety, can be used to communicate about the program to external stakeholders, such as restoration practitioners, resource agency staffers, policy makers, and others interested in wetland restoration.

It is currently anticipated that the SFBJV and NERR might share portions of the Fit-Gap Analysis with their own restoration practitioners and researchers as part of the funded outreach effort associated with the Wetland Program Development grant referenced above. Accordingly, this document will feature some provisional data visualizations, used as examples of potential program output, that can serve to prompt internal discussion as well as to illustrate program objectives to external stakeholders.

INDICATORS

The Steering Committee and Core Team pre-determined the indicators for the TAC to focus on to address Management Question #1A: *What is the distribution, abundance, diversity, and condition of tidal marsh ecosystems, and how are they changing over time?* At the July 2020 TAC meeting, they revised the set of indicators to omit indicator 4 (Map of "complete marshes" as defined by the Baylands Ecosystem Habitat Goals Science Update (BEHGU) and fluvial/upland/riparian connectivity) and include indicator 6 (Map of changes in the lateral extents of natural foreshores [tidal marsh and beach]). In the course of considering the map of “complete marshes,” the TAC determined that they could be derived from data produced by Indicators 1 and 3. Therefore, the datasets to inform this indicator can be understood as being satisfied through indirect means. Indicator 6 was included since the shoreline edge is part of the geomorphic process.

The TAC identified several high-priority indicators that would help address Management Question #1A, including:

> 1 - Map of baylands habitat types and elements (vegetated tidal marsh, tidal flats, diked marsh types, levees, channels, pannes, etc); impact areas and projects
>
> 2 - Map of tidal wetland elevations and elevation capital
>
> 3 - Map of estuarine-terrestrial transition zones

6 - Map of changes in the lateral extents of natural foreshores and backshores of tidal marsh

7 - Percent cover, height, and patch characteristics of major dominant vegetation groups within sub-basins

A few of the indicators (Indicators 2, 3 and 7) were further separated into sub-indicators to accommodate the level of detail required to answer different aspects of the related Management Question:

2a - Map of tidal marsh elevations and elevation capital
2b - Map of tidal mudflat elevations and elevation capital

3a - Map of developed space

3b - Map of undeveloped space
3c - Map of stream course

7a - Identification of alliances of vegetation groups within sub-basins

7b - Percent cover of major dominant vegetation groups within sub-basins

7c - Height of major dominant vegetation groups within sub-basins

7d - Patch characteristics of major dominant vegetation groups within sub-basins

Data Sources

Table 1. List of datasets considered in the analysis.

Name of dataset	Steward / Contact Information
Adaptation Atlas Dataset	SFEI
Bay Area Aquatic Resource Inventory (BAARI)	SFEI Pete Kauhanen, SFEI petek@sfei.org
California Avian Data Center	PRBO Julian Wood jwood@pointblue.org
California Vegetation Classification and Mapping Program (VegCAMP)	CDFW
CALVEG	USDA Forest Service

Coastal Change Analysis Program (C-CAP) Regional Land Cover and Change	NOAA Office for Coastal Management Nate Herold Nate.Herold@noaa.gov
Continuously Updated Shoreline Product (CUSP)	NOAA
EcoAtlas Project Tracker	SFEI Cristina Grosso cristina@sfei.org
Global Surface Water Inventory	European Commission Joint Research Centre
Habitat Evolution Mapping Project (HEMP)	Brian Fulfrost, Fultrost & Associates Brian Fulfrost bfaconsult@gmail.com
High-resolution DEM of SF Bay	USGS Theresa Fregoso tfregoso@usgs.gov Bruce Jaffe bjaffe@usgs.gov Amy Foxgrover afoxgrover@usgs.gov
Imagery from County mapping projects: Low tide LiDAR collected for the tidal wetlands of Santa Clara, Santa Cruz, and Marin County	Technology Services and Solutions Nelly Decker Nelly.Decker@tss.sccgov.org
LEAN-Corrected DEM for Suisun Marsh	USGS Karen Thorne kthorne@usgs.gov
LEAN-corrected San Francisco Bay DEM	USGS Karen Thorne kthorne@usgs.gov
Metropolitan Transportation Commission (MTC) Land Use Dataset	SFEI Lester McKee lester@sfei.org
National Agriculture Imagery Program (NAIP) imagery	USDA
National Hydrography Dataset (NHD) Improvement	DWR Jane Schaffer-Kramer jane.schafer-kramer@water.ca.gov
National Wetlands Inventory (NWI)	USFWS Elaine Blok elaine_blok@fws.gov
New Life for Eroding Shorelines	SFEI Ellen Plane ellenp@sfei.org

USGS New mudflat change DEM	USGS Theresa Fregoso tfregoso@usgs.gov Bruce Jaffe bjaffe@usgs.gov
Pacific Marine and Estuarine Fish Habitat Partnership (PMEP) West Coast Estuary Viewer	PMEP
San Francisco Bay Nutrient Management Strategy Observation Program	SFEI, RMP NMS Dave Senn davids@sfei.org
SF Bay Tidal Datums (2016)	BCDC Todd Hallenbeck todd.hallenbeck@bcdc.ca.gov
Shallow Groundwater Response to Sea Level Rise	SFEI Ellen Plane ellenp@sfei.org
Tidal Wetland Vegetation Mapping for the San Francisco Estuary	Kass Green kassgreen@earthlink.net Tukman Geospatial Mark Tukman mark@tukmangeospatial.net
USGS Marsh Elevation Data for San Francisco Bay	USGS Karen Thorne kthorne@usgs.gov
USGS Topobathymetric DEM (CoNED)	USGS Earth Resources Observation and Science (EROS) Center Jeffrey Danielson daniels@usgs.gov
Various research projects	Various
WQIF Baylands Change Basemap	SFEI Cristina Grosso cristina@sfei.org

Criteria for Selection of Data

The TAC provided a list of criteria to consider when describing existing available data sources, including:

- Resolution
- Geospatial extent

- Last update year
- Frequency of updates and consistency across years
- Documentation and data quality
- Format and level of effort to format data
- Associated with a government program
- Readily available data, costs, and data use restrictions
- Steward and contact information
- Provides multiple benefits across indicators

From this list, the TAC identified critical criteria for determining the minimum standards for each indicator. A survey was distributed to the TAC to obtain the following information for each of the high-priority indicators:

- **Resolution:** What is the minimum resolution required?
- **Geographic Extent:** What is the minimum useful geospatial extent?
- **Frequency of Updates**: How frequently would the information need to be updated?
- **Documentation/Data Quality:** What assurances would you require for minimum data quality?

Table 2 summarizes the minimum standard requirements for the high-priority indicators and sub-indicators, as furnished by the TAC. (As we discovered over the course of composing the present analysis, the precise values of these minimum standards remain somewhat in flux. We would therefore anticipate that a future deliberative body, such as the WRMP's Geospatial Workgroup, may refine, alter, or override the following figures.)

Table 2. Minimum standard requirements for high-priority indicators and sub-indicators.

No.	Indicator/Sub-indicator Name	Resolution	Geospatial Extent	Frequency of Updates	Documentation / Data Quality
1	*Map of baylands habitat types and elements (vegetated tidal marsh, tidal flats, diked marsh types, levees, channels, pannes, etc); impact areas and projects*	Minimum mapping unit for polygon: 5 sq m (0.0005 ha); Minimum mapping unit for polyline: 1 m width, 25 m length	Entire SF baylands in initial phase, then later integration with Delta mapping	Every 5 years	Robust metadata with data sources, collection and processing steps, methodology, and data quality assurance steps/checks
2a	*Map of tidal marsh elevations and elevation capital*	1 sq m cell size (horizontal resolution), 5-10 cm vertical resolution	Entire SF baylands in initial phase, then later integration with Delta mapping	Every 2 to 5 years	Need complete metadata, processing/modeling methodology, uncertainty scores, and good protocols for tide gauges, GPS,

					benchmarks, etc.
2b	*Map of tidal mudflat elevations and elevation capital*	1 sq m cell size (horizontal resolution), 5-10 cm vertical resolution	Entire SF baylands in initial phase, then later integration with Delta mapping	Every 2 to 5 years	Need complete metadata, processing/modeling methodology, uncertainty scores, and good protocols for tide gauges, GPS, benchmarks, etc.
3a	*Map of developed space*	5 sq m (0.0005 ha)	Need complete metadata, processing/modeling methodology, and validation scores	Every 2 to 5 years	Within upland buffer utilized by Adaptation Atlas
3b	*Map of undeveloped space*	5 sq m (0.0005 ha)	Within upland buffer utilized by Adaptation Atlas	Every 5 years	Need complete metadata, processing/modeling methodology, and validation scores
3c	*Map of stream course*	TBD	Within upland buffer utilized by Adaptation Atlas	Every 5 - 10 years	Need complete metadata and processing/modeling methodology
6	*Map of changes in the lateral extents of natural foreshores and backshores of tidal marsh*	Horizontal resolution consistent with approach developed by Beagle et al. (likely 1 m horizontal resolution w/ 1 m error)	Bayward edges of marshes mapped in Indicator 1	Every 5 years, but modify schedule if necessary to cover El Nino years of rains that generate high winds and high sediment yields from local watersheds	Need complete metadata and processing/modeling methodology, including error rates for each measurement of change and protocols that stipulate the data source, vintage of imagery, magnification used to measure change, minimum mapping unit and data QAQC steps, etc.

7a	*Identification of alliances of vegetation groups within sub-basins*	Minimum mapping unit of 0.25 ac for all estuarine tidal wetlands, but perhaps finer resolution (eighth of an acre?) for Benchmark, Reference, and Project sites. Need to use a hierarchical system whereby finer-scale/association data can be rolled up into larger-scale/alliance data.	All baylands (larger-scale); Benchmark/Reference/Project sites (finer-scale)	Every 2 years for restoring wetlands and every 5 years for millennial marsh	Need complete metadata, processing/modeling methodology, and validation procedures
7b	*Percent cover of major dominant vegetation groups within sub-basins*	Minimum mapping unit of 0.25 ac for all estuarine tidal wetlands, but perhaps finer resolution (eighth of an acre?) for Benchmark, Reference, and Project sites. Need to use a hierarchical system whereby finer-scale/association data can be rolled up into larger-scale/alliance data.	All baylands (larger-scale); Benchmark/Reference/Project sites (finer-scale)	Every 5 years	Need complete metadata, processing/modeling methodology, and validation procedures
7c	*Height of major dominant vegetation groups within sub-basins*	Minimum mapping unit of 0.25 ac for all estuarine tidal wetlands, but perhaps finer resolution (eighth of an acre?) for Benchmark, Reference, and Project sites. Need to use a hierarchical system whereby finer-scale/association data can be rolled up into larger-scale/alliance data.	All baylands (larger-scale); Benchmark/Reference/Project sites (finer-scale)	Every 5 years	Need complete metadata, processing/modeling methodology, and validation procedures

7d	*Patch characteristics of major dominant vegetation groups within sub-basins*	Minimum mapping unit of 0.25 ac for all estuarine tidal wetlands, but perhaps finer resolution (eighth of an acre?) for Benchmark, Reference, and Project sites. Need to use a hierarchical system whereby finer-scale/association data can be rolled up into larger-scale/alliance data.	All baylands (larger-scale); Benchmark/Reference/Project sites (finer-scale)	Every 5 years	Need complete metadata, processing/modeling methodology, and validation procedures

A list of the minimum requirements for each data source is available in Table 3 in the Appendices.

Criteria for Evaluation

To determine if a dataset met the minimum requirements identified for an indicator, a decision tree was developed (**Figure 3**). This was especially helpful in evaluating how to handle a dataset that did not meet the minimum standard requirements. There options were explored: (1) the dataset could be enhanced, e.g., by incorporating additional data, so it could meet the minimum criteria and therefore could be used; (2) the dataset could be not used and replaced with another dataset that met the minimum criteria; or (3) the TAC could modify the minimum requirements to allow for the use of the dataset.

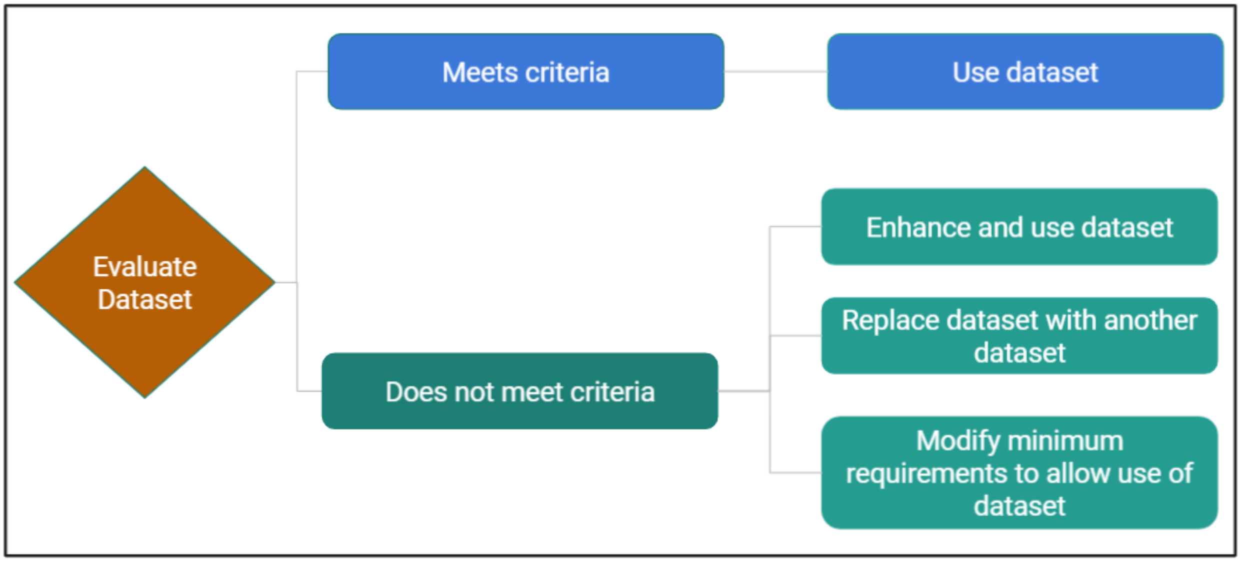

Figure 3. Decision tree for evaluating if a dataset met the minimum requirements for an indicator.

A second survey was distributed to the TAC to help identify critical data gaps and confirm the evaluation of a dataset. TAC members were asked to select a dataset for an indicator in their area of expertise, provide a decision, and offer justification for their decision.

STEPS TOWARDS USABLE DATA

Challenges leading to higher levels of effort

As the TAC and Data Management Team forged meaningful connections among data and indicators (Figure 4), they also determined the level of effort to adapt the individual datasets to the needs of their associated indicators. The challenges leading to higher effort for a given dataset might be related to any of the following:

- **The dataset does not meet one or more of the minimum criteria.** The more criteria it fails to meet, the higher the effort to adapt it for use with the WRMP's indicators.
- **The dataset must be synthesized with another in some way.** To make use of a dataset, it must be combined with another, compared to another, or otherwise measured against another dataset.
- **The dataset consists of imagery, rather than a classified map.** In some cases, a given dataset might offer raw data without the interpretative framework to make it readily usable in the context of the program's indicators.[3]

[3] An example of this basis in imagery, rather than an analytical data product is National Agriculture Imagery Program (NAIP).

Depending on the evaluation of TAC experts and these measures of effort, the Data Team made determinations, since reviewed by the TAC, regarding the suitability for the datasets to meet the requirements of each indicator. The levels of effort range from low to high (Table 4). In addition, listed in level of effort are the closely related determinations “exclude,” “future,” and “unknown.” Exclude reflects a decision to omit the dataset, not from the program itself, but from its relationship to inform an indicator. “Future” reflects what we call “horizon” datasets: datasets that are promised for delivery in the next few years and are therefore potentially key contributors to meet indicator data needs. “Unknown” reflects a need for further information. A determination towards a given level of effort is inconclusive at this time.

Omitted from these graphically represented linkages and later evaluative surveys are the relationships to secondary indicators. This omission was the product of a practical decision to ensure that the TAC would remain focused on the highest priority determinations. Given the sheer number of datasets, indicators, and relationships among them, we focused on evaluating the level of effort for the datasets to inform the primary indicators. That said, in making subsequent decisions regarding the application of resources, the Steering Committee and/or TAC might also take into account relationships to secondary indicators, as visualized in the following graphic:

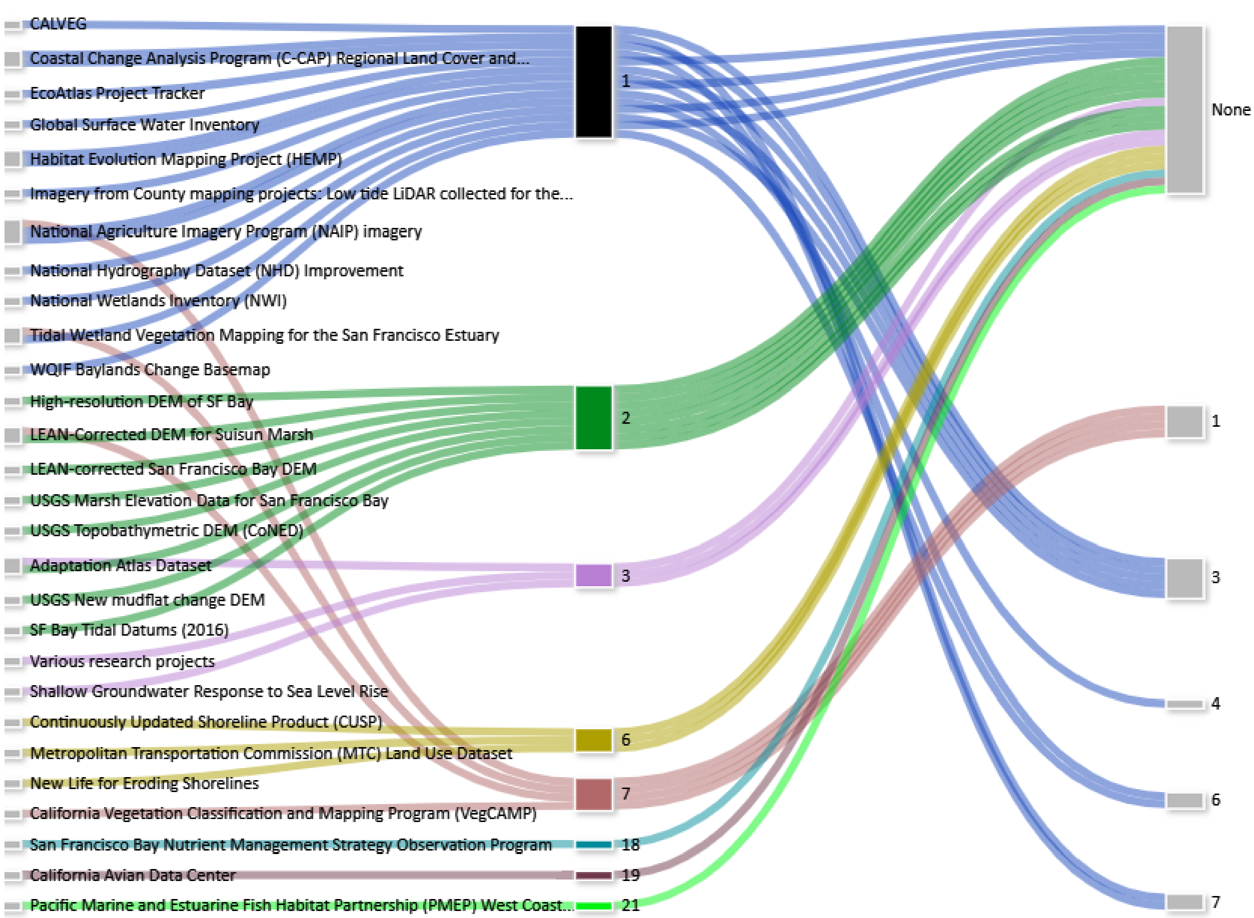

Figure 4. Illustration of the relationships among datasets, primary, and secondary indicators.

The levels of effort associated with each indicator are critical to determining the practical *gaps* remaining. It is often the case that levels of effort translate into funding required. (While this is not always the case — sometimes in-kind contributions or alternate innovations can address the more challenging situations — we can roughly understand that "high effort" indicators may be addressed with additional funding allocation.) Recognizing that the WRMP is limited in its available funding for the foreseeable future, the Steering Committee must carefully evaluate levels of effort to avoid shortfalls in meeting high-priority data needs.

If there are no "easy" pathways towards informing an indicator, then one or more of the following courses of action might be adopted by the Steering Committee, in consultation with the TAC:

1. More resources would need to be applied toward the indicator's needs.
2. The indicator might "make do" with a limited data profile, limiting how much can be determined with great certainty.
3. The indicators might need to be reprioritized.

Which path to take for the portfolio of datasets and indicators to address can be determined by examining each indicator and its associated portfolio of datasets, with each dataset associated with its own level of effort.

Estimated Effort and Cost

Effort and cost may be derived from the need for such resources as:

- Deliberation and discussion among experts
- Hardware processing time
- GIS specialization
- Database management

Levels of Effort

The variability associated with the resources listed above introduce a great deal of uncertainty to the cost estimations. Therefore, we translate the levels of effort into cost ranges to capture a general sense of effort expressed as either cost or a judgment on suitability for the dataset to meet indicator requirements.

Table 4. Levels of effort to describe relationships among datasets and indicators

Level of Effort	Descriptions
High	>$30K
Medium	$10-30K

Low	<$10K
Exclude	Dataset not recommended for use
Unknown	Amount of effort unknown
Future	Dataset not yet available

Under certain conditions, costs and levels of effort can be reduced/mitigated by taking one or more of the following pathways:

- Awaiting, hastening, or facilitating the emergence of “horizon” datasets: datasets that are slated for delivery within the next 1 to 4 years.
- Influencing the conceptualization of future datasets: those not yet funded for development.
- Sequencing the deliberation of concepts in such a way that builds upon a logical framework of time investment. The WRMP’s master matrix is formulated in such a way that indicators often build upon and relate to one another. The data to inform one indicator therefore often lays the foundation for subsequently sequenced indicators.

These factors related to effort, cost, and mitigation inform some of the gaps and recommendations that you will find below (Figures 5-9).

Indicator 1: Map of baylands habitat types and elements (vegetated tidal marsh, tidal flats, diked marsh types, levees, channels, pannes, etc); impact areas and projects

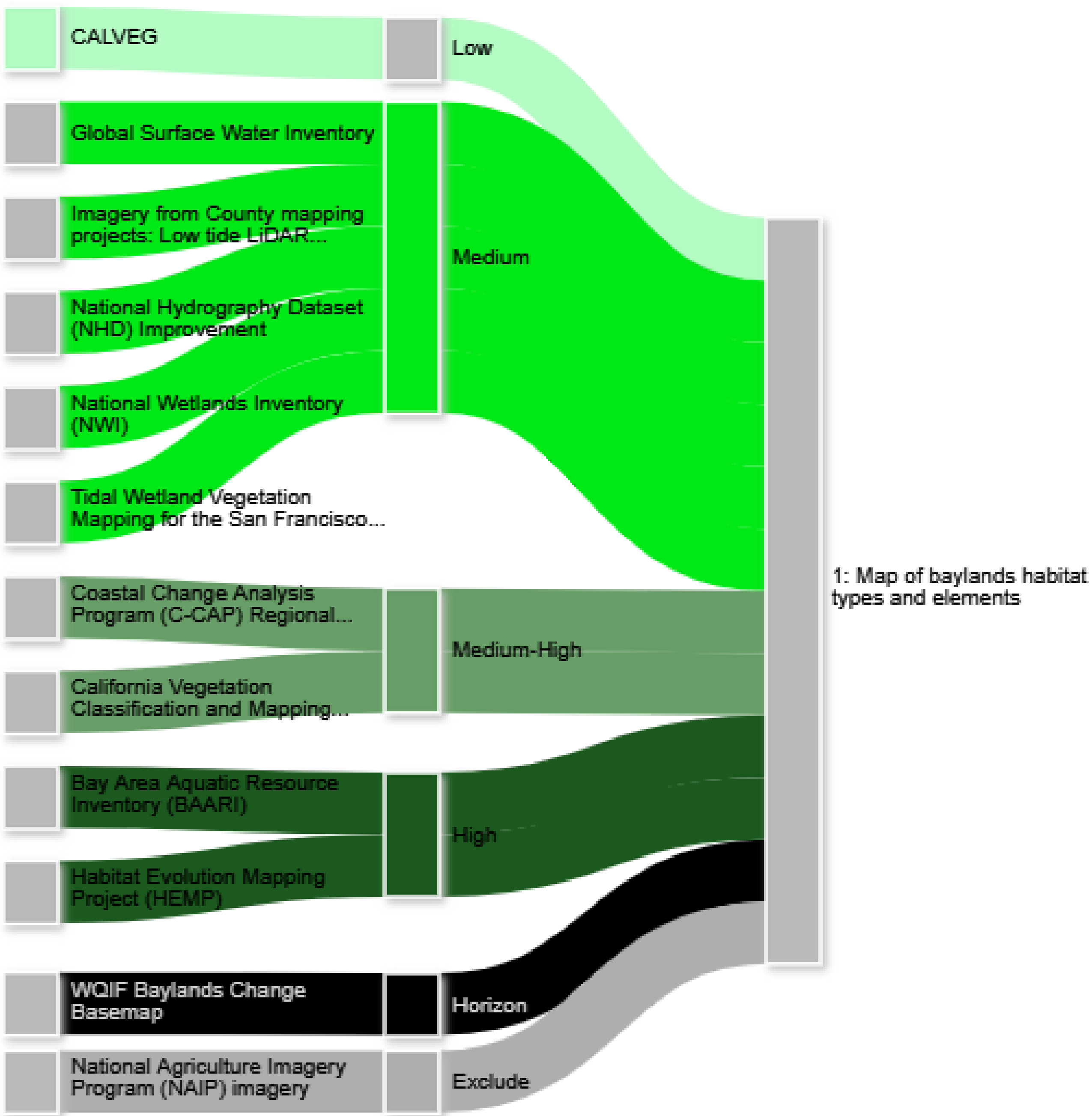

Figure 5. Illustration showing the datasets related to Indicator 1, color-coded by level of effort.

Indicator 2: Map of tidal wetland elevations and elevation capital

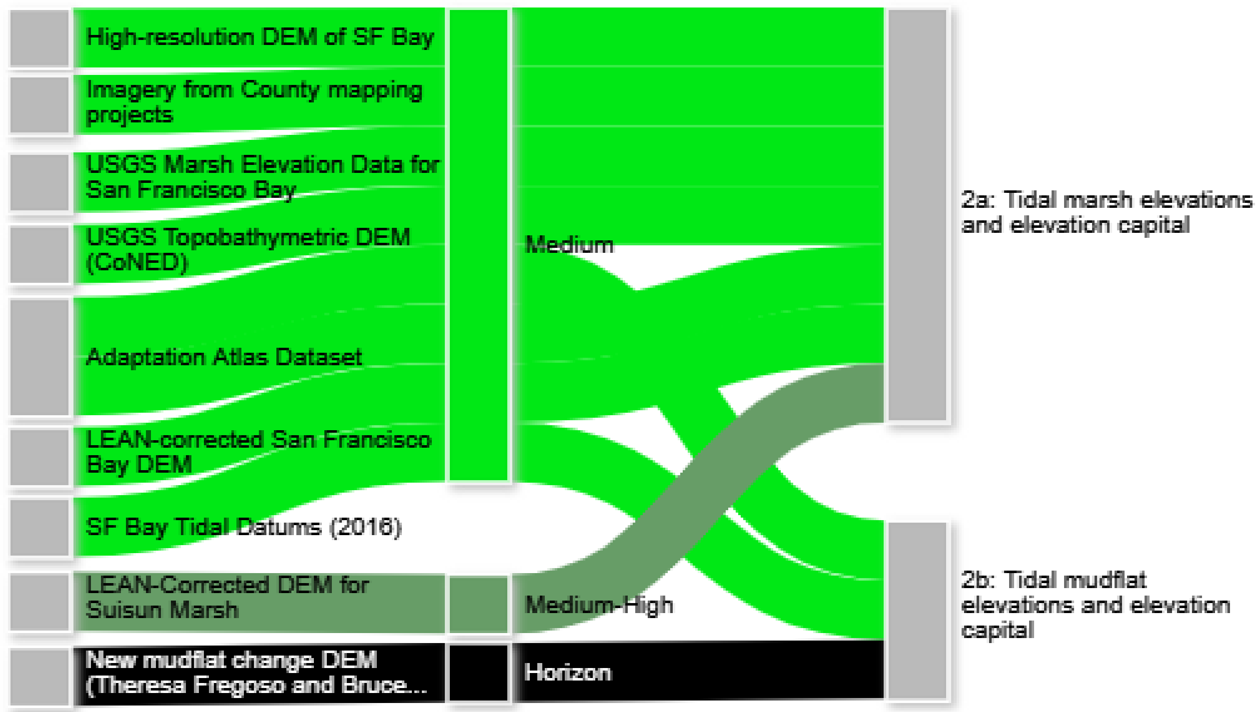

Figure 6. Illustration showing the datasets related to Indicator 2, color-coded by level of effort.

Indicator 3: Map of estuarine-terrestrial transition zones

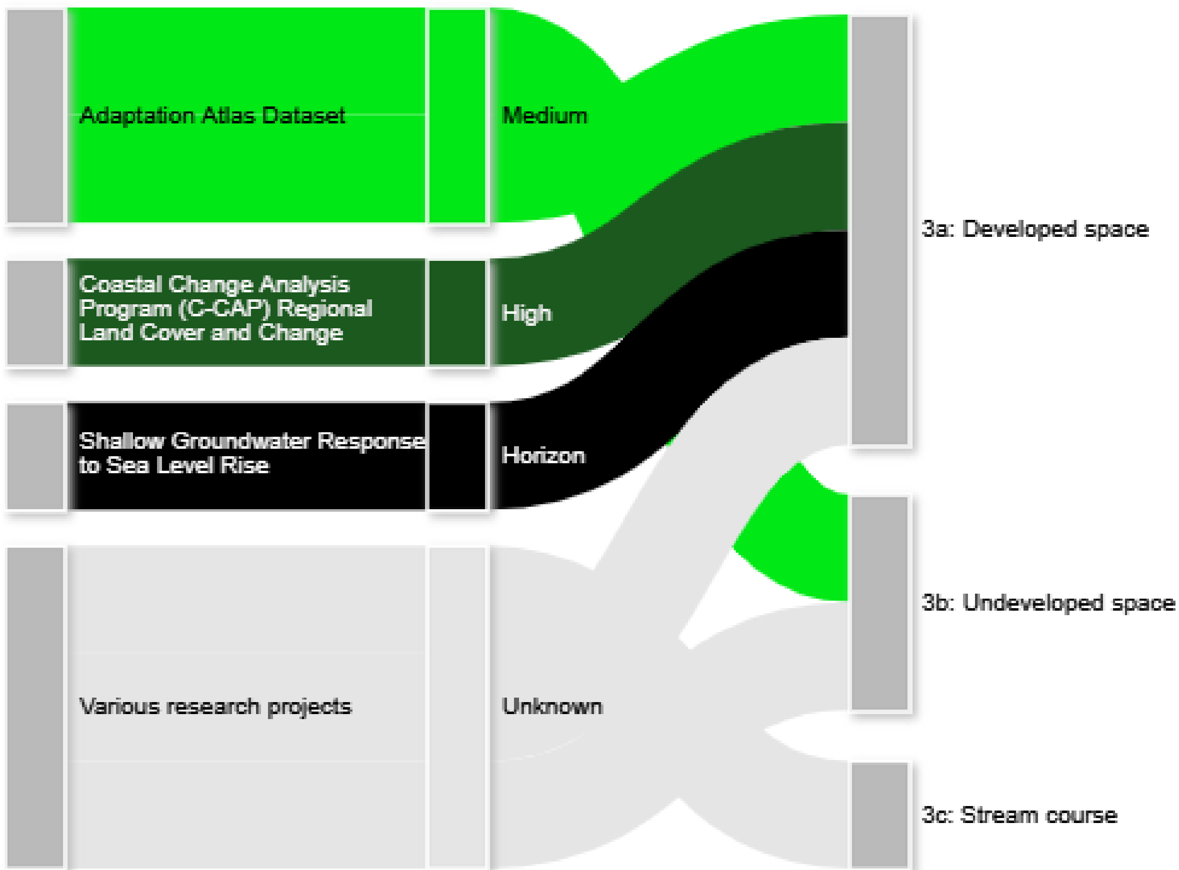

Figure 7. Illustration showing the datasets related to Indicator 3, color-coded by level of effort.

Indicator 6: Map of changes in the lateral extents of natural foreshores and backshores of tidal marsh

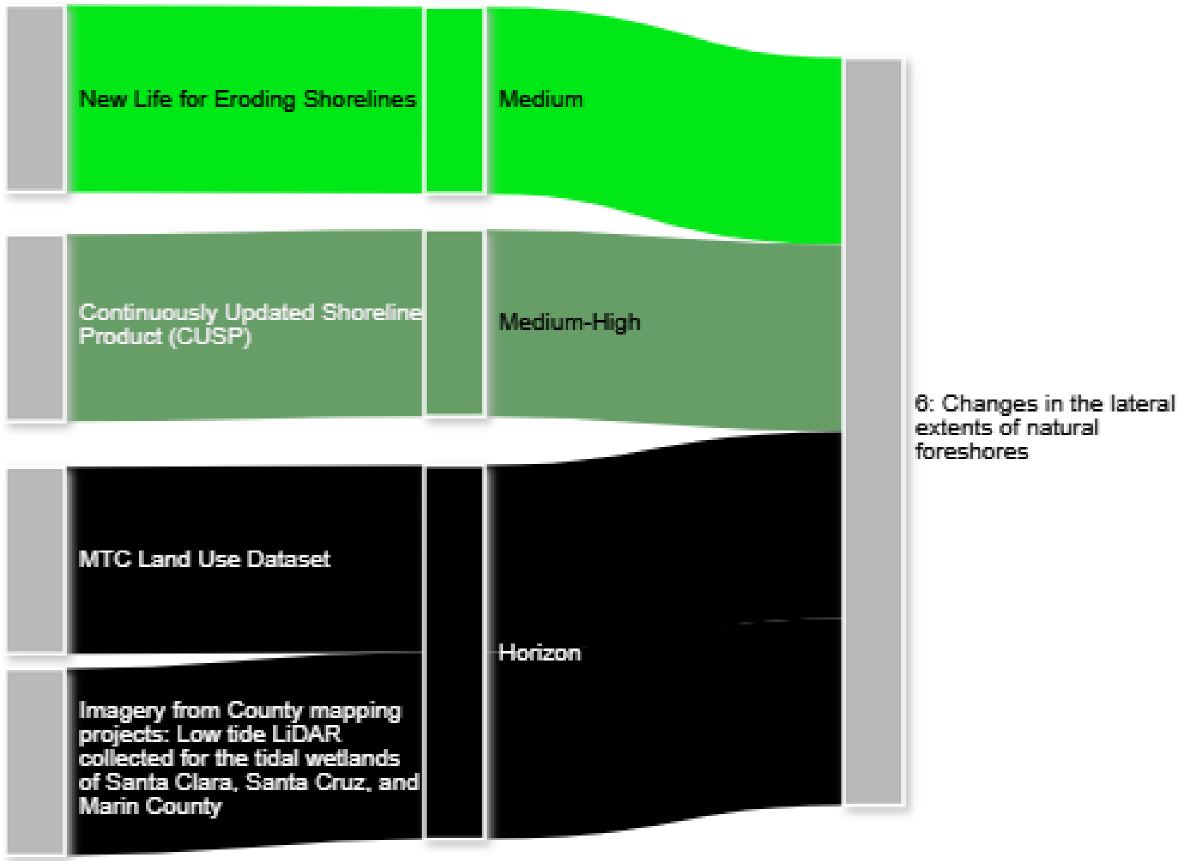

Figure 8. Illustration showing the datasets related to Indicator 6, color-coded by level of effort.

Indicator 7: Percent cover, height, and patch characteristics of major dominant vegetation groups within sub-basins

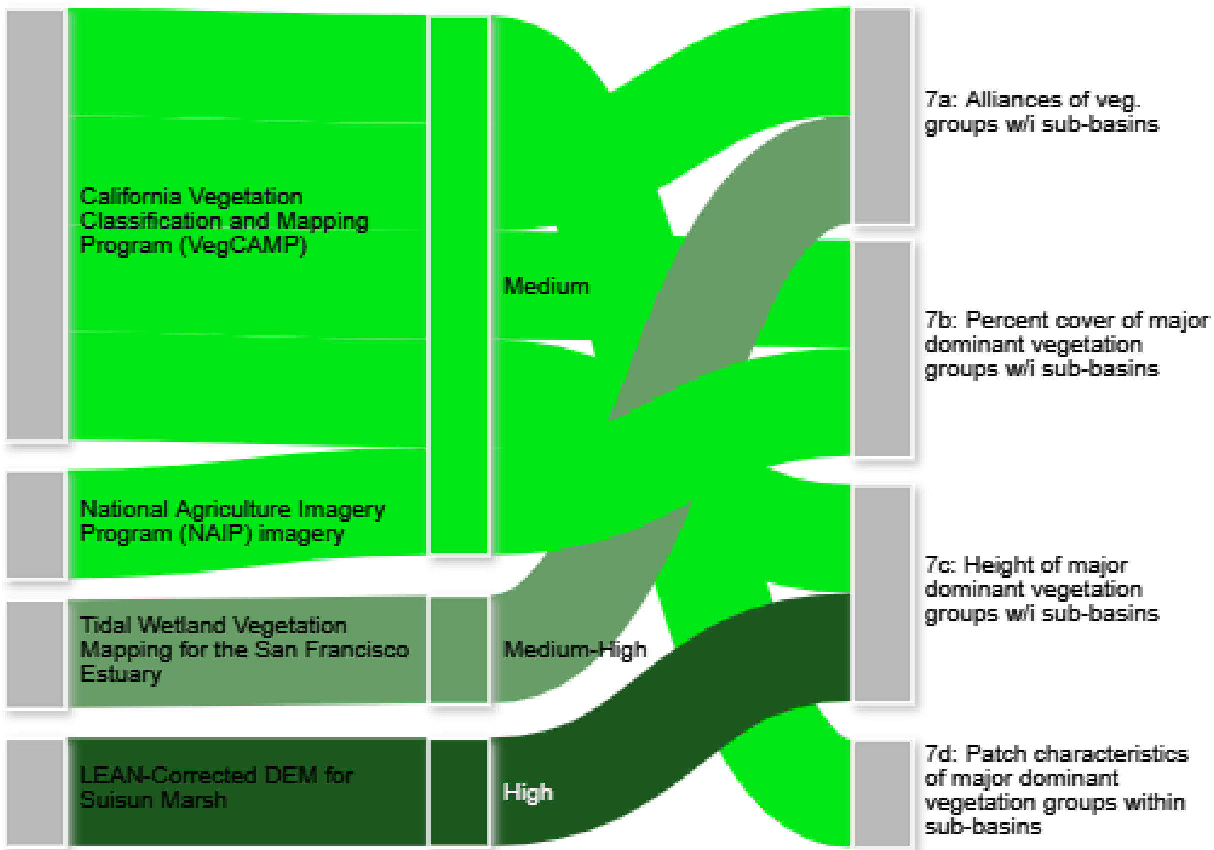

Figure 9. Illustration showing the datasets related to Indicator 7, color-coded by level of effort.

Gaps and Recommendations

Building upon the "challenges" associated with individual datasets, the indicators themselves often possess gaps that are not binary in nature, but are instead partial or contingent upon a number of complex factors. We have accordingly tried to characterize the gaps to account for the range of datasets and contingent conditions associated with each indicator. Those indicator-centric gaps can be broadly classified as following:

- **Gap 1 - The available datasets, taken collectively, do not meet one or more of the minimum criteria.** The more criteria it fails to meet, the higher the effort to adapt it for use with the WRMP's indicators.
- **Gap 2 - The datasets must be synthesized with one another in some way.** To make use of a dataset, it must be combined with another, compared to another, or otherwise measured against another dataset.

- **Gap 3 - The datasets consist of imagery, rather than a classified map.** In some cases, a given dataset might offer raw data without the interpretative framework to make it readily usable in the context of the program's indicators.
- **Gap 4 - There are "horizon" datasets that will likely address the salient indicator's needs, but such datasets are not yet available.** So-called "horizon" datasets are known quantities under active development, with known objectives, attributes, and project proponents. However, they are not publicly available for distribution.
- **Gap 5 - No suitable data yet exists.** Data suggested as potential matches do not meet minimum requirements or are not available.

It is worth highlighting that only one of the indicators (Indicator 7) has no suitable data yet (Gap 5). Therefore, the WRMP is being founded on a solid foundation of existing data and information. Several recommendations for the indicators (Indicators 1, 2, 6, and 7) include waiting for "horizon" datasets to be completed (Gap 4). This approach allows the WRMP to leverage existing projects and avoid duplicating efforts or recreating datasets. This report is intended to be a living document and will be updated periodically as new datasets are identified and gaps are resolved.

The Steering Committee may wish to regard the gaps associated with individual indicators as decisions regarding either allocation of resources or priority setting. We have indicated in the following list recommendations that the Steering Committee or related authority should consider and/or deliberate:

- ***Indicator 1:*** *Map of baylands habitat types and elements (vegetated tidal marsh, tidal flats, diked marsh types, levees, channels, pannes, etc); impact areas and projects*

  There are many datasets, but most don't meet the minimum requirements identified by the TAC (e.g., the minimum mapping unit is larger than many of our wetlands) and would require significant effort to synthesize. The high-resolution imagery and Lidar products for Marin, San Mateo, and Santa Clara counties will be available in the near future. The WQIF Baylands Change Basemap will be available in 2023.

  Minimum requirements

  Gap Type(s): Gap 1, Gap 2, Gap 3, Gap 4

  Recommendation: The TAC Geospatial Workgroup will guide the development of the Baylands Change Basemap and SOPs and determine the appropriate habitat types and elements to map. Wait for the WQIF Baylands Change Basemap to be completed since it addresses several gaps. Use the online editor tool to achieve the level of detail needed when and where needed (e.g., benchmark, reference, and project sites). Confirm habitat types for relevant projects and impact areas are correctly mapped in Project Tracker.

- *Indicator 2: Map of tidal wetland elevations and elevation capital*

  The TAC Geospatial Workgroup will need to help determine the best method for synthesizing the various datasets to address elevation capital, including which future high water level to use in the calculation.

  Minimum requirements

  Gap Type(s): Gap 2, Gap 4

  Recommendation: The TAC Geospatial Workgroup will determine the best methodology for mapping elevation capital.

- *Indicator 3: Map of estuarine-terrestrial transition zones*

  Various research projects with an unknown level of effort and C-CAP with a high level of effort means there is not a lot of available data. Existing C-CAP is at 30m resolution, but it is currently being refined for the Bay Area using the data developed by Mark Tukman, Kass Green, and others to update C-CAP at 1m resolution. However, it will not be consistent across all counties.

  Minimum requirements

  Gap Type(s): Gap 2

  Recommendation: The TAC Geospatial Workgroup will determine the best methodology for mapping transition zones, based on the broadest definition in BEHGU and consistent with mapping being performed for the Adaptation Atlas.

- *Indicator 6: Map of changes in the lateral extents of natural foreshores and backshores of tidal marsh*

  Many datasets are available in the near future so may want to wait until these are ready, for example the county imagery and Lidar efforts.

  Minimum requirements

  Gap Type(s): Gap 4

Recommendation: Wait until county imagery and Lidar projects have been completed and have published their data, and the MTC dataset has been released to inform land use planning. The county Lidar data are critical for detecting change.

- ***Indicator 7:*** *Percent cover, height, and patch characteristics of major dominant vegetation groups within sub-basins*

  Ready to analyze when the Tidal Vegetation mapping data are available for Marin, San Mateo, and Santa Clara counties.

  Minimum requirements

  Gap Type(s): Gap 4, Gap 5

  Recommendation: Wait until adequate Tidal Vegetation mapping data are available. Mapping is currently funded for Marin, San Mateo, and Santa Clara counties. Hopefully other counties will fund similar efforts.

Potential Tasks for Geospatial Workgroup

The WRMP TAC is currently organizing a Geospatial Workgroup as a subcommittee of its membership. This workgroup will be charged with several goals, some of which have been captured by way of the present document. For convenience, we have recapitulated some of the higher priority tasks before the workgroup below. However, the timeline for completing these tasks depends on the schedules and availability of Workgroup members.

1. The Geospatial Workgroup will guide the development of the Baylands Change Basemap, and SOPs for integrating the prioritized datasets and determine the appropriate habitat types and elements to map (Indicator 1). The workgroup must consider the proposed data sources, bearing in mind the repeatability of the analysis and expectation for map renewal to detect near-term changes in habitat extent, type, and distribution.

   Estimated timeline: 2021-2023

2. Review minimum standard requirements for the high-priority indicators and sub-indicators outlined in Table 2.

3. Determine best methodology for mapping elevation capital (Indicator 2).

4. Determine best methodology for mapping transition zones, based on the broadest definition in BEHGU and consistent with mapping being performed for the Adaptation Atlas (Indicator 3).

5. Standardize the terms we use for the different major parts of the Estuary (e.g., basin/sub-basin, region/sub-region) and ensure consistency with terms used in the Delta.

6. Explore relationships with federal agencies who are acquiring imagery and coordinate authorization for its use.

7. Coordinate decisions regarding methodology and data sources with related workgroups, the San Francisco Estuary Geospatial Workgroup (Bay Area-focused) and the Regional Imagery Collaborative (Delta-focused).

Related Documents

The following documents are forthcoming, based on the fit-gap analysis contained in the present document:

- **Indicator Calculation Document** will show how specifically the data in various datasets are synthesized to produce essential metrics.
- **Standard Operating Procedures (SOPs)** will document the required processes for collecting the datasets, capturing the steps related to data processing, including any enhancements, and integrating them into a WRMP-focused data portal.

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DATA SOURCES

All data sources cited in this document are listed under Table 1.

APPENDICES

Table 3. Minimum Requirements for Data Sources.

Name of dataset	Resolution	Geospatial Extent	Frequency of Updates	Documentation / Data Quality
Aboveground Biomass High-Resolution Maps for Selected US Tidal Marshes, 2015[4]	30 m biomass maps	SF Bay (doesn't include South Bay but K. Byrd is able to quickly update the maps to include that area)	Last Updated (v1.1): 03/22/21	User Guide: https://daac.ornl.gov/CMS/guides/Tidal_Marsh_Biomass_US_V1-1.html
Adaptation Atlas Dataset		SF Estuary (lower)		
Bay Area Aquatic Resource Inventory (BAARI)	Tidal wetlands mapped at scale of 1:2500. Minimum mapping unit is 0.005 ha (50 sq m) for tidal polygonal features and 25m for length of tidal channels (natural and unnatural).	All watersheds that are contained within the San Francisco Bay Regional Water Quality Control Board (RB2) boundary.	Last Updated: 12/28/17	SOPs: https://www.sfei.org/sites/default/files/general_content/SFEI_MAPPING_STANDARDS_08092011_v8_0.pdf

[4]Dataset received in August 2021 and was not included in the Fit-Gap Analysis.

California Avian Data Center		Pacific Flyway	Continual updates through contributions	Best practices last updated in 2010. Covers surveys and data management standards.
California Vegetation Classification and Mapping Program (VegCAMP)	Minimum of 10 m accuracy - Alliances and Associations	California; Alliance scale vegetation polygons	2007 - 2018	Classification and mapping standards (2020): https://nrm.dfg.ca.gov/FileHandler.ashx?DocumentID=102342&inline
CALVEG	Spatial resolution? Classification: 213 types at the alliance level	California (USFS Region 5) - SF part of several mapping regions: North Coast Mid, North Coast West, and Central Coast	Infrequent. Bay Area at cusp of "North Coast", "Central Coast," and "Central Valley." Most are on the Central Coast. North Coast last mapped 2007. Central Coast and Central Valley in 2001.	https://www.fs.usda.gov/detail/r5/landmanagement/resourcemanagement/?cid=stelprdb5347192 Also shares assurances of crosswalks to FGDC-approved systems. The CALVEG classification is a provisional system that meets the floristically based level of the National Vegetation Classification Standard hierarchy. These vegetation alliances were originally developed by the Region's Ecology Program in 1978. (USDA Forest Service. 1981. CALVEG: A Classification of California Vegetation. Pacific Southwest Region, Regional Ecology Group, San Francisco CA. 168 pp.)

Coastal Change Analysis Program (C-CAP) Regional Land Cover and Change	30 m Currently being refined for Bay Area to 1 m resolution	Coastal counties	Updated every 5 years	C-CAP Classification Scheme and Class Definitions Use of standardized data and procedures assures consistency through time and across geographies
Continuously Updated Shoreline Product (CUSP)	> 1 m	Continental U.S	Continuous	
EcoAtlas Project Tracker		California	Continuous	
Global Surface Water Inventory	30 m	World. Available for California.	Last survey year 2019. Shows water year history for each pixel in 36-year period.	Non-standard. Metadata available on following attributes: Occurrence Occurrence change intensity Seasonality Recurrence Transitions Maximum water extent Data User's Guide available from this page.

Habitat Evolution Mapping Project (HEMP)	0.5 m (2019 and 2021) 1 m (2009-2011) Maps vegetation to alliance level	South Bay - map over 15,000 acres of marsh habitats and mudflats	Phase 1: 2009-2011 Phase 2: 2019 & 2021 (in process)	**HEMP 1 Final Report:** https://www.southbayrestoration.org/sites/default/files/documents/hemp_finalreport_072312.pdf **HEMP 2 Preliminary Report:** https://www.southbayrestoration.org/document/habitat-evolution-mapping-project-decadal-update-2019-2021-preliminary-results-2019 **Year Two Annual Report (2010-2011):** https://www.southbayrestoration.org/document/annual-report-year-two-habitat-evolution-mapping-project-south-bay-salt-pond-restoration
High-resolution DEM of SF Bay	1 m	Northern San Francisco Bay	Data Collection: 1999-2016	Metadata: https://www.sciencebase.gov/catalog/file/get/5e1cb737e4b0ecf25c5f0bf6?f=__disk__fe%2Fde%2F90%2Ffede90165e5b9223546a151280cbb66bb3992544&transform=1&allowOpen=true

Imagery from County mapping projects: Low tide LiDAR collected for the tidal wetlands of Santa Clara, Santa Cruz, and Marin County	LiDAR: 10 cm	Santa Clara County	Per SOW table in Section 2: County will collect orthos of the entire county every year from 2020 through 2023-2024, with another round of countywide LiDAR in 2022-2023.	
LEAN-Corrected DEM for Suisun Marsh	5m	Suisun Marsh	2018	Contact Kevin J Buffington Email: kbuffington@usgs.gov
LEAN-corrected San Francisco Bay DEM	1m	San Francisco Bay	2018	
Metropolitan Transportation Commission (MTC) Land Use Dataset	Varies	9 Bay Area Counties	June 2021	Pending development
National Agriculture Imagery Program (NAIP) imagery	1 m	USA	Flights aren't timed with the tide, therefore the imagery may not always work, even if the dates are technically available. 3-year cycle	Documentation is not as strong as expected. Users have produced metadata in various forms -- eg, https://mnnaturalresourceatlas.org/metadata/2015_FSA.html

National Hydrography Dataset (NHD) Improvement	40 m	USA	Continuous	Data Framework, User's Guide, and other documentation: https://www.usgs.gov/core-science-systems/ngp/ss/hydrography?qt-science_support_page_related_con=4#qt-science_support_page_related_con https://www.epa.gov/waterdata/learn-more#Documentation
National Wetlands Inventory (NWI)	Multi-scale	USA	5/1/2016, version 2. Noted departure from version 1. Most comes from 1980s data.	Detailed metadata and SOPs: https://www.fws.gov/wetlands/Data/Metadata.html
New Life for Eroding Shorelines		Not complete for Bay	2020	
USGS New mudflat change DEM				
Pacific Marine and Estuarine Fish Habitat Partnership (PMEP) West Coast Estuary Viewer	5 m	West Coast estuaries: https://psmfc.sharefile.com/share/view/s459af5f65f8419a9		
San Francisco Bay Nutrient Management Strategy Observation Program			2016	
SF Bay Tidal Datums (2016)		SF Estuary (lower)		
Shallow Groundwater Response to Sea Level Rise				

Tidal Wetland Vegetation Mapping for the San Francisco Estuary	fine-scale resolution (100+ classes); 6-in orthoimagery	Sonoma, Marin, San Mateo, San Francisco, Santa Clara, Santa Cruz Counties and Elkhorn Slough	2017-2021 Sonoma - completed 2017 Marin, San Mateo, San Francisco - completed 2017-2018 Santa Cruz, Santa Clara, Napa - started in 2019 Alameda, Contra Costa, Solano - pending	
USGS Marsh Elevation Data for San Francisco Bay		San Francisco Bay	2018	
USGS Topobathymetric DEM (CoNED)	2m	SF Coastal Waters, Open Bay, and Baylands		
Various research projects				
WQIF Baylands Change Basemap	1st order channels, 5 sq-m pannes	SF Bay	2021-2023	Pending

Table 5. Management Questions of the WRMP.

Management Question Number	Management Question
1A	What is the distribution, abundance, diversity, and condition of tidal marsh ecosystems, and how are they changing over time?
1B	Are changes in tidal marsh ecosystems impacting water quality?
2A	How are tidal marshes and tidal flats, including restoration projects, changing in elevation and extent relative to local tidal datums?

2B	What are the regional differences in the sources and amounts of sediment available to support accretion in tidal marsh ecosystems?
3A	Where and when can interventions, such as placement of dredged sediment, reconnection of restoration projects to watersheds, and construction of living shorelines, help to sustain or increase the quantity and quality of tidal marsh ecosystems?
4A	How are habitats for assemblages of resident species of fish and wildlife in tidal marsh ecosystems changing over time?
4B	How are the distribution and abundance of key resident species of fish and wildlife of tidal marsh ecosystems changing over time?
5A	What mosquito and vector control strategies need to be considered in restoration design and management to understand the effects that restoration can have on mosquito and vector populations?
5B	What monitoring data are needed to optimize the relationship between tidal marsh restoration, fish and wildlife support, and mosquito and vector control?

Table 6. Master Matrix of the WRMP.

Mgmt Questions	Monitoring Questions	Ind No.	Indicators	Metrics	Data Type and Source
All, but mainly 1	What is the distribution and abundance of the estuary's tidal wetlands and other baylands?	1	Map of baylands habitat types and elements (vegetated tidal marsh, tidal flats, diked marsh types, levees, channels, pannes, etc); impact areas and projects.	Acres and locations of habitat types and elements differentiated by hydrology, salinity, vegetation cover, and elevation capital.	Impact Areas and Project areas using Project Tracker SOP; Remote Sensing Special Study will provide details but new BAARI SOP will likely involve satellite LiDAR w/ ground-truthing for a regional comprehensive inventory
All, but mainly 1	What are the elevations of the estuary's existing and restoring tidal wetlands? What is their elevation capital?	2	Map of tidal wetland elevations and elevation capital	Elevations (ft NAVD) and elevation capital (Z*); relative to local MHHW)	Remote Sensing Special Study will provide some needed details; likely to include elevation relative to MHHW and local geodesy, based on LiDAR w/ LEAN correction, drone motion-for-structure data,

Mainly 1	Where do tidal wetlands have space to migrate upslope?	3	Map of estuarine-terrestrial transition zones		on-site elevation transects and SETs tied to dedicated tide gauges and geodetic benchmarks at Benchmark Sites; migration space derived from DEM using NOAA, BCDC and other transgression models/maps, plus ABAG land use maps and best available veg maps
All	Where do tidal wetlands support complex habitat diversity and connectivity?	4	Map of "complete marshes" as defined by BEHGU and fluvial/upland/riparian connectivity.	Acres and location of marshes with combinations of the elements of "complete marshes" (marsh plain, channel, pond/panne, transition zones, riparian connection)	See Indicators 1, 2, and 3 above
All	What is the distribution and abundance of tidal wetland habitats that can support special-status species?	5	Map of tidal wetland special-status species habitats.	Acres and location of habitat types that could support special-status species.	See Indicators 1, 2, and 3 above; Answers are derived from interpretations of maps of marsh 3D and vegetation (e.g. high tide refugia, pannes, some channel, etc within specific salinity regimes)
Mainly 2-4	Where are shorelines eroding landward and/or growing seaward?	6	Map of changes in the lateral extents of natural foreshores and backshores of tidal marsh	Shoreline location	SFEI/BCDC shoreline change detection tool
All, but mainly 1	What is the current distribution, extent, and diversity of dominant vegetation communities in the estuary?	7	Percent cover, height, and patch characteristics of major dominant veg. groups within sub-basins.	Remote Sensing Special Study will provide details; Likely to include acres and location of dominant tidal wetland vegetation alliances, patchiness, total % cover, veg height, etc.	Remote Sensing SpecialStudy will provide details; SOPs will likely involve satellite and UAS aerial imagery (4-band) and gradsects along channels and along elevation and salinity gradients within each sampled marsh
Mainly 2-4	What are the rates of change over time in the spatial extent and distribution of dominant vegetation communities (including native and non-native vascular plants) along the primary and secondary salinity gradients of the estuary	8	Direction and magnitude of changes in percent cover, height, and patch characteristics of major dominant veg. groups within sub-basins.	Remote Sensing Special Study will provide details; Likely to include acres and location of dominant tidal wetland vegetation alliances, patchiness, total % cover, veg height, etc.	SOPs will likely involve satellite and UAS aerial imagery (4-band) and gradsects along channels and along elevation and salinity gradients within each sampled marsh
Mainly 2-4	Where are unvegetated areas such as channels, ponds, and pannes expanding?	9	Changes in drainage network length, channel density, channel width, numbers and sizes of pannes, size of un-vegetated areas of tidal marsh plains.	Remote Sensing Special Study will provide details; Likely to include 2nd-order and larger channels, mosquito control and other ditches, size-frequency of pannes, etc.	SOPs will likely involve Lidar and satellite and UAS aerial imagery (4-band) plus ground-truthing
All, but mainly 1 - 3	Where are non-native species a significant component of the dominant tidal wetland vegetation community? Where are they expanding?	10	Distribution and abundance of selected non-native, invasive plant species.	Remotely sensed marsh 3D and veg metrics; CRAM Index and Attribute Scores	Regional WRMP habitat maps and CRAM surveys

All, but mainly 2 - 4	What is the overall condition or health of the estuary's tidal wetlands?	11	CRAM site scores and regional Cumulative Distribution Functions (CDFs).	CRAM Index and Metric scores relative to regional CRAM CDFs	CRAM assessments using the CRAM SOP
All, but mainly 2 - 4	How are the elevations of marsh plains (including high tide refugia) changing over time, and where in the estuary are tidal wetland accretion rates keeping up with rates of sea level rise?	12	Spatial and temporal trends in marsh plain and tidal flat vertical change and accretion rates.	Marsh plain and tidal flat accretion rates relative to local tidal datums and NGVD	SETs, field surveys and remotely sensed elevationdatatided to vertical control benchmarks
All, but mainly 2 - 4	Where is there adequate suspended sediment to support rates of accretion that are equal to or greater than sea level rise (SLR), and monitoring data are needed to develop and calibrate numerical models that forecast the variations in suspended sediment supply?	13	Spatial and temporal trends of SCC in tidal marsh channels in relation to watershed yields of SS and SSC in estuarine shallows and bays.	Suspended sediment concentrations	Acoustic SSC sondes co-located with water level sondes (continuous), grab samples (event-based), sediment rating curves, near-shore SSC (Bay RMP), and rainfall, flow data and wave energy estimates for Benchmark Sites
All	How do tidal inundation regimes differ throughout the estuary's tidal wetlands, and are they muted, choked, or otherwise different from source tides?	14	Spatial and temporal trends in the frequency, duration, and depth of tidal inundation of marsh plains.	Tidal inundation regime	Tidal stage and tide height statistics plus site topography relative to local MHHW.
All	What are the regional rates of sea level rise and how do they vary throughout the estuary?	15	Spatial and temporal trends in the rate of sea level rise.	Annual mean sea level rise. There will be the ongoing observations by NOAA at the GG and other permanent tide stations, plus the gages at the BM sites, plus any other gauges properly installed and maintained for at least one year.	Tide height data from all gauges in the region that meet QAQC requirements
All, but mainly 2 - 4	How are the primary and secondary salinity gradients in the estuary's tidal wetlands changing over time?	16	Spatial and temporal trends in aqueous salinity of tidal marsh channels and porewater salinity along gradsects.	Aqueous (in-channel) and porewater salinity	Sonde salinity data in tidal marsh channels; Seasonal in situ porewater salinity measurements in root zone along gradsects
All, but mainly 1, 3, and 5	Where do tidal wetlands and channels provide adequate water quality to support fish and other aquatic life?	17	Mercury loading into tidal marsh food webs.	Hg concentrations in blood or tissue of bio-sentinel species representing tidal flats, young marshes (reference sites) , and mature marshes (Benchmark Sites).	Dedicated field collection of biota or their tissue/blood using existing bio-sentinel SOPs
All, but mainly 1, 3, and 5	Where do tidal wetlands and channels provide adequate water quality to support fish and other aquatic life?	18	DO in tidal marsh channels.	DO concentrations	DO concentrations from in-situ instrument in selected tidal marsh channels

All, but mainly 2-4	What is the response of resident tidal marsh birds?	19	Distribution and abundance of indicator species.	California Ridgway's Rail, California Black Rail, tidal marsh Song Sparrow spp., Saltmarsh Common YellowThroat, throat, abundance, trends in abundance	Dedicated field surveys at selected Benchmark Sites, Reference Sites, and Projects using existing SOPs:Tidal marsh passerines,Secretive marsh birds.
All, but mainly 2-4	What is the response of resident tidal marsh small mammals?	20	Distribution and abundance of indicator species	SMHM, perhaps California Vole	Dedicated field surveys at selected Benchmark Sites, Reference Sites, and Projects using existing SOPs
All, but mainly 2-4	What is the response of resident tidal marsh fishes?	21	Distribution and abundance of indicator species	Abundance of Longjaw Mudsucker; community composition, abundance, and distribution of estuarine fish (pelagic/larval and marshplain), and anadromous fish (Chinook salmon and steelhead trout)	Dedicated field surveys at selected Benchmark Sites, Reference Sites, and Projects using existing SOPs
Mainly 5	What is the distribution and abundance of tidal marsh mosquito habitats?	22	Distribution and abundance of potential mosquito breeding areas	Total area and patch size of known and potential areas of mosquito production	Maps based on LiDARand satellite and UAS aerial imagery (4-band)and vegetation
Mainly 5	What is the production of mosquitoes by tidal marshes?	23	Mosquito production	Counts of mosquito adults and larvae by species	Surveillance SOP