Performance Measure 4.15: Seasonal Inundation

Performance Measure (PM) Component Attributes

Type: Outcome Performance Measure

Description

Restoring land-water connections to increase hydrologic connectivity and seasonal floodplain inundation.

Expectations

Increased hydrologic connectivity and increased frequency of seasonal inundation contributes to achieving a healthy Delta ecosystem and viable populations of native species.

Metric

Acres within the Sacramento-San Joaquin Delta and Suisun Marsh that are:

1) Hydrologically connected to fluvial and tidally influenced waterways.
2) A floodplain[1] area that inundates[2] at least once every two years.

Metric will be evaluated annually.

Baseline

As of the year 2013:

1) An estimated 75,000 acres of land physically connected to the fluvial river and tidal system.

[1] Area that is inundated on a two-year recurrence frequency and is connected to the fluvial river or tidal system.
[2] There is no depth threshold for the inundation analysis, as inundation occurs at any depth. While depth of inundation is important for ecological processes, the available data do not include depth measurements.

2) Approximately 15,000 acres of the connected land inundated at a two-year interval, calculated as a long-term average for 1998-2018.

Target

By 2050:

1) Additional 51,000 acres added to the 75,000-acre baseline that are physically connected to the fluvial river and tidal system.
2) At least an additional 19,000 acres of floodplain area is inundated on a two-year recurrence interval, for the total of at least 34,000 acres.

Basis for Selection

Since the 1800s, 91 percent of historical wetland habitat in California has been lost (Dahl 1990), including 95 percent of Central Valley floodplain habitat (Opperman et al. 2010, Whipple et al. 2012). In the Delta, most of these wetlands and floodplains have been drained and converted to agricultural land use (Robinson et al. 2014). Although most of the natural wetlands no longer remain, some agricultural land, floodways, and floodplains can provide similar functions, including greatly increased aquatic food production compared to other converted land uses (Moyle and Mount 2007, Corline et al. 2017, Katz et al. 2017). However, in order for these functions to be maintained or restored, areas must be hydrologically connected, and inundated for at least part of the year (Sommer et al. 2001a, Jeffres et al. 2008, Opperman et al. 2010, Katz et al. 2017).

The ecological health of the Delta is fundamentally dependent on the reestablishment of more natural inundation patterns and land-water connections. It is expected that increased area and frequency of floodplain inundation will result in enhanced primary productivity, an improved food web and flow of nutrients that better support a healthy and functioning ecosystem (Ahearn et al. 2006, Cloern et al. 2016). Floodplain inundation occurs when rivers or waterways exceed their channel capacity and flow onto adjacent lands. In the Delta, this most often occurs during winter and spring months.

Restoration of land-water connections to provide the biological benefits of floodplain inundation requires two components: 1) physical or hydraulic connectivity for water to flow onto land; and 2) sufficient flow of water to inundate these connected areas (Merenlender and Matella 2013).

Hydrologic Connectivity

Connectivity between areas of fresh and saline water, riverine, riparian, floodplain, and other aquatic and terrestrial transitions is critical for the health and productivity of aquatic ecosystems (Opperman 2012, Robinson et al. 2014, Cloern et al. 2016, Robinson et al. 2016). The aquatic food web benefits from an exchange between land and water habitats (Polis et al. 1997, Ahearn et al. 2006, Opperman et al. 2010). However, transformation of the Delta from its mid-1800s condition has also increased connectivity of some waterways in manners that may negatively affect ecosystem functions, such as through construction of water conveyance structures and channels that cross the Delta (Whipple et al. 2012). In some areas, limiting connectivity of waterways from such structures could improve ecosystem function (Robinson et al. 2016). For this reason, this performance measure excludes several conveyance structures from the connectivity portion of this metric.

The connectivity metric in this performance measure tracks the landscape in which physical dynamics, supported by geomorphic land-water interaction, can take place. This interaction requires two components: 1) physical or hydraulic connectivity that allows water to flow onto land; and 2) sufficient flow of water to inundate these connected areas (Merenlender and Matella 2013). Within the Delta, the terrestrial system has been largely disconnected from fluvial and tidal connectivity, even during periods of high flows. Restoring physical connectivity to the fluvial river and tidal system can help restore ecosystem processes and support many native species.

Seasonal Floodplain Inundation

Seasonal floodplain inundation is critical for providing a range of ecosystem benefits such as freeing and transformation of nutrients, increasing primary productivity, and creation of habitat that can serve as a migratory pathway, rearing habitat, and refuge for juvenile salmonids (Junk et al. 1989, Sommer et al. 2001b). Such areas promote wetland ecosystem functions and are a high-value area for rearing and spawning of fish species such as Sacramento splittail and Chinook salmon, leading to increased survival rates. Food production (phytoplankton and zooplankton biomass) requires sufficient duration of inundation to develop, thus food-web processes and habitat provision increase with duration of inundation (Sommer et al. 2001b, Moyle et al. 2008, Katz et al. 2017). Illustrative areas within or near the Delta include the Yolo Bypass, Sutter Bypass, agricultural and other vegetated lands that are regularly inundated, and areas of the Cosumnes River Preserve.

The hydrologically connected metric tracks the area of land available to tidal and freshwater inundation, and the floodplain metric tracks seasonal water surface area that inundates these connected areas.

Linkages to Delta Reform Act and the Coequal Goals

Delta Reform Act

The Delta Reform Act mandates that the Delta Plan include measures that promote specified characteristics of a healthy Delta ecosystem (Water Code section 85302(c)). Increased hydrologic connectivity and seasonal inundation of floodplains contribute to achieving "diverse and biologically appropriate habitats and ecosystem processes" (Water Code section 85302(c)(3)) and support "Conditions conducive to meeting or exceeding the goals in existing species recovery plans and state and federal goals with respect to doubling salmon populations" (Water Code section 85803(c)(5)).

Native resident and migratory fish species rely on habitat connectivity and floodplain inundation for their life cycle and the ecosystem functions they provide, aligning with "Viable populations of native and resident and migratory species" (Water Code section 85302(c)(1)). Restored land-water connectivity will provide diverse habitats and ecosystem processes such as primary production and energy transfer which supports "diverse and biologically appropriate habitats and ecosystem processes" (Water Code section 85302(c)(3)).

Delta Plan Core Strategy

4.2 Restore Ecosystem Function.

4.4 Protect Native Species and Reduce the Impact of Nonnative Invasive Species.

Methods

Baseline Methods

Connectivity

Council staff developed a hydrologically connected spatial dataset by combining data for levee locations (to identify in-channel areas), bypasses, and floodways. Levee locations were compiled from multiple levee data sources, and from aerial imagery. Levee data sources included the following data sets. Data is listed in priority of use, with items first on the list being used in place of items later in the list when there is spatial overlap:

1. **DWR 2012:** i7 Delta Levee Centerline Classifications. Available online.
2. **URS 2007:** Delta Vision. Draft dataset provided by DWR and compiled by the consulting firm Arcadis in 2014 as part of the Council's Delta Levee Investment

Strategy (DLIS) process. Not available online. DLIS feature class name: *DeltaVision_Levee_Reach_by_Hydro*

3. **DWR and URS 2007:** Delta Risk Management Strategy (DRMS) – Developed for DWR by URS Corporation in 2007; last updated 2013. Version used compiled by the consulting firm Arcadis in 2014 as part of the DLIS process. Not publicly available. DLIS feature class name: *levee_delta_centerlines_DRMS*
4. **Groves et al. 2019:** Decision Support Tool for the San Francisco Bay-Delta Levees Investment Strategy. Available online.
5. **DWR 2015:** Non-Project Levees. Part of a database intended to assist public agencies in assessing public safety needs for areas protected by levees. Compiled by the consulting firm Arcadis in 2014 as part of the DLIS process. Not publicly available. feature class name: *DWR_Levees_AllRDs*

Using the software program ArcGIS (version 10.4.1), these data were merged and clipped to the boundaries of the Delta and Suisun Marsh. Council staff removed areas when satellite imagery (NAIP 2016) indicated that the areas were unconnected, for example, when located on the landside of a levee. The connected areas were then compared to Global Surface Water Extent (GSWE) data to confirm if at least part of the contiguous area had been inundated at any point within the last 30 years. The baseline was then calculated as the entire hydrologically connected area, regardless of the area actually inundated during this period.

Inundation

To calculate the baseline, the 1984-2018 GSWE data (Pekel et al. 2016) was used to identify areas that were inundated at least once every two years, but not inundated all of the time (i.e., inundation occurrence frequency between 50 and 90 percent). The inundated dataset was clipped to hydrologically connected areas within the Legal Delta and Suisun Marsh (Liberty Island was removed because it is now open-water area). This analysis identified approximately 15,000 acres of inundated area; however, this area represents a long-term average over more than 20 years. In addition, much of this area can be found within channel margins (bounded by levees) and along riparian areas/levee-water interfaces and is not limited to floodplains. Due to this and other limitations with the currently available data (see below), the baseline was set at zero acres as of the year 2013. This baseline emphasizes that the target focuses on new, not currently inundated areas, as of 2013, which is when the Delta Plan was adopted.

There is no depth threshold for the inundation analysis since the data sources do not include this information.

Target Methods

Connectivity

The connectivity target is based on quantitative goals provided in the 2016 Central Valley Flood Protection Plan (CVFPP) Conservation Strategy, Appendix H (DWR 2016a, pp. H-4-6 to H-4-8) which identified numeric floodplain and tidal marsh area targets. These targets were based on the area modeled to help recover spring and fall-run Chinook salmon to meet the Central Valley Project Improvement Act (CVPIA) of 1992 salmon doubling goal. The area modeled to achieve this goal is reported in the 2016 CVFPP Conservation Strategy, Appendices H (DWR 2016a) and L (DWR 2016b) as follows: 11,000 acres for the Sacramento River Basin, and 4,500 acres for the lower San Joaquin River Basin. Analysis for the CVFPP identified that on average, only 17 percent of floodplains are considered suitable for salmonid species (DWR 2016a). To account for this, the areas required were divided by 17 percent to generate 64,705 acres needed for the Sacramento River Basin and 26,471 acres for the San Joaquin River Basin. Council staff then scaled these areas by the relative proportion of the Conservation Planning Areas (CPA) for the CVFPP within the Delta and Suisun Marsh as determined by a spatial analysis: approximately 52 percent of the Lower Sacramento CPA and 67 percent of the Lower San Joaquin CPA fall within this area. Multiplying by these respective factors (see equations below) results in 33,647 acres in the Lower Sacramento CPA and 17,735 acres in the Lower San Joaquin CPA, for a sum of 51,382 acres of floodplain habitat (see below). After rounding, the connectivity target is set to 51,000 acres. Here are the equations to set the targets:

- Sacramento CPA: 64,705 acres x 52% = 33,647 acres
- San Joaquin CPA: 26,471 acres x 67% = 17,735 acres

Inundation

The 2016 CVFPP Conservation Strategy (Appendix H, p. H3-H7) calculated the amount of new floodplain needed in the Sacramento and San Joaquin watersheds to support doubling salmon populations, and it suggested that floodplains should be inundated in two-year intervals to support salmon life cycles (DWR 2016). To calculate the area required for inundation targets, the connectivity target of 51,000 acres was proportionally split into non-tidal (fluvial) and tidal areas based on estimation of historical habitats. San Francisco Estuary Institute's (SFEI) historical ecology spatial data estimates 63 percent of the Delta as tidal, and 37 percent as non-tidal (Whipple et al. 2012). Multiplying the non-tidal estimate of 37 percent by the target of 51,000 acres of connectivity represents the floodplain inundation target of 19,000 acres (number rounded).

Data Sources

Primary Data Sources

The primary data sources listed below will be used for tracking this performance measure:

Connectivity

1. The Delta Stewardship Council Covered Actions Website. On-the-ground projects that restore connectivity (such as levee breach, levee notch, weir modification, and tidal marsh restoration) are likely to meet the definition of a covered action and will need to establish consistency with the Delta Plan before implementation.
    a. Content: Covered actions' project description and supporting documentation provide details on project restoration activities and acres of land opened for hydrologic connectivity.
    b. Update Frequency: As covered actions are submitted and hydrologic connectivity is implemented.
2. San Francisco Estuary Institute (SFEI), EcoAtlas. Geographic Information System of wetland habitats, past and present.
    a. Content: EcoAtlas Project Tracker is a mapping and tracking tool for restoration projects and includes acres of habitat types restored for hydrologic connectivity.
    b. Update Frequency: Frequency of restoration project updates varies. Council staff will review EcoAtlas at least every five years for restoration project updates.

Inundation

1) GSWE from the European Commission Joint Research Center (JRC).
    a. Content: Global water surface areas (water extent, duration, and seasonality derived from remote sensing data).
    b. Update Frequency: Annually.

Alternative Data Sources

Alternative data sources will be used if the primary data sources become unavailable or are insufficient. Alternative data sources can be used concurrently with the primary data sources depending on best available science and the availability of the primary sources.

Connectivity

1. Two-dimensional hydrologic model and digital elevation model to identify the area that would physically allow fluvial or tidal surface water to flow onto land during events below the 1-in-100 recurrence interval flood flow, without pumping or modification of physical landforms. These areas may be dry in most conditions, but they could be hydrologically connected during high flows.
   a. Content: Data to be developed based on two-dimensional hydrologic model (for example, SCHISM), high-resolution digital elevation model (based on 2017 or most up to date LiDAR-derived elevation).
   b. Update Frequency: Updates are based on alternative methodology described above, when new elevation data or recurrence interval updates are available.

Inundation

1. NASA Surface Water and Ocean Topography Mission (SWOT). This mission is planned for launch in 2021 with data available after successful deployment.
   a. Content: Water surface extent, change, and seasonality derived from remote sensing data.
   b. Update Frequency: After the 2021 launch, anticipate updates about every 11 days.
2. European Space Agency SENTINEL Program. Sentinel-1 and Sentinel-2 platforms with combined overpass frequency of every five days for a given location on Earth, including the Delta. Sentinel data would help avoid an issue with the primary data source, where cloud cover affects imagery during periods of the year.
   a. Content: Water surface extent, change, and seasonality derived from remote sensing data.
   b. Update Frequency: Every five days. Sentinel water surface areas are anticipated to be incorporated into the base JRC GSWE data (Pekel 2019).

Process

Data Collection and Assessment

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

Connectivity

1. Reviewing Council Covered Actions website for projects that restore hydrologic connectivity (tidal marsh and floodplain restoration), and if necessary, contact project manager for clarifications on project status (construction status).
2. Adding project locations to the connected-land dataset and calculate acres open to hydrologic connectivity.
3. Calculating annual change in connected areas. Acres connected will be then calculated as the entire hydrologically connected area, regardless of the area actually inundated during this period.
4. If alternative or additional data sources are used, these sources will be disclosed on the Performance Measures Dashboard.

Inundation

1. GSWE data for surface water extent occurrence (primary data) will be downloaded in GeoTIFF format at~98 feet resolution (30 meters) in October of each year.
2. Data will be clipped to the boundaries of the Delta and Suisun Marsh, and converted to a projected coordinate system.
3. Council staff will analyze GSWE data primarily on the Google Earth Engine platform. Surface water area will be analyzed to determine maximum water extent during each water year (October 1 to September 31) for areas inundated 50-90 percent of the year.

Process Risks and Uncertainties

Assessments of the performance measure and the evaluation of interim milestones will account for issues within and outside of management actions and the long-term periods required to implement large-scale, on-the-ground projects.

Restoration of land-water connections to increase the areas with hydrologic connectivity that allow for increase in seasonal inundation depends on:

- Activities and effects within human management control (e.g., breaching or notching levees)
- Effects outside management control (e.g., peak flood flows, near- and medium-term sea level rise).

While areas outside of direct management control must be considered, the opportunities for reaching the target acreage require a concerted focus on modifications to the physical geometry of the Delta and Suisun Marsh.

Five-year averages will be used as interim milestones. However, a linear trajectory of annual acreage increases may not be a reasonable expectation. Rather, long lead times of restoration projects may cause non-linear increase in restored areas based on type and size of restoration project completed.

Reporting

Reporting of this performance measure will include maps of connected areas and seasonally inundated areas, together with project locations that restored the connectivity. Restoration project details will be displayed (e.g., year of restoration, type of connectivity restoration, acreages).

Every year, Council staff will report assessment of this performance measure by:

1. Posting annual updates on the Performance Measures Dashboard
2. Using Council annual reports published in January of each following year
3. Communicating management-relevant results at Council and Delta Plan Interagency Implementation Committee (DPIIC) public meetings
4. Presenting findings at technical interagency groups, professional gatherings, and conferences

Every five years through 2050, Council staff will assess and report the status of this performance measure by:

1. Communicate findings in the five-year review of the Delta Plan
2. Informing Council’s adaptive management and other relevant decision-making.

Five-year averages will be used as interim milestones for assessments towards the target over the 30-year time period of 2020-2050 (i.e., every five years, to increase connected land by 8,500 acres and inundated areas by 3,000 acres).

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