Performance Measure 4.15: Seasonal Inundation

Performance Measure (PM) Component Attributes

Type: Outcome Performance Measure

Delta Plan Description

Restoring land-water connections to increase seasonal floodplain inundation.

Expectation

Increased hydrologic connectivity and 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, of which:

(2) Approximately 15,000 acres are inundated at a two-year or more frequent interval. This baseline is reset to zero acres for purposes of reporting.[3]

[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. Although this is important for ecological processes, the available data does not include depth measurements.

[3] Appendix H of the 2016 CVFPP estimates an area of approximately 500 acres. However, between the adoption of the Delta Plan and the CVFPP analysis, projects were put in place that likely increased this acreage. Furthermore, the appendix H numbers were based on models rather than empirical methods, the latter of which are the preferred method for reporting. The baseline of 15,000 acres includes riparian and other areas besides floodplains and there are known issues with the data available at this time. See methods for additional background on this calculation. The baseline of zero acres is set to focus on future projects that increase the area or frequency of inundation. The zero baseline does not represent the existing area that is currently inundated at this frequency.

Target

By 2050:

(1) 51,000 additional acres that are physically connected to the fluvial river and tidal system, of which:

(2) At least additional 19,000 acres of floodplain area inundated on a two-year recurrence interval.

Basis for Selection

Since the 1800s, California is estimated to have lost 91% of its historic wetland habitat (Dahl 1990), including 95% of floodplains in the Central Valley (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. 2001b; Jeffres et al. 2008; Opperman et al. 2010; Katz et al. 2017).

The ecological health of the Delta is fundamentally dependent on the re-establishment 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. Floodplain inundation occurs when rivers or waterways exceed their channel capacity and spill onto adjacent land. In the Delta, this most often occurs during the winter and spring months. Shallow or seasonally inundated areas and hydrologic connectivity are key factors affecting nutrient transfer, primary productivity, food web health, and ultimately ecosystem health (Ahearn et al. 2006; Cloern et al. 2016).

Restoration of land-water connections to provide the biological benefits of floodplain inundation requires two components: 1) physical connectivity that allows water to flow onto land; and 2) sufficient 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 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 state prior to the mid-1800s has also increased connectivity in some ways 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 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 PM tracks the landscape in which physical dynamics, supported by geomorphic land-water interaction, can take place. This interaction requires two components: 1) physical connectivity that allows water to flow onto land; and 2) sufficient 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 and 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. 2001). 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., 2001, 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 the tidal and freshwater inundation, and the floodplain metric tracks seasonal water surface area that inundates these connected areas.

Linkage to Delta Reform Act and the Coequal Goals

Delta Reform Act: WC85803

Increased hydrologic connectivity and seasonal inundation of floodplains contribute to achieving “diverse and biologically appropriate habitats and ecosystem processes” (WC 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)

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 data was manually sketched based on aerial imagery for areas with visible levees, but no spatial data identified. Levee spatial data was acquired from a variety of sources. In areas with existing data, Council staff traced existing levee lines and merged this with manually sketched areas. Existing data used in the creation of a levee location dataset was acquired from multiple sources due to slightly different spatial coverage in each dataset:

1. Delta Levee Centerline Classifications (Department of Water Resources, DWR) – 2012 (“i17”).
2. Levee Centerline (Federal) – Provided by DWR. Part of a database intended to assist public agencies assess public safety needs for areas protected by levees.
3. Levee Delta Vision – URS, 2007. Draft dataset provided by DWR and delivered to DLIS in 2014.
4. DRMS – URS, via Delta Risk Management Strategy, 2007; last updated 2013
5. Levee Arcadis HS – from DLIS somewhere.
6. Levee Non Project – Provided by DWR. Part of a database intended to assist public agencies assess public safety needs for areas protected by levees.

Using the software program ArcGIS (version 10.4.1), these data were merged and clipped to the Delta and Suisun Marsh. Council staff removed areas when satellite imagery (NAIP 2016) indicated that the areas were unconnected, for example, when on the landside of a levee. The connected areas were then compared to 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, Global Surface Water Extent (GWSE) (https://global-surface-water.appspot.com/download) in 1984-2018 was reclassified to identify areas that were inundated at least once every two years, but not inundated all of the time, by selecting an inundation occurrence frequency between 50 and 90%. These data were clipped to hydrologically-connected areas within the Legal Delta and Suisun Marsh. The resultant raster was then converted to a polygon in order to remove Liberty Island, which is now permanent open water (it is identified as intermittent water in the data, because it flooded part way through the period of record). This identified approximately 15,000 acres. However, this represents a more than twenty-year, long term average. In addition, much of this area can be found within channel margins (bounded by levees) and along riparian areas/levee-water interface and is not limited to floodplains. Due to this and other data limitations with the currently available data (see below), this baseline was set at zero acres as of the year 2013. This emphasizes that the target focuses on new, not currently inundated areas, as of 2013.

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

Target and Analysis Methods

Connectivity

The connectivity target is based on quantitative goals in the 2017 CVFPP, Appendix H, pg. H-4-6 to H-4-8 which identified numeric floodplain and tidal marsh area targets. These targets were based on the area required to help recover spring and fall-run Chinook salmon to meet the CVPIA salmon doubling goal. The area required to achieve this goal is reported in the 2017 CVFPP, Appendices H and L: 11,000 acres for the Sacramento River basin and 4,500 acres for the lower San Joaquin River basin. However, analysis for the CVFPP identified that on average, only 17% of floodplains is considered suitable for salmonid species (CVFPP 2017). To account for this, the area required was divided by 17% to generate 64,705 acres for the Sacramento and 26,471 acres for the San Joaquin. 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% of the Lower Sacramento CPA and 67% of the Lower San Joaquin CPA falls within this area. Multiplying by these respective factors (see equations below) result in 33,647 acres in the Lower Sacramento and 17,735 acres in the Lower San Joaquin, for a sum of 51,382 acres of floodplain habitat (see below). After rounding, this value informs the connectivity target: 51,000 acres.

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

Inundation

The 2016 CVFPP Conservation Strategy calculated the amount of new floodplain needed in the Sacramento and San Joaquin watersheds to support doubling salmon populations (DWR 2016), Appendix H, p. H-3-7. Based on the Conservation Strategy, floodplains should inundate in two-year intervals to support salmon life cycles. To calculate the area required for inundation targets, the 51,000 acres of floodplain habitat from above was disaggregated to fluvial and tidal data by analyzing the proportional overlap with historical tidal and fluvial areas. San Francisco Estuary Institute's historical ecology spatial data estimate 63% of the Delta as tidal and 37% as non-tidal (Whipple et al. 2012). Multiplying the non-tidal estimate of 37% by the target of 51,586 acres of connectivity represents the floodplain inundation target of 19,000 acres (rounded).

Data Sources

Primary Data Sources

Connectivity

1. Council staff-compiled spatial data for floodways, floodplains, bypasses, and connected areas based on formal definitions. Council staff will manually update this spatial data (1) when a new ecosystem restoration project is completed that is known to have altered connectivity, or (2) at least once every five years. These data will be used as an input into the analysis of connectivity by calculating the area using a spatial analysis program and equal area projection
   a) Content: Data compiled from the CVFPP (2017), DWR, and manual edits made by Council staff in select areas.
   b) Update frequency: As needed: (1) when a new ecosystem restoration project is completed that is known to have altered connectivity, or (2) at least once every five years.

Inundation

1. Global Surface Water Extent (GWSE) from the European Commission Joint Research Center (JRC) (https://global-surface-water.appspot.com/download)
   a) Content: Global water surface on 1984-2018 (water extent, duration, and seasonality derived from remote sensing data)
   b) Update Frequency: anticipated to be made available on an annual basis

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 depending on best available science and the availability of the primary source.

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 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: Update based on alternative methodology described above when new elevation data or recurrence interval updates area are available.

Inundation

1) NASA Surface Water and Ocean Topography Mission (SWOT). This mission is planned for launch in 2021 with data available after this date. https://swot.jpl.nasa.gov/app_areas.htm
    a) Content: Water surface extent, change, and seasonality derived from remote sensing data.
    b) Update frequency: Once available, data is anticipated to be updated globally approximately every 11 days.
2) Sentinel-1 and Sentinel-2 platforms with combined overpass frequency of every five days for a given location on Earth, including the Delta. This 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: Data could theoretically be obtained and processed using semi-automated tools, and reported monthly and annually. These data are anticipated to be incorporated into the base JRC GWSE data (Jean-Francoise Pekel, personal communication, 2019) so this alternative is unlikely to be used.

Process

Data Collection

Connectivity

- Using the software program ArcGIS (version 10.4.1), primary data will be collected every October 1, and merged and clipped to the Delta and Suisun Marsh.
- Council staff will remove areas when satellite imagery (NAIP 2016) indicate that the areas were unconnected, for example, when on the landside of a levee.
- Connected areas will be compared to GSWE data to confirm if at least part of the contiguous area had been inundated at any point within the last 30 years.
- Acres connected will be then calculated as the entire hydrologically-connected area, regardless of the area actually inundated during this period.

Inundation

- GWSE data for surface water extent occurrence (primary data) will be downloaded in GeoTIFF format (~98 feet resolution (30 meters)) every October 1.

- Data will be clipped to the Delta and Suisun Marsh, converted to a projected coordinate system, and analyzed for areas that had water occurrence between 50-90% of the time during the 30-year period.
- Council staff will analyze GSWE data primarily on the Google Earth Engine platform. Surface water area will be analyzed to determine maximum extent during each water year (October 1 to September 31) for areas inundated 50-90% of the year.

Reporting

Reporting of this performance measure will include maps comparing the acres of inundation and connectivity. Maps while be linked to the tables that indicate the change of acres of each community compared to the baseline.

References

Ahearn, D. S., Viers, J. H., Mount, J. F., & Dahlgren, R. A. (2006). Priming the productivity pump: flood pulse driven trends in suspended algal biomass distribution across a restored floodplain. Freshwater Biology, 51(8), 1417–1433. https://doi.org/10.1111/j.1365-2427.2006.01580.x

Cloern, J. E. (2007). Habitat Connectivity and Ecosystem Productivity: Implications from a Simple Model. The American Naturalist, 169(1), E21–E33. https://doi.org/10.1086/510258

Cloern, J., Robinson, A., Grenier, L., Grossinger, R., Boyer, K., Burau, J., … Simenstad, C. (2016). Primary Production in the Delta: Then and Now. San Francisco Estuary and Watershed Science, 14(3). https://doi.org/10.15447/sfews.2016v14iss3art1

Corline, N. J., Sommer, T., Jeffres, C. A., & Katz, J. (2017). Zooplankton ecology and trophic resources for rearing native fish on an agricultural floodplain in the Yolo Bypass California, USA. Wetlands Ecology and Management. https://doi.org/10.1007/s11273-017-9534-2

Department of Water Resources. (2016). Appendix H. Central Valley Chinook Salmon Rearing Habitat Required to Satisfy the Anadromous Fish Restoration Program Doubling Goal (p. 70). Retrieved from Department of Water Resources website: http://www.water.ca.gov/conservationstrategy/docs/app_h.pdf

Jeffres, C. A., Opperman, J. J., & Moyle, P. B. (2008). Ephemeral floodplain habitats provide best growth conditions for juvenile Chinook salmon in a California river. Environmental Biology of Fishes, 83(4), 449–458. https://doi.org/10.1007/s10641-008-9367-1

Katz, J. V. E., Jeffres, C., Conrad, J. L., Sommer, T. R., Martinez, J., Brumbaugh, S., … Moyle, P. B. (2017). Floodplain farm fields provide novel rearing habitat for Chinook salmon. PLOS ONE, 12(6), e0177409. https://doi.org/10.1371/journal.pone.0177409

Merenlender, A. M., & Matella, M. K. (2013). Maintaining and restoring hydrologic habitat connectivity in mediterranean streams: an integrated modeling framework. Hydrobiologia, 719(1), 509–525. https://doi.org/10.1007/s10750-013-1468-y

Moyle, P. B., & Mount, J. F. (2007). Homogenous rivers, homogenous faunas. Proceedings of the National Academy of Sciences, 104(14), 5711–5712. Retrieved from http://www.pnas.org/content/104/14/5711.short

Opperman, Jeffrey J. (2012). A conceptual model for floodplains in the Sacramento-San Joaquin Delta. San Francisco Estuary and Watershed Science, 10(3). Retrieved from https://escholarship.org/uc/item/2kj52593.pdf

Opperman, Jeffrey J., Luster, R., McKenney, B. A., Roberts, M., & Meadows, A. W. (2010). Ecologically functional floodplains: connectivity, flow regime, and scale. Retrieved from http://onlinelibrary.wiley.com/doi/10.1111/j.1752-1688.2010.00426.x/full

Opperman, J.J., Moyle, P. B., Larsen, E. W., Florsheim, J. L., Manfree, A., & Manfree, A. (2017). Floodplains: Processes and Management for Ecosystem Services. Berkeley: University of California Press.

Robinson, A., Safran, S., Beagle, J., Grossinger, R., Grenier, J., & Askevold, R. (2014). A Delta Transformed: Ecological Functions, Spatial Metrics, and Landscape Change in the Sacramento-San Joaquin Delta.

Robinson, April, Safran, S., Beagle, J., Grenier, J., Grossinger, R., Spotswood, E., … Richey, A. (2016). A Delta Renewed: A Guide to Science-Based Ecological Restoration in the Sacramento-San Joaquin Delta. Retrieved November 1, 2017, from http://www.sfei.org/sites/default/files/biblio_files/DeltaRenewed_v1pt3_111516_lowres.pdf

Sommer, T., Harrell, B., Nobriga, M., Brown, R., Moyle, P., Kimmerer, W., & Schemel, L. (2001). California's Yolo Bypass: Evidence that flood control can be compatible with fisheries, wetlands, wildlife, and agriculture. Fisheries, 26(8), 6–16. Retrieved from http://www.waterboards.ca.gov/waterrights/water_issues/programs/bay_delta/docs/cmnt081712/sldmwa/sommeretal2001b.pdf

Sommer, T. R., Nobriga, M. L., Harrell, W. C., Batham, W., & Kimmerer, W. J. (2001). Floodplain rearing of juvenile chinook salmon: evidence of enhanced growth and survival. Canadian Journal of Fisheries and Aquatic Sciences, 58(2), 325–333. https://doi.org/10.1139/cjfas-58-2-325

Whipple, A., Grossinger, R., Rankin, D., Stanford, B., & Askevold, R. (2012). Sacramento-San Joaquin Delta Historical Ecology Investigation: Exploring Pattern and Process. San Francisco (p. 438). Retrieved from San Francisco Estuary Institute website: http://www.sfei.org/sites/default/files/biblio_files/Delta_HistoricalEcologyStudy_SFEI_ASC_2012_highres.pdf

Appendices

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