Performance Measure 4.13: Barriers to Migratory Fish Passage

Performance Measure (PM) Component Attributes

Type: Output Performance Measure

Description

Resolve fish passage at priority barriers and select large dams in the Sacramento-San Joaquin River watershed, and screen diversions along native, anadromous fish migration corridors within the Delta.[1]

Expectations

Resolving priority fish migration barriers and screening Delta diversions improves fish migration, reduces fish entrainment, enhances aquatic habitat connectivity, and contributes to anadromous species recovery.

Metric

Priority fish migration barriers and select large dams in the Sacramento-San Joaquin River watershed, and unscreened diversions along native, anadromous fish migration corridors in the Delta and Suisun Marsh. This metric will be evaluated annually.

Baseline

Number of fish passage barriers, rim dams, and unscreened diversions listed in:

1. California Department of Fish and Wildlife (CDFW) Priority Barriers (2018).
2. Central Valley Flood Protection Program (CVFPP) Conservation Strategy (Appendix K, 2016).
3. Rim dams in the Sacramento–San Joaquin River watershed.

[1] *Resolve* in this context means to construct, modify, or remove a barrier to allow migratory fish to travel past the barrier or former barrier. For unscreened diversions, resolve means to screen the diversion so that juvenile or adult fish are physically protected from entrainment.

4. Unscreened diversions along Delta native, anadromous migration corridors listed in the Passage Assessment Database (PAD), March 2018 version (CalFish 2019).

Target

1. By 2030, resolve all (100 percent) of the priority fish migration barriers (listed in CDFW 2018 Priority Barriers (2018) and CVFPP 2016 Conservation Strategy).
2. By 2050, resolve 50 percent of fish passage at rim dams in the Sacramento-San Joaquin River watershed, and screen 50 percent of unscreened diversions along native, anadromous fish migration corridors in the Delta.

Basis for Selection

General Purpose

Several species of native, anadromous fish travel through the Delta and upstream as part of their lifecycle. Instream barriers or unscreened diversions of water from the streams can impede migratory movements; limit, or cut off access to spawning and rearing grounds and to areas that offer refuge from predation; and exacerbate stressors that adversely affect overall species survival (CDFW et al. 2014; NMFS 2009 and 2011).

Resolving fish passage barriers and screening diversions, to prevent fish from being drawn into (entrained) water diversion pipes, is important for the survival of several listed species, including salmonids that migrate through the Delta (CDFW et al. 2014; Merenlender and Matella 2013).

Rim dams are large dams along the rim or edge of the Sacramento and San Joaquin Valleys and Sierra Nevada mountains (Herbold et al. 2018). It is necessary to provide fish passage above rim dams so that fish can access high-elevation, cooler habitat (NMFS 2009).

It is unlikely that all barriers can be resolved—especially large rim dams that provide water supply and flood control benefits. However, resolving many fish passage barriers could contribute to native fish population survival and an increase in species resilience and genetic diversity, among other benefits (CDFW et al. 2014; DWR 2014).

This performance measure tracks instream fish migration barriers and rim dams that have fish passage resolved to allow for anadromous fish to travel upstream and

downstream from the barrier. Screening of an unscreened diversion means juvenile or adult fish are physically protected from entrainment.

Barriers, Diversions, and Non-Structural Issues

The term *barrier* can refer to several different types of impediments including dams, weirs, and low-flow road crossings such as culverts. Barriers can be partial or complete. Some barriers can change with instream flow, and are therefore affected by water year type, weather, sediment loads, and other factors. Water diversion pipes also pose a risk to fish, especially salmon and steelhead (Vogel 2011). Installing fish screens at these diversions is an effective means of preventing fish entrainment (Goodman et al. 2017, Poletto et al. 2015).

Barriers to migration and unscreened diversions are two of many factors affecting fish survival. Other factors include predation, food availability, suitable habitat and refuge, and water temperature (DWR 2014). The size of a fish population and its use of different migration routes are also important (Perry and Skalski 2008). The importance of different migration routes depends on factors such as flow, water operations, and infrastructure. For example, when the Delta Cross Channel is closed, a lower proportion of migrating fish pass through the interior Delta (Perry and Skalski 2008), reducing the negative impact on fish migration of unscreened diversions or barriers in the interior Delta.

Within the Delta, reduced survival during migration may result from a combination of lack of suitable refugia and food sources, challenging environmental conditions (e.g., water temperature), and the cumulative effect of unscreened diversions. There are about 1,400 unscreened diversion on the Delta migratory routes (Figure 1) *(*CalFish 2019*)*.

Complete barriers are a major obstacle in the Sacramento and San Joaquin River watersheds. Rim dams in particular have dramatically altered fish passage and access to upstream, cool-water spawning habitat (Herbold et al. 2018). Rim dams are estimated to have cut off access for salmonids to approximately 80 percent of their pre-dam accessible habitat (Lindley et al. 2006). This habitat is especially valuable because it is at higher elevation, influenced by snowmelt, and could provide an important climate refuge as water temperatures are projected to rise over the remainder of the twenty-first century. Without access to this habitat, native runs of salmon may become extinct over the coming century. As noted in the 2009 Biological Opinion on Long-Term Operations of the Central Valley Project and State Water Project (BiOp), there are likely to be large impacts on salmonid populations due to inadequate cold water available downstream of rim dams, especially in dry and critically dry years (NMFS 2009, pp. 659-660). Because of the importance of habitat above rim dams, it is important to continue to study and find creative solutions to facilitate fish passage past rim dams.

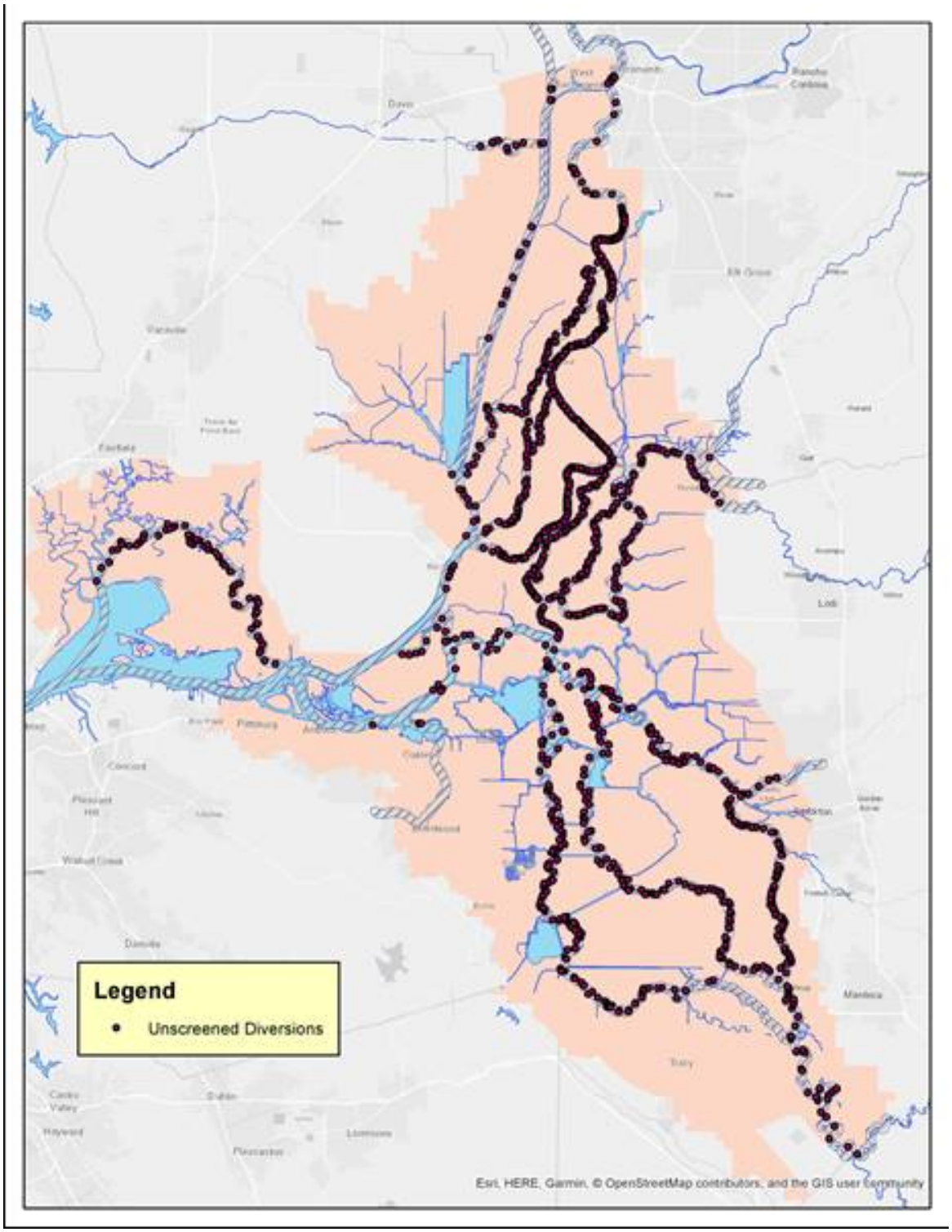

Figure 1. Unscreened Diversions (1,400 locations) Along Native, Anadromous Fish Migration Corridors in the Delta and Suisun Marsh

Source: CalFish PAD 2018

Figure 1. Unscreened Diversions (1,400 locations) Along Native, Anadromous Fish Migration Corridors in the Delta and Suisun Marsh (contd.)

This map shows the locations of 1,400 unscreened diversions along native, anadromous fish migration corridors within the Sacramento-San Joaquin Delta and Suisun Marsh. The Legal Delta and Suisun Marsh are unlabeled and shown in solid pink. The map depicts unlabeled rivers, streams, lakes, and canals/aqueducts within the Legal Delta colored in a solid blue.

Migration corridors are depicted in gray hatching, and consist of the Sacramento River Deep Water Ship Channel and toe drain, Sacramento River, Elk Slough, Sutter Slough, Steamboat Slough, Georgiana Slough, the Cosumnes River, North and South Fork of the Mokelumne River, Threemile Slough, the San Joaquin River, Burns Cutoff, Paradise Cut, Middle River, Old River, Marsh Creek, Sand Creek, and Montezuma Slough. Priority Migration Corridors are also depicted running through Grizzly Bay and Suisun Bay within Suisun Marsh, and heading west to Carquinez Strait.

Unscreened diversions are depicted as black points along the migration corridors. Concentrations of points are located, moving from the north Delta clockwise, on the Sacramento River, Elk Slough, Sutter Slough, and Steamboat Slough in the north Delta; Georgiana Slough, and the North and South Forks of the Mokelumne River on the eastern edge of the central Delta; the San Joaquin River, Burns Cutoff, Middle River, and Old River in the south Delta, and Montezuma Slough in Suisun Marsh. Unscreened diversions are present, but at relatively lower densities, along the Sacramento River Deep Water Ship Channel and toe drain, the portion of the Sacramento River that is within the cities of West Sacramento and Sacramento, Threemile Slough (in the western Delta), and the portion of the San Joaquin River near Sherman Island and Big Break (in the western Delta).

Please contact the Delta Stewardship Council with any questions regarding this figure.

Prioritization of Barriers

Due to a large number of fish passage barriers located within the Sacramento-San Joaquin watershed, resource agencies prioritize the most important barriers to resolve:

1. CDFW 2018 Priority Barriers, including Priority Barriers in North Central and Central Regions (CDFW regions 2 and 4)

CDFW (2018) prioritizes barriers across both coastal and Central Valley watercourses based on these criteria:

1. high likelihood to improve migration for anadromous species
2. availability of recent data of fish and habitat
3. willing partners and land access
4. known political support at a local, state, or national level
5. the site is a barrier to a federal recovery plan "core" population
6. the watercourse is an eco-regional significant watershed
7. CDFW is committed to monitoring before, during and after any barrier improvement project is undertaken

8. the site is considered to be a *keystone barrier*, meaning the barrier was the lower-most in that river or creek

The CDFW priority barrier list is updated on an annual basis.

2. Central Valley Flood Protection Plan (CVFPP) Conservation Strategy, Appendix K (DWR 2016), including the Central Valley Flood System Fish Migration Improvement Opportunities (FMIO) study (DWR 2014)

DWR's CVFPP contains prioritized fish passage barriers in the FMIO study and Appendix K of the CVFPP Conservation Strategy. The fish barriers are prioritized using dual metrics in each of the following three categories:

1. Barrier frequency:
    a. Waterway hydrology – frequency of migratory corridor containing water.
    b. Barrier status – total barrier, partial barrier, or temporal barrier.
2. Barrier intensity:
    a. Barrier location in the target area – barriers are given a score to reflect their spatial distribution in the target area. Highest scores for anadromous species are given to barriers farthest downstream.
    b. Species diversity/presence – number of anadromous species that can reach the barrier from upstream or downstream.
3. Upstream habitat:
    a. Upstream miles of waterway - when comparing two or more barriers, the barrier with the most upstream miles of habitat (to the next barrier) gets the highest score.
    b. Type of upstream habitat – spawning, rearing, and holding habitats.

DWR's priority barriers list does not consider diversions, and there are no plans to regularly update DWR prioritization lists. The lists from these studies are included because they represent the most in-depth analysis of barriers, and opportunities for improvements, currently available.

Rim Dams and Climate Change

Climate change introduces new stressors to migratory salmon in the Sacramento and San Joaquin Rivers, including higher water temperatures and more frequent extreme weather events such as droughts. Central Valley rim dams block access to historical, cold-water spawning habitat. A spatially explicit model of salmon population dynamics for Butte Creek indicates that due to flow limits and high temperatures, salmon in the system are vulnerable to extinction without access to upstream areas (Thompson et al.

2012). Historically, the climate has been variable in the Central Valley of California, salmon have had access to heterogeneous habitats, and genetic and phenotypic diversity among populations was high, resulting in population resilience (Herbold et al. 2018). Current management seeks to improve salmon adaptive capacity in response to climate change by reconnecting and restoring habitats to facilitate ecosystem processes, providing refuge from temperature stress and predation risk as well as increasing food availability (Crozier et al. 2019).

Linkages to Delta Reform Act and the Coequal Goals

Delta Reform Act

Habitat fragmentation and limited access to spawning and rearing grounds are major stressors to conservation and recovery of salmon species. Entrainment of fish into unscreened water diversions increases mortality of native resident and migratory fish species. Achieving the target in this performance measure would support the following characteristics of a healthy Delta, as identified in the Delta Reform Act:

- **"Viable populations of native resident and migratory species." (Water Code section 85302(c)(1)).** Resolving instream barriers and screening Delta diversions is important for the survival of several listed species by improving fish migration, reducing fish entrainment, enhancing aquatic habitat connectivity, and contributing to anadromous species recovery.
- **"Functional corridors for migratory species." (Water Code section 85302(c)(2)).** Instream barriers and unscreened water diversions impede migratory movements, and they limit or cut off access to spawning and rearing grounds and areas that offer refuge from predation (CDFW et al. 2014; NMFS 2009 and 2011). Resolving instream barriers and screening Delta diversions restores corridors for migratory species, enhances aquatic habitat connectivity, and opens access to salmon spawning and rearing grounds.
- **"Reduced threats and stresses on the Delta ecosystem." (Water Code section 85302(c)(4)).** Instream barriers and unscreened water diversions exacerbate stressors that adversely affect migratory fish species (CDFW et al. 2014; NMFS 2009 and 2011). Allowing migratory salmon to access historical, cold-water spawning habitat blocked by rim dams will improve salmon adaptive capacity by providing refuge from temperature stress and predation risk (Crozier et al. 2019).
- **"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 85302(c)(5)). Meeting

the target of this measure will contribute to the recovery of salmon populations by improving fish migration and opening access to additional spawning and rearing grounds.

Achieving the target in this performance measure supports the following subgoal and strategy for restoring a healthy ecosystem: **"Establish migratory corridors for fish, birds, and other animals along selected Delta river channels." (Water Code section 85302(e)(2)).**

This performance measure tracks priority fish migration barriers. Resolving fish passage at priority barriers restores corridors for migratory species, enhances aquatic habitat connectivity, and opens access to salmon spawning and rearing grounds, contributing to the Doubling Goal for Central Valley Chinook Salmon Natural Production (PM 4.6).

Delta Plan Core Strategy

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

Methods

Baseline Methods

The baseline is all of the priority barriers identified by CDFW and DWR—10 rim dams in the Sacramento-San Joaquin Delta watershed, and 1,400 unscreened diversions along migratory routes in the Sacramento-San Joaquin Delta and Suisun Marsh.

Table 1. Comparative List of Priority Fish Migration Barriers Identified in the Sacramento River Watershed

Sacramento River Fish Migration Barriers	Priority Barrier in CVFPP 2016 Conservation Strategy	Priority Barrier in CDFW 2018
Lisbon Weir	Yes	No
Yolo Bypass Road Crossings	Yes	No
Cache Creek Settling Basin	Yes	No
Fremont Weir[1]	Yes	Yes
Oroville-Thermalito Complex	Yes	No
Knights Landing Outfall Gates (KLOG)[2]	Yes	No
Tule Canal Crossings	Yes	No
Sacramento Weir	Yes	No
Sunset Pumps Diversion Dam	Yes	Yes
Sutter Bypass Weir No. 1	Yes	Yes
Sutter Bypass (multiple structures)	Yes	No
Tisdale Weir	Yes	Yes

Table 1. Comparative List of Priority Fish Migration Barriers Identified in the Sacramento River Watershed (contd.)

Sacramento River Fish Migration Barriers	Priority Barrier in CVFPP 2016 Conservation Strategy	Priority Barrier in CDFW 2018
Moulton Weir	Yes	No
One-Mile Dam	Yes	Yes
Big Chico Creek Gates (Five-Mile Dam)	Yes	Yes
Lindo Channel Gates	Yes	No
Sewer Pipe Crossing, Dry Creek	No	Yes
Bellota Weir	No	Yes

Sources: DWR 2016 and CDFW 2018
Key:
CDFW = California Department of Fish and Wildlife
VFPP = Central Valley Flood Protection Plan

Notes:
[1] Upstream migration over the Fremont Weir was partially addressed in 2018. However, it remains a barrier to downstream migration until overtopping under high flow conditions.
[2] The KLOG had operational gates added in 2015 as part of the EcoRestore project. It is operated as an intentional barrier to keep migrating salmonids in the mainstem of the Sacramento River, under certain conditions.

Table 2. Comparative List of Priority Fish Migration Barriers Identified in the San Joaquin River Watershed

San Joaquin River Fish Migration Barriers	Priority Barrier in CVFPP 2016 Conservation Strategy	Priority Barrier in CDFW 2018
San Joaquin River Headgates	Yes	No
Sack Dam	Yes	Yes
Mendota Dam	Yes	Yes
San Joaquin River Control Structure	Yes	No
Donny Bridge	Yes	No
Lost Lake Rock Weir #1 (Lower)	Yes	No
Mariposa Bypass Control Structure	Yes	No
Mariposa Bypass Drop Structure	Yes	No
Eastside Bypass Rock Weir	Yes	No
Eastside Bypass Control Structure	Yes	No
Dan McNamara Road Crossing	Yes	No
Merced Refuge Weir #1 (Lower)	Yes	No
Merced Refuge Weir #2 (Upper)	Yes	No
Avenue 21 County Bridge	Yes	No
Ave 18½ County Bridge	Yes	No
Pipeline Crossing	Yes	No
Eastside Bypass Drop 2 (Upper)	Yes	No

Table 2. Comparative List of Priority Fish Migration Barriers Identified in the San Joaquin River Watershed (contd.)

San Joaquin River Fish Migration Barriers	Priority Barrier in CVFPP 2016 Conservation Strategy	Priority Barrier in CDFW 2018
Eastside Bypass Drop 1 (Lower)	Yes	No
Chowchilla Bypass Control Structure	Yes	No
Hosie Low Flow Road Crossing	No	Yes
Central California Traction Railroad Bridge	No	Yes

Sources: DWR 2016 and CDFW 2018

Key:
CDFW = California Department of Fish and Wildlife
CVFPP = Central Valley Flood Protection Plan

Table 3. Rim Dams to Provide Fish Passage Identified in Recent Recovery Plan Biological Opinion for Salmonids

Dam Name	River Name	Watershed
Shasta Dam	Sacramento River	Sacramento River
Folsom Dam	American River	Sacramento River
Oroville Dam	Feather River	Sacramento River
Englebright Dam	Yuba River	Sacramento River
New Bullards Bar Dam	North Yuba River	Sacramento River
Daguerre Point Dam	Yuba River	Sacramento River
Friant Dam	San Joaquin River	San Joaquin River
New Melones	Stanislaus River	San Joaquin River
New Don Pedro	Tuolumne River	San Joaquin River
New Exchequer Dam	Merced River	San Joaquin River

Source: NMFS 2014 and 2009

Target Methods

Setting the target of resolving 50 percent of fish passage at the rim dams, and screening 50 percent of unscreened diversions, considers the feasibility of developing technological solutions to fish passages at large dams that also provide water supply and flood control benefits and the large number of mostly agricultural water diversions within the Delta.

Data Sources

Primary Data Sources

This primary data source will be used for tracking this performance measure annually:

1. California Fish Passage Assessment Database (PAD). The PAD is an "inventory of known and potential barriers to anadromous fish in California," and includes all instream dams, including the rim dams, in the Sacramento-San Joaquin River watershed. The PAD database reports the fish passage status of the barriers, dams, and unscreened diversions.
    a. Content: Updated fish passage status of resolved barriers.
    b. Update frequency: Three times per year.

Alternative Data Sources

Alternative data sources will be used if the primary data sources become unavailable or insufficient. These data sources were used in compiling the passage priorities, and updates to fish passage barrier priorities can be used concurrently with the primary data sources as a reference, or as supplemental information.

1. CDFW Watershed Restoration Grants Branch. CDFW provides a list of fish passage priorities in grant proposal solicitation notices. Proposition 68 awards grants to projects that improve a community's ability to adapt to the unavoidable impacts of climate change; or ones that improve and protect coastal and rural economies, agricultural viability, wildlife corridors, or habitat. Proposition 1 awards grants to projects that meet objectives of reliable water supplies, restoration of important species and habitat, and more resilient, sustainably managed water resources system.
    a. Content: Updated prioritization of fish passage barriers to be available for Prop 1 and Prop 68 proponents.
    b. Update frequency: Annually.
2. Updates to Central Valley Flood Protection Plan (CVFPP) Conservation Strategy. DWR updates the Conservation Strategy as a system-wide conservation plan to support integrated flood system planning and integration of environmental stewardship into the CVFPP.
    a. Content: Updated prioritization of fish passage barriers within the Central Valley Flood Protection Plan.

b. Update frequency: Every five years.

Process

Data Collection and Assessment

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

1. Obtaining the latest data from the California Fish Passage Assessment Database.
2. Council staff will contact the responsible agencies (DWR, CDFW, or other agencies involved) conducting fish passage improvement activities and restoration projects to retrieve supplemental data and to determine if some (or all) of the passage priorities are still relevant.
3. For all of the identified priority barriers (Table 1 and Table 2), identify those that were resolved each year.
    i. Calculate the percent change between the total number of priority passage barriers and the total number of the newest available barrier dataset (from the PAD) at the time of analysis.

Example:

$$\frac{V2\ (New\ Dataset\ Total) - V1(Passage\ Priorities)}{V1\ (Passage\ Priorities)} \times 100 = \%\ of\ Resolved\ Barriers$$

$$\frac{45\ (New\ Dataset\ Total) - 49\ (Passage\ Priorities)}{49\ (Passage\ Priorities)} \times 100 = -8.16\ \%\ change$$

(8.16% of the priority barriers have been resolved).

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

1. Obtaining the latest data from the California Fish Passage Assessment Database.
2. For unscreened diversions (about 1,400 locations) along native, anadromous fish migration corridors within the Delta, calculate the percentage change of unscreened diversions between the baseline and the most recent PAD dataset at the time of analysis. Only unscreened diversions located on native, anadromous fish migration corridors within the Legal Delta and Suisun Marsh will be included. Unscreened diversions on small sloughs and drains that are not within the anadromous corridors will not be included.

i. Build query for PAD data by using the "select by" attribute function:

- BarStatus = 'unscreened' AND SiteType = 'Diversion'
- Use the percent change equation in subset (a).

3. For the rim dams, identify those dams where fish passage was resolved, including either upstream passage for adult fish or downstream passage for juvenile salmon. Calculate the percent change between rim dams' baseline and the most recent PAD dataset at the time of analysis.

Process Risks and Uncertainties

As previously discussed in the basis for selection, it is unlikely that all fish instream barriers will be resolved, but resolving the prioritized barriers will benefit native fish survival and resilience. Large rim dams provide water supply and flood control benefits, and the technological solutions to upstream and downstream fish passage are complex. Process risks and uncertainties related to this measure are:

a. Natural conditions such as climate, ocean, hydrology, freshwater flow, and native fish species.

b. Managed conditions such as land access and willing partners; support at a local, state, or national level; agency priorities; funding; and feasible fish passage technologies.

The annual evaluation will allow Council staff to coordinate with responsible agencies (DWR, CDFW, and other agencies) on updates to fish passage barrier priorities.

The Delta Plan five-year review process provides a mechanism to use results from annual and five-year evaluations of this performance measure, and to incorporate updates to best available science to inform Council adaptive management and decision-making processes.

Reporting

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

1. Posting annual updates on the Performance Measures Dashboard.
2. Reporting results in Council annual reports. The annual report is prepared in the fall of each year and then published in January of the following year.
3. Communicating management-relevant results at Council and Delta Plan Interagency Implementation Committee (DPIIC) public meetings.

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

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

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For Further Assistance

For further assistance interpreting the content of this document, please contact Delta Stewardship Council staff.

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