FISH*Pass* Fish Passage Remediation Cost Analysis

California Fish Passage Forum – FISH*Pass* Working Group

**Goal**

Update estimated costs used in FISH*Pass*, by using fish passage remediation project data recently compiled by the California Fish Passage Forum (Forum). This analysis was conducted on data available to the FISH*Pass* Working Group as of August 9, 2019.

**Sources of Cost Data**

The following agencies/organizations/grant programs provided the fish passage cost data the Forum utilized in this analysis. Data requested included the locations, available project details, and total (implementation) project costs of all completed and ongoing fish passage remediation projects from the year 2000 to the present within Forum’s geographic scope. The Forum would like to thank these organizations for providing these data for the analysis.

* Pacific Coastal Salmon Recovery Fund (PCSRF) - NOAA
* Fisheries Restoration Grants Program (FRGP) - CDFW
* NOAA Restoration Center
* Aquatic Organism Passage Dataset - U.S. Forest Service
* American Rivers
* U.S. Fish and Wildlife Service
* California Fish Passage Forum
	+ Includes costs from Forum-funded projects and data compiled from a previous analysis of fish passage cost data.

The following information sources were used to compile additional fish passage project information, including location, but costs were not available or were not provided. These data were not utilized in this analysis, but contributed to the larger compiled layer in FISH*Pass* depicting the locations of fish passage remediation sites in California.

* Caltrans
* California Passage Assessment Database (PAD)

Some project information was determined through online searches. These include a few large and notable dam removal projects outside the scope of the Forum’s mission and objectives; but were included to increase the amount of data within this remediation category and scale in this analysis. These dams include (*State, year remediated*); Condit Dam (WA, 2012), Marmot Dam (OR, 2007), Gold Ray Dam (OR, 2010), and the Savage Rapids Dam (OR, 2009). Another component of project information collected through online sources included estimated dam removal costs associated with larger dams in California which are in the initial planning or feasibility stages. These dams include; Matilija Dam, Scott Dam, and Cape Horn Dam. Ultimately, these larger dam remediation data were not utilized in the cost analysis (see Dam, below), and only projects within the Forum’s scope were included.

**Data Compilation/Standardization**

The basic data structure of the cost data was developed by the Forum in order to meet the needs of this analysis. Key fields tracked in the data include: PAD\_ID, (*data*) Source, Source IDs, Year Remediated, Project Name, Barrier/Site type, Project Status, Project Lead, Description of Remediation, Project URL, and Total (*site*) Cost. Before and after photograph links of the remediated sites were included, when available. Data compiled and analyzed through this process considered implementation costs for completed projects. Monitoring, design, and assessment costs were not included in the analysis.

During the data compilation process, efforts were taken to ensure that projects and sites with more than one data source were not included more than once, and locations were verified (and updated if needed) based on available information including the PAD, online information, satellite imagery, and other data sources describing the same site.

When costs differed amongst available data sources for the same site or project, the data with the greater/greatest costs were selected for the analysis, since the limited feedback provided to the Forum for previous estimates suggested FISH*Pass* costs were underestimated.

**Data Formatting**

Data compiled by the Forum included location (GIS point dataset), details used to track the data sources, year of remediation, total cost (by site), details associated with the barrier remediation (site type, PAD\_ID, project name, project lead, remediation description, dimensions of site remediation or restoration, links to project summaries, before/after photo links, road type, and information associated with the stream reach the site is located on (NHDPlus COMID, or Intrinsic Potential reach ID).

Additional fields were created in order to standardize the data, including ‘remediation type’ – which was based on the predominant fish passage restoration activity at the site. The values in this field were developed organically based on the data provided, and with as much specificity as available in contributed (and searched) information. While this information is informative outside of the scope of this analysis, estimated costs in FISH*Pass* are driven by the ‘SiteType’ attribute in PAD, which does not include any details on the appropriate remediation at specific sites, and does not break down ‘road crossings’ into further details (e.g. low-flow road crossing, or culvert road crossing).

At stream crossing sites, a ‘road type’ attribute was collected, based on available road data and/or imagery at the site of the road/stream crossing. Attributed ‘road type’ values include; path, dirt road, forest road, surface street, highway, split highway. In this analysis “dirt road” and “forest road” were considered the same.

Reach IDs (COMID) from the National Hydrography Dataset (NHD) Plus (Vers. 2.1) were attributed to each site in order to leverage attributes in this dataset for the analysis (e.g., active channel width and stream flow). If the site was not located on a NHDPlus stream, the Intrinsic Potential dataset was used to determine values of active channel width and/or stream flow. These attributes enabled exploration of site-specific analysis using these variables (i.e., road crossings).

**Data Filtering**

While data was gathered and standardized on all fish passage remediation design and implementation projects submitted, only some of the projects contained all of the necessary information required to meet the criteria for this analysis. Projects included in the analysis contained complete information on: remediation year, site type, dam height (if ‘SiteType’ = Dam), total site costs, remediation type (<> ‘unknown’).

Project data from various sources sometimes included more than one fish passage remediation site for each project, making the determination of accurate site costs difficult. If there were sufficient non-fish passage remediation activities involved within the project scope, the data were not included in the analysis. If the project sites contained mostly fish passage-related work, did not appear to be substantially different in scope, and the provided costs were not broken down at the site level, it was decided that costs would be equally divided amongst the sites and only one of the sites would be utilized in the analysis. We were not comfortable counting these costs more than once.

**Development of 2019 Costs**

Once the data were filtered based on the above criteria, site costs for 2019 were estimated using a simple 2.5% annual inflation rate, using the ‘remediation year’ attribute. This rate of 2.5% likely represents a low-end inflation estimate for construction projects (CDFW, 2019, pers.comm; University of North Carolina Environmental Finance Center). This inflation factor was agreed upon by the Forum Science & Data Committee after searching through various information sources on construction cost inflation statistics and standards, and likely represents the lower end of annual construction inflation costs. **All cost data within this document reflect these 2019 inflation adjusted costs.** [GIS Calculate Field tool syntax: (!Cost\_Total! \* 0.025 \* !Year\_Diff\_2019!)+!Cost\_Total!]

**Data Analysis**

The data were analyzed in order to update the estimated fish passage remediation costs currently used in FISH*Pass*. These estimates were based on ‘SiteType’ (PAD attribute), and certain site types’ estimates were based on site-specific attributes such as the size of the stream at the site, the road type associated with road/stream crossing, and the height of dams remediated. Other site types were estimated without respect to site attributes, and were simply the average (mean) costs associated with the remediation of the particular site type which were generally rounded down to even dollar figures to indicate the uncertainty in these estimates. The rounded numbers represent conservative estimates as to not discourage users from considering sites for remediation. All types of remediation were included in the analysis ranging from retrofit/improvement of an existing structure, to full removal and potentially replacement of a structure.

During the analysis, a limited number of outliers were identified and removed from the analysis based on the scope of the project or other factors which made the site or project especially unique. For instance, projects where the scope expanded well beyond barrier remediation (e.g. wetland construction, reseeding vegetation, complete realignment of stream channel) were not included in this analysis.

All ‘SiteTypes’ were analyzed for patterns relating total (2019) costs and stream size (active channel with and/or mean annual flow). Most ‘SiteTypes’ did not show clear patterns relating to these variables, and the average (mean) values were chosen for estimated costs for many ‘SiteTypes’ (see Results, below). Additionally, all of the recommended estimates have been rounded, in some cases higher, and mostly lower. This was done to convey uncertainty in the estimates within the FISH*Pass* tool, acknowledging the high amount of variability in the data, and the desire to not overestimate restoration costs within the tool.

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**Results**

The following includes brief explanations of the data (previously and currently available), calculations and analysis, recommendations, and planned/desired future refinement of the cost data for the SiteTypes currently being used in FISH*Pass.*

**Road Crossing**

**PAD Definition:** A structure crossing a creek or stream that allows water underneath or over the road. Includes culvert, bridge, low-flow, etc.

**Previous Cost Estimate (site-specific):** see table below

*Note: These figures are listed as “culvert replacement” cost estimates in the information from the prior cost analysis, but FISHPass had used these figures for all road crossing barrier remediation projects.*

|  |
| --- |
| **"Culvert Replacement" - $/project** |
| Size of Waterway (active channel width) | Road Type |
| Dirt Road | Paved Road | Highway | Split Highway & Railroads |
| Small (0-10)' | $47,500  | $75,000  | $150,000  | $275,000  |
| Medium (10-20') | $75,000  | $190,000  | $275,000  | $375,000  |
| Large (20-30') | $230,000  | $460,000  | $700,000  | $1,400,000  |

**Analysis:** The analysis of road crossing costs were limited by the small number of data points within certain road types (railroads, split highways, and highways) and larger size classes of streams. Within these data, there were no significant differences between surface streets, paths, highways, split highways, and railroads. Paths included in this dataset were generally paved pedestrian or bicycle paths, and the remediation of these sites generally resembled remediation performed for paved road sites. These were lumped into a single group for all paved roads. There was a significant difference between dirt/forest road and paved roads (Student’s t test P<0.05). The data were also analyzed to explore relationships between road type and stream width or flow, with dirt/forest road crossing not showing a clear relationship and paved roads showing a weak relationship.

Based on the analysis, it is recommended that the estimated costs of road crossings be based on surface (dirt/forest vs. paved) using a simple median or mean cost of the analyzed data. See table below for these figures.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Road type** | **Median Cost** | **Mean Cost** | **Std. deviation** | **Range**  |
| Dirt/Forest (n=83) | $216,758 | $321,395 | 310,115 | $18,307-$3,313,685 |
| Paved roads (n=128) | $446,550 | $683,584 | 999,300 | $14,410-$16,800,000 |

**Recommendation:** Based on the wide variability within these road types and costs, it is recommended that the estimated costs be set more conservatively than the mean costs and that the amounts be rounded to even dollar figures to indicate the uncertainty in these estimates. Recommended values are halfway between the median and mean for each road type, and rounded to the nearest $10,000.

Recommended estimated cost for a dirt road/forest road = $270,000

Recommended estimated cost for paved road crossings (including paths and railroads) = $570,000

The road crossing cost data are asymmetrically distributed with a positive skew (right skew). The FISH*Pass* Work Group (FPWG) recommends using these conservative estimates between the median and mean as to not discourage users from considering sites for remediation.

**Future refinement:** The Forum will continue to seek cost data for this site type.

**Dam**

**PAD Definition:** A barrier built across a stream or river to obstruct the flow of water. Includes debris, earth, rock, flashboard, drop structure, arch, weir, gravity, wing gabion, etc.

**Previous Cost Estimate (site-specific) dam removal** = $26,000 per vertical foot\*

\* Source listed as American Rivers, but the specific source citing this equation could not be determined.

**Analysis:** There were only evident relationships between dam height and total costs for smaller and medium-large sized dams, with the largest dams not showing a clear relationship among these variables. Dams between 1’ and 47’ were included in the analysis, the range of 2019 inflation adjusted costs for small and medium size dam remediation was $11,250-$6,860,000 (n=39). For dams less than 50’ in height, the following equation was generated based on a plot of total costs (2019) and dam height:

Estimated dam removal cost (*linear regression*) = 116,262 (X) -9,123

* (R2 = 0.47)
* X = stream size (Stream Active Channel Width [SACW], in meters)

**Recommendation:** Proposed simple equation for estimating dam costs under 50’ in height = $100,000 per vertical foot

For dams greater than 50’ in height, the FPWG proposes that a maximum estimate be made on all dam sites, acknowledging the increased variables and uncertainties associated with such large-scale dam removal projects like sediment management and completion of downstream infrastructure improvements prior to physical dam modifications or removal . Based on the proposed equation used in estimating dam removal costs, a 50’ dam would be estimated to cost $5,000,000 to remove. If this method and maximum estimate are adopted by the Forum, the User Guide should clearly state this aspect of the estimated costs of large dams used in FISH*Pass*.

Proposed maximum figure for estimating dam (removal) costs for those 50’ or greater, in height = $5,000,000.

**Future refinement:** The Forum will continue to seek cost data for this site type.

**Grade Control**

**PAD Definition:** Stabilizing weirs constructed in the streambed to prevent lowering of the channel bottom. This includes man-installed bedrock chutes.

**Previous Cost Estimate** = $85,000

**Analysis:** Small sample size (n = 4). Mean of 4 grade control remediation sites = $321,045 (min. = $69,882, max. = $913,687) Median = $162,233

**Recommendation:** Based on the limited sample size, it is recommended that the estimated costs be set more conservatively than the average costs and that the amount be rounded to even dollar figures to indicate the uncertainty in these estimates.

Recommended estimated cost for grade control structures = $300,000

**Future refinement:** The Forum will continue to seek cost data for this site type.

**Fish Passage Facility (*modification*)**

**PAD Definition:** Provide fish passage past obstructions that would otherwise prevent or hinder their upstream progress. Fishways include Step-and-pool, Denil ladders, and Alaskan steep-pass types.

**Previous Cost Estimate (site-specific):** “Fish passage structures vary predictably with SACW. SACW under 20’ are $40,000 to remediate and SACW over 20’ are $90,000 to remediate”

**Analysis:** Small sample size (n = 4). After removing one outlier, a significant relationship was observed between stream size (SACW) and total cost.

Estimated fish passage facility modification cost (*linear regression*) = -349,784 + 65,720 (x)

* x = stream size (SACW), (R2 = 0.87)

*Note: This formula will not work for stream below ~ 5 meters wide (SACW), as the estimated costs would be negative.*

A simple average of the four projects = $78,774 (min. = $7,019, max. = $151,943). These 4 projects took place from 2003-2005. The 2019 inflation adjusted mean for these four projects is $82,696.

**Recommendation:** Based on the limited sample size, the variability in the data, and the era of these projects, it is recommended that the estimated costs be set higher than the mean (non-inflation adjusted) costs and that the figure be rounded to even dollar amount to indicate the uncertainty in the estimate.

Recommended estimated cost for fish passage facility (modification) = $80,000

**Future refinement:** The Forum will continue to seek cost data for this site type.

**Log Debris Accumulations**

*Note: Log debris accumulation remediation will no longer be considered in the updated FISHPass tool, but cost estimates were updated, for reference.*

**Previous Cost Estimate (site-specific):** “Log jam remediation costs varies predictably with SACW. SACW of 15’ or less results in a cost of $30,000, SACW of 16’-61’ results in a cost of $55,000, and SACW of 61’ or greater results in a cost of $70,000.”

No relationship was observed between stream size (SACW) and total cost. Simple average of 16 log debris accumulation (remediation) projects = $23,347 (min. = $5,460, max. = $65,960)

**Flood Control Channel (*fishway installation*)**

**Definition:** Any partially or completely excavated channel intended to convey above-normal discharges.

**Previous Cost Estimate** = $1,365,000

**Analysis:** Small sample size (n = 3). Cost data for the remediation of flood control channel sites all involved the construction of lengthy fishways within the channel to improve fish passage. Simple average of 3 flood control channels = $3,631,029 (min. = $1,661,418, max. = $5,367,094).

**Recommendation:** Based on this small sample size, it is recommended that the estimated cost of these sites be updated to $3,000,000.

*Note: While the length of the fishway constructed is likely a significant factor in the site cost, such details are not available for each flood control channel site within PAD, and thus cannot be utilized for applying estimated costs.*

**Future refinement:** The Forum will continue to seek cost data for this site type.

**Flow Measurement Weir**

**PAD Definition:** A notch or depression in a levee, dam, embankment or other barrier across or bordering a stream, through which the flow of water is measured or regulated.

**Previous Cost Estimate** = $70,000

**Analysis:** Small sample size (n = 1). Costs for the one flow measurement weir remediation site were $1,042,728. This site had additional work done beyond the remediation of the weir: “Removed 2 weirs and aprons. Relocated stream gauge 35. Graded stream channel. Constructed 4 concrete horizontal weirs.”

**Recommendation:** Based on having a very small sample size within this category, it is proposed that the generic estimate of $200,000 be utilized for these sites.

**Future refinement:** The Forum will continue to seek cost data for this site type.

**Diversion (*screening and modifications*)**

**PAD Definition:** A place where the flow of water has been diverted from one course to another or directed in order to control the drainage from a section of ground. Includes screened and unscreened water diversions.

**Previous Cost Estimate** = $275,000

**Analysis:** Cost data collected for diversion sites were primarily fish-screening projects, or diversion modifications. Several years ago the Forum decided not to include unscreened/screened diversions in the barrier dataset used by FISH*Pass*. However, some diversion records are listed in the PAD as known barriers (i.e., total, temporal or partial) and were included in the dataset provided for FISH*Pass*. These locations will need to be reviewed. The FISH*Pass* working group has begun reviewing some of the sites listed as diversions in the FISH*Pass* dataset and it appears many of these sites can be reclassified as dams or non-barrier diversions.

**Recommendation:** It is proposed that until these sites are clarified, they be combined with the “other” site types and the generic estimate of $200,000 be applied.

**Future refinement:** Based on this information, efforts are being made to review diversion barriers in the PAD with the goal of attributing these to other site types as appropriate.

**Tidegate (*replacement/upgrade*)**

**PAD Definition:** A structure at a stream ocean mouth that limits the tidal flow within the estuary.

**Previous cost estimate** = $20,000

**Analysis:** Small sample size (n = 1). Costs for the one tidegate replacement site were $286,137.

**Recommendation:** Due to the very small sample size, and general feedback that the previous estimate in this category was very low, the FPWG recommendation is to increase the estimated cost of a tidegate replacement to $250,000. This is likely an underestimate for many of these types of projects, but the lack of data does not allow us to make a more informed estimate at this time.

**Future refinement:** The Forum will continue to seek cost data for this site type. Possibly utilizing the Tidal Connectivity project currently being initiated by the Forum in partnership with the Pacific Marine Estuarine Partnership (PMEP) and the Pacific Lamprey Fish Habitat Partnership (PLFHP) through the 2019 Multi-State Conservation Grant funding.

**Utility Crossing**

**PAD Definition:** Some type of utility line, water, gas, etc. that crosses a creek or stream and impedes passage of fish.

**Previous Cost Estimate** = $111,000

**Analysis:** Small sample size (n = 1). Costs for the one utility crossing remediation project were $148,153.

**Recommendation:** Due to the small sample size, it is recommended to increase the estimated cost of utility crossing remediation to $150,000. It is likely that the unique nature of any utility crossing would significantly impact the cost to treat the site, but without more data on this site type, we lack the information to make more educated estimate.

**Future refinement:** The Forum will continue to seek cost data for this site type.

**Fish Trap**

**PAD Definition:** A trap set up to catch fish usually for counting and monitoring purpose; should always be only a temporal barrier.

**Previous Cost Estimate** = $70,000.

**Analysis:** The Forum did not receive any data on fish trap remediation projects. There are only three fish trap sites in the barrier dataset for FISH*Pass*, and it appears these could likely be grouped as dams and cost estimates determined based on the dam regression equation above**.**

**Recommendation:** For the initial FISH*Pass* release, we recommend that dam regression equation above be used as cost estimates for these site types. For those that do not include a weir or dam structure as part of the fish trap, we recommend these sites be included in the “other” category and the generic estimate of $200,000 be assigned.

**Future Refinement:** Based on this information, fish trap data is being reviewed and cost data for this site type should be equivalent to dam site types used in the FISH*Pass* analysis.

**Unknown**

**PAD Definition:** Dataset does not specify the structure/site type.

**Previous Cost Estimate** = $95,000

**Analysis:** No cost data currently available

**Recommendation:** Based on having no cost data within this category and the high variability of potential costs associated with ‘unknown’ sites, it is proposed that the generic estimate of $200,000 be utilized for this category.

**Future Refinement:** Efforts are being made to review these records in PAD, with the goal of attributing these to other site types, as appropriate.

**Other**

**PAD Definition:** Any structure type not included in the above list (type is noted in the site/passage name or site comments/notes).

**Previous cost estimate** = $90,000

**Analysis:** N/A.

**Recommendation:** Based on having no cost data within this category and the high variability of potential costs associated with ‘other’ sites, it is proposed that the generic estimate of $200,000 be utilized for this category.

**Future Refinement:** Efforts are being made to review these records in PAD, with the goal of attributing these to other site types, as appropriate. Difficult to define barrier site-types e.g. unknown, diversion, and fish trap should be included in this category if they do not fit into another existing site-type.

**Data Challenges, Limitations, and Appropriate Use**

The data analyzed were limited to the information provided from various organization and agency databases. These databases were not always complete, and some lacked data being requested by the Forum, such as accurate cost share contributions.

By the nature of fish passage remediation work, costs vary greatly from site to site, often based on factors which are difficult to predict or model. This analysis looked into how factors such as stream size, stream flow, dam height, and other site attributes may affect the total costs of the site, but many of the sites types did not show clear patterns of increased costs for larger streams, for example. For these cases, the mean and median was used to estimate costs of treatment, and the spread of the data around these averages were significant. The generic estimate provided to FISH*Pass* represents a “ballpark” number between the median and the mean.

This analysis contained limited numbers of data points within many of the site types, which limits the confidence in the results.

The costs of various fish passage remediation treatments vary widely, according to many factors, and the type of site is often not prescriptive of the specific type of remediation chosen for a barrier.

The FPWG recognizes that as the Forum continues to collect cost data, other factors (not currently known or identified) could be included in future cost data analysis.

**Actions Currently Underway**

**Review of PAD SiteTypes**

A review of the PAD barrier SiteTypes “other”, “unknown”, “diversion”, and “fish trap” is necessary. These sites are being reviewed and will be assigned to other existing site types, if appropriate. If the “other” site type cannot be reclassified, it should likely encompass “unknown” and “fish trap” if those also cannot be reclassified. Many “diversion” barriers can likely be reclassified as “dams” or screened/unscreened “diversions”.

**Recommendations**

**Transparency in Uncertainties Surrounding Cost Data**

When FISH*Pass* is publically released this fall, it will be important to include language within the tool itself and supporting documents (User Guidance, FAQ etc.) stressing the high variability in the costs of barrier remediation projects that appear in the FISH*Pass* tool. Users should be encouraged to enter their own costs into the model if they have received estimates on specific barriers, or if they want to update estimated costs for particular site types.

User training/guidance should also encourage users to approach optimization runs utilizing cost estimates in the following way:

* Given the uncertainty in predicting costs, using the “ballpark” cost estimates provided to FISH*Pass* in optimization runs should be one tool of many that users can incorporate to help set restoration priorities. Users should also communicate with fish biologists and watershed stakeholders to help determine the feasibility and need for barrier treatments in their area of interest.
* Once users have determined barriers of interest and obtained barrier specific cost estimates, users can edit each barrier of interest to reflect a better estimate of actual costs and perform a FISH*Pass* optimization run including only those barriers of interest.

User guidance and trainin[g should:

* Emphasize that using FISH*Pass* “ballpark” estimates should be one of many sources used when determining restoration priorities.
* Encourage users to return to the model and perform optimization runs using actual costs by editing individual barriers of interest, once restoration priorities have been set and barrier specific costs are known.

**Expanding Cost Data**

The Forum should continue to seek cost data, especially for grade control, fish passage facility, flood control structure, flow measurement weir and tide gate site types where the sample size was four or less. Outreach and/or a data call to local watershed groups and others is needed to gather more cost data for all site types as well as focusing efforts on collecting cost data for site types with a small sample size (e.g., a sample site less than five). Forum member organizations should annually query cost data within their organizations to continue to build this important dataset.



Figure 1. Fish Passage Implementation Sites compiled as a part of this analysis.