Lower Mokelumne River Restoration Assessment

User Manual | September 2015

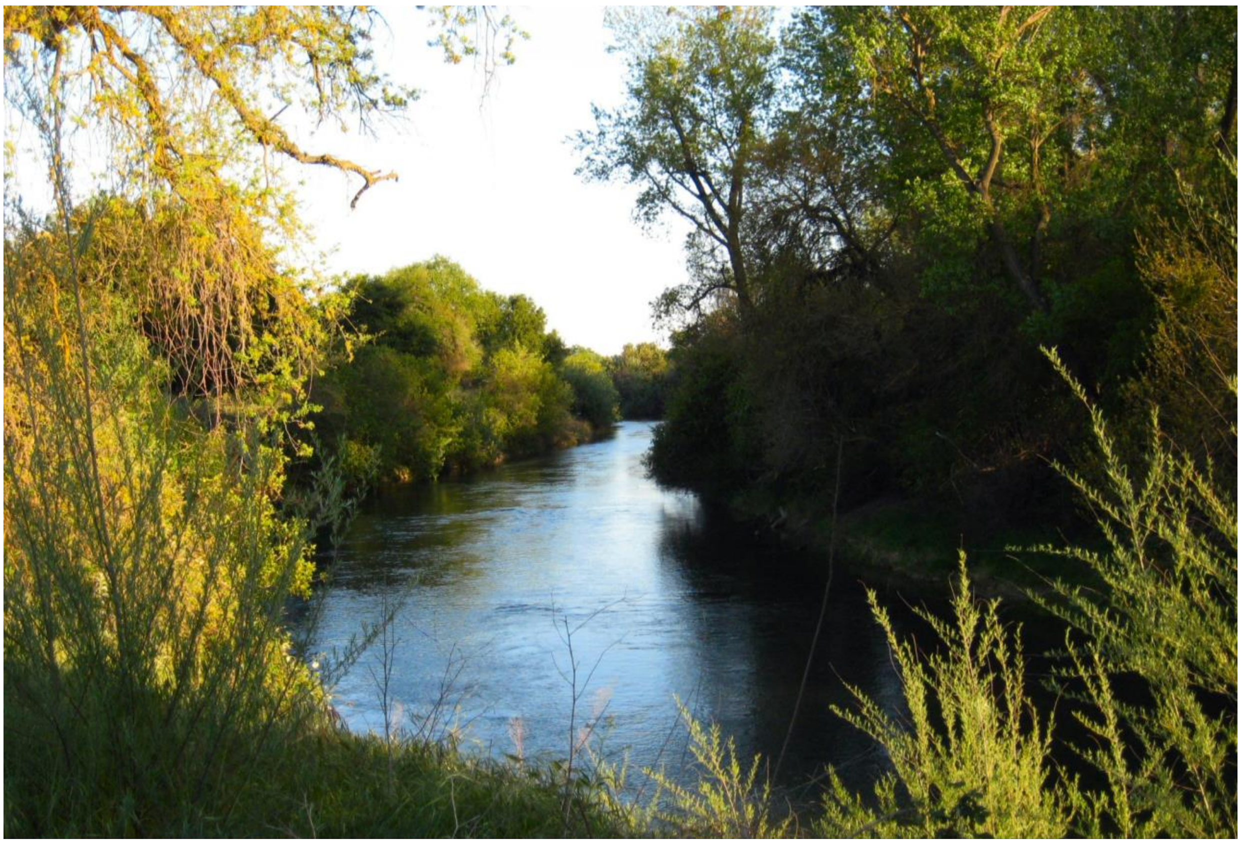

Photo Credit: Matt Hoffman

Sustainable Conservation

I. Introduction

This User Manual is intended to help you understand and use the results of Sustainable Conservation's **Lower Mokelumne River Restoration Assessment** (Assessment), an assessment of the potential for riparian restoration along the Lower Mokelumne River and an estimate of the associated costs and benefits. Please visit the **Sustainable Conservation website** to learn more about our Assessment and access the following results and supporting documents:

- Executive Summary
- Results Spreadsheet
- User Manual (this document)
- Overview Presentation
- GIS Map Files

Key results are included in the **Executive Summary**, while the full cost and benefit information is included in the more comprehensive companion **Results Spreadsheet**. The **Results Spreadsheet** includes additional functionality beyond simply sharing results: it allows users to make changes to cost estimates interactively and see the effects of those changes in real time. To make the most of this feature, we recommend you review the results in Excel.

This **User Manual** includes the **Executive Summary**, provides guidance for how to use the **Results Spreadsheet**, and details the methodology used for the Assessment.

An **Overview Presentation** outlining the results is also available as a stand-alone supporting document, along with the **GIS map files** used during this assessment.

Suggested Citation:

Sustainable Conservation. (2015). *Lower Mokelumne River Restoration Assessment*. Retrieved from: http://suscon.org/ecosystemservices/Mokelumne_River_Assessment.php

Contents

II. Executive Summary – Lower Mokelumne River Restoration Assessment

Purpose of Assessment: To inform and support public agencies and stakeholders in their work to collectively target conservation investments to achieve a healthy, functioning Lower Mokelumne River corridor. This assessment: 1) Quantifies the riparian area in need of restoration along the Mokelumne River; 2) Estimates the costs and benefits (using Riparian Habitat Quantification Tools) of conducting this restoration; 3) Identifies areas for focused landowner outreach, and provides decision-support information for stakeholders and agencies to make funding decisions.

Results: How much land is left to restore along the Lower Mokelumne River? What would it cost to restore, and what are the benefits? What types of restoration are most cost-effective for the benefits they produce?

Table 1 - Benefits and Costs of Riparian Restoration along the Lower Mokelumne River

Vegetation Types that could be restored to Native Riparian Forest or Shrub	Area (acres)	Implementation Cost (10 Acre Project)	Total Cost[1] (10 Acre Project)	Total Cost To Treat All Acres	Total Benefit (Functional Acre Unit Uplift[2])	
					Low landscape context[3]	*High landscape context[3]*
Annual Grassland	545.97	$36,938	$112,806	$6,158,923	76.44	65.53
Introduced Perennial Grassland	7.72	$65,834	$141,702	$109,396	1.04	0.95
Introduced Riparian Shrub	12.11	$48,360	$124,228	$150,391	1.63	1.49
Introduced Riparian Forest	13.84	$45,079	$120,947	$167,350	1.72	1.38
Riprap	1.12	$62,337	$138,205	$15,466	0.14	0.12
Totals	**580.75**			**$6,601,527**	80.97	69.47

Table 2 - Functional Acre Unit Uplift (per $100,000)

Vegetation Type	Bird[4]		Fish[4]		Flood[4]		Shade[4]		Combined Riparian Uplift	
Landscape context[3]:	*Low*	*High*	*Low*	*High*	*Low*	*High*	*Low*	*High*	*Low*	*High*
Annual Grassland	**3.77[5]**	**1.62**	**0.60**	**1.99**	0.15	0.50	***0.44***	***0.15***	**1.24**	**1.06**
Introduced Perennial Grassland	2.83	1.21	0.47	1.58	***0.17***	***0.56***	0.32	0.12	0.95	0.87
Introduced Riparian Shrub	3.23	1.39	***0.54***	***1.80***	**0.19**	**0.64**	0.37	0.14	***1.08***	***0.99***
Introduced Riparian Forest	***3.38[5]***	***1.45***	0.53	1.76	0.02	0.07	0.19	0.02	1.03	0.83
Riprap	2.66	1.14	0.43	1.45	0.08	0.27	**0.51**	**0.19**	0.92	0.76

Key conclusions:

- Within the existing landscape, the most benefit (relative to cost) is gained by restoring Annual Grasslands to Native Riparian Forest or Shrub habitats. This is the case from a riparian ecosystem-wide perspective, and when targeting the fish or bird habitat ecosystem functions specifically.
- Annual Grassland makes up the majority of the riparian habitat that could be restored: 94% (546 of 580.75 ac, total). Annual Grassland makes up 29% of the total riparian habitat (1895 ac)[6] in the study area[7].
- 69% of the total riparian habitat is currently intact, or not in need of restoration (1314 of 1895 ac). If all Annual Grasslands are restored to Native Riparian Forest or Shrub habitats, this number will increase to 98%.

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[1] We estimate that it will cost ~ $75,868 to plan and permit a 10 acre project.

[2] The quality of riparian habitat is measured in "Functional Acre Units" (FAU), defined as fully (100%) functioning areas. If a 10 acre project is assessed to be functioning at 50%, it is considered to provide 10 ac * 0.50 = 5 Functional Acre Units. Uplift is measured relative to baseline conditions before restoration, in which 580.75 acres provide 71.35 FAU in a low landscape context, and 282.01 FAU in a high landscape context.

[3] The Landscape Context is considered low when only 30% of the surrounding habitat is intact, and high when 100% is intact. The scope of the surrounding habitat that needs to be considered varies for each function.

[4] Benefits are reported for four specific ecosystem functions: riparian bird habitat, fish habitat, downstream flood attenuation, and stream shade

[5] Highest benefit/cost are shown in **bold**, and the second highest are shown in *blue italics*.

[6] For the purpose of this assessment, riparian habitat is considered all land along the river, excluding agricultural and urban areas.

[7] Confluence of the Cosumnes River upstream to Camanche Dam (Reach 2 through Reach 6 – see descriptions in **Study Area** below)

- 36% (194 ac) of this Annual Grassland is in Reach 2; 31% (169 ac) is in Reach 6; 14% (74.5 ac) is in Reach 5.
- Landscape context makes a big difference in the benefits gained through restoration, and the effects vary for each ecosystem function (see additional information in **Table 3** and **Table 4** below). For example, birds gain more from restoration within a **low functioning** surrounding landscape, while fish gain most from restoration within a **high functioning** surrounding landscape. This context needs to be considered when considering sites for restoration.
- The most benefit for shade ecosystem function results from restoration close to Camanche Dam: Reaches 5 & 6, which together have 45% (243.5 ac) of Annual Grassland. Restoring areas with low-lying vegetation (like Annual Grassland and Riprap) should provide the most benefit for shade, depending on position relative to the river.

Table 3 - Baseline Environmental Condition (% of potential function)[8]

Vegetation Type	**Bird**		**Fish**		**Flood**		**Shade**		**Combined Riparian Baseline Score**	
Landscape context[3]:	*Low*	*High*	*Low*	*High*	*Low*	*High*	*Low*	*High*	*Low*	*High*
Annual Grassland	15.3%	72.7%	5.2%	17.3%	5.5%	18.4%	23.0%	85.5%	12.24%	48.47%
Introduced Riparian Shrub	15.1%	72.6%	6.3%	21.0%	6.0%	19.9%	23.2%	85.4%	12.65%	49.72%
Introduced Riparian Forest	18.4%	74.0%	5.3%	17.5%	6.6%	22.0%	24.2%	86.8%	13.61%	50.08%
Riprap	15.6%	72.8%	8.1%	27.0%	7.2%	24.0%	22.1%	84.3%	13.27%	52.02%
Native Riparian Forest	58.3%	91.1%	11.9%	39.8%	7.2%	23.8%	27.6%	86.9%	26.25%	60.43%
Native Riparian Shrub	53.1%	88.9%	13.5%	44.9%	8.5%	28.2%	26.4%	86.9%	25.36%	62.23%

Table 4 - Percent Uplift from Baseline[9]

Vegetation Type	**Bird**		**Fish**		**Flood**		**Shade**		**Combined Riparian Uplift**	
Landscape context[3]	*Low*	*High*	*Low*	*High*	*Low*	*High*	*Low*	*High*	*Low*	*High*
Annual Grassland	42.6%	18.2%	6.7%	22.5%	1.7%	5.6%	5.0%	1.7%	14.00%	12.00%
Introduced Riparian Shrub	40.2%	17.2%	6.7%	22.4%	2.4%	7.9%	4.6%	1.7%	13.46%	12.31%
Introduced Riparian Forest	40.9%	17.5%	6.4%	21.3%	0.3%	0.8%	2.3%	0.3%	12.46%	9.98%
Riprap	36.7%	15.7%	6.0%	20.0%	1.1%	3.7%	7.0%	2.6%	12.71%	10.51%

Interpretation of landscape context's effect on restoration benefits for each ecosystem function:

- To birds, the benefit of restoration on any individual site is higher in a **low functioning** surrounding landscape than in a **high functioning** surrounding landscape. Birds are highly mobile, and if the surrounding landscape is already restored and provides access to quality habitat, they don't benefit significantly by filling in a single hole in the habitat. In a degraded landscape, the birds gain significantly from the newly improved habitat available to them.
- The benefits that stream shade provides to water temperature and fish habitat are higher in a **low functioning** surrounding landscape than in a **high functioning** surrounding landscape. If the stream is fully shaded, restoring any individual site would not add any significant benefit. In a degraded habitat, it is most effective to focus restoration to keep cold water cool by increasing stream shade closest to the source of the cold water, which in this case is Camanche Dam (Reach 6).

[8] This table shows the baseline environmental condition (as a percent of full function) of various vegetation communities along the Lower Mokelumne River. These are shown for four separate ecosystem functions and a combined riparian habitat ecosystem function.

[9] This table shows the environmental uplift (as a percent of full function) as a result of restoring the various riparian vegetation communities to the desired future conditions: native riparian forest or shrub habitat. This is shown for the same four separate ecosystem functions as well as the combined riparian habitat ecosystem uplift.

- To fish, the opposite is true. The benefit of restoration on any individual site is higher in a **high functioning** surrounding landscape than in a **low functioning** surrounding landscape. For fish, the entire river is considered important habitat, because the river needs to support all life stages of the fish, which require different habitat characteristics. In other words, if one site along the river contains nice habitat, but is surrounded by degraded habitat, fish don't benefit as much.
- The benefits that restoration provides for downstream flood attenuation is higher in a **high functioning** surrounding landscape than in a **low functioning** surrounding landscape. Flood water does not stop moving downstream, and any individual restoration site cannot absorb an entire flood. Instead, the system benefits the most from an individual site being restored when the surrounding landscape is also fully functioning.

Study area:

- This assessment focuses on the area of the Lower Mokelumne River from the confluence of the Cosumnes River upstream to the Camanche Dam (Reaches 2-6, as described by Reeves & Jones [2004]).
    - Reach Two: confluence of the Cosumnes River upstream to Woodbridge Dam
    - Reach Three: Woodbridge Dam upstream to the Highway 99 Bridge
    - Reach Four: Highway 99 Bridge upstream to the Elliott Road Bridge
    - Reach Five: Elliott Road Bridge upstream to the Mackville Road Bridge
    - Reach Six: Mackville Road Bridge upstream to Camanche Dam
- This assessment is based on the vegetation map produced by Reeves & Jones (2004), updated to reflect recent restoration projects (methods included in **Appendix 1a.** Updating the Reeves & Jones (2004) vegetation map and map file metadata). The total area mapped includes 100 m on either side of the Mokelumne River from Reach 2 through Reach 6, totaling 3242 acres. We excluded agricultural (1108 ac) and urban areas (239 ac) to determine the total riparian habitat area (1895 ac).

Notes and Constraints:

- We identified five vegetation types that could be restored. We considered the Native Riparian Shrub and Forest habitats described by Reeves & Jones (2004) as the desired future conditions when estimating restoration actions and associated costs. For more information, see full vegetation community descriptions in Appendix 2. Vegetation Communities Described in Reeves & Jones (2004).
- We only considered restoration actions to improve vegetation, ruling out major changes to the physical structure of the river or floodplain (i.e. no levee setbacks were considered). This explains why we do not see close to 100% function for the fish habitat and flood attenuation ecosystem functions, which require additional aquatic habitat and floodplain connectivity to reach 100% function.
- We did not have potential benefit information for Introduced Perennial Grassland habitats (which consist primarily of *Arundo donax*), and used the benefit estimates for Introduced Riparian Shrub habitats as a proxy.

Guide to Technical Resources Contained in Results Spreadsheet

This section is intended to provide the guidance needed to understand and use the technical resources contained in the Lower Mokelumne River Restoration Assessment Results Spreadsheet. The Results Spreadsheet (available for download on the Sustainable Conservation website) consists of a set of tabs (individual spreadsheets) that include all of the information that informed our analysis. These include a summary of the riparian area that could be restored along the Lower Mokelumne River and the associated cost and benefit information detailing the potential results of that restoration.

As noted above, the Results Spreadsheet provides additional utility beyond simply containing the results of our analysis: it allows users to make changes to cost estimates interactively and see the effects of those changes in real time. To make the most of this feature, we recommend you review the results in Microsoft Excel.

As you explore and use the Results Spreadsheet, please refer to the corresponding sections of this User Manual.

III. Results Spreadsheet Contents (Tabs)

1. Table of Contents
2. Area Summary
3. Cost & Benefit Summary

Cost Estimates:

4. Annual Grassland (Implementation)
5. Introduced Perennial Grassland (Implementation)
6. Introduced Riparian Shrub (Implementation)
7. Introduced Riparian Forest (Implementation)
8. Riprap (Implementation)
9. Project Planning and Permitting

Environmental Benefit Estimates:

10. Annual Grassland
11. Introduced Riparian Shrub
12. Introduced Riparian Forest
13. Riprap
14. Supporting environmental function data, produced by Stillwater Sciences

IV. Tab 2: Area Summary

Tab 2 provides a summary of the riparian area that could be restored along the Lower Mokelumne River, and provides the spatial context for understanding our assessment. All information in this tab is drawn directly from the GIS map files containing the updated Reeves & Jones (2004) vegetation map (see Appendix 1a. Updating the Reeves & Jones (2004) vegetation map for a detailed explanation of how this map was updated based on recent restoration).

These GIS map files (available for download on the Sustainable Conservation website) provide information about the vegetation types that exist within our study area and were used to quantify the extent of land that could be restored to riparian habitat. This tab shows the area (in acres) in each specific vegetation community mapped by Reeves & Jones (2004) broken up by reach and totaled for Reach 2 through 6. These vegetation communities are separated into the following five large groups (see details in Appendix 2. Vegetation Communities Described in Reeves & Jones (2004)):

1. Agriculture
2. Restorable Communities, or vegetation types that could be restored to native riparian forest/shrub habitats
3. Intact Communities, or those *not* in need of restoration
4. Urban, including levee roads, off channel water, roads, and urban communities
5. Mokelumne River

This tab also shows the percentage of land each vegetation community occupies within each individual group, within the Total Riparian Habitat (Intact + Restorable Communities), the Total Non-Urban Land area, and the Total Land Area (all but River).

V. Tab 3: Costs and Benefits Summary

Tab 3 provides a summary of the benefit and cost information produced through this assessment, drawing from the more detailed cost and benefit tabs for each individual vegetation type within the Results Spreadsheet. This tab should serve as the primary focus for most users of this assessment, and will help identify areas further exploration.

Table 1 summarizes the cost estimates for restoring the five vegetation communities identified as "Restorable": Annual Grassland, Introduced Perennial Grassland, Introduced Riparian Shrub, Introduced Riparian Forest, and Riprap (see details in Appendix 2. Vegetation Communities Described in Reeves & Jones (2004)). This table includes the field implementation cost, project planning and permitting cost, and the total cost per 10 acre project, along with the total cumulative cost to treat all acres. For comparison, these cost estimates are shown next to the total estimated environmental benefit of restoring these vegetation communities (the quality of riparian habitat is measured in "Functional Acre Units," defined as fully [100%] functioning habitat – see more below). Landscape context makes a big difference in the benefits gained through restoration, and the effects vary for each ecosystem function. For this reason, benefits are estimated for both *low* and *high landscape contexts* throughout this assessment. The *landscape context* is considered *low* when only 30% of the surrounding habitat is intact, and *high* when 100% is intact. The degree to which the surrounding area affects habitat quality varies for each ecosystem function (e.g. bird habitat vs. fish habitat), and these effects are factored into the

Riparian Habitat Quantification Tool used to estimate benefits. An explanation of why landscape context effects each ecosystem function differently is included in the **Executive Summary.**

Table 1 is static and shows the results of our assessment based on the cost information we decided to use. However, to make this document most useful for decision-making, we've included an additional table directly below Table 1, titled Table 1A, which will update automatically based on any changes a user makes to the cost information in Tabs 4-9 (see VI. Tabs 4-9: Cost Estimates below for detailed instructions on these tabs). Table 1A mirrors the columns and rows included in Table 1.

Table 2, directly to the right of Table 1, shows the estimated environmental baseline conditions for each vegetation community we considered, shown as a percent of the total potential for each of four specific ecosystem functions: riparian bird habitat, fish habitat, downstream flood attenuation, and stream shade. Table 3 shows the estimated environmental uplift resulting from restoration to the desired future conditions (native riparian shrub or forest habitat), shown as a percent of total potential gained (read more about how these benefits were calculated in VII. Tabs 10-14: Environmental Benefit Estimates and in II. Estimating environmental benefits as uplifts from baseline data).

The next set of tables (Tables 4 and 5) show this same baseline and uplift information, but translated from percentages to Functional Acre Units. The Functional Acre Unit is calculated by multiplying the percent of possible function (environmental baseline, or uplift) by the total area in that vegetation community. This puts the baseline conditions in the context of the number of fully functioning acres of habitat, and how many additional fully functional acres would be gained through restoration.

The final two tables (Tables 6 and 7) show the benefits gained in slightly different ways, both intended to help compare the benefits to the costs. Table 6 shows the Functional Acre Uplift gained per 10 acre restoration project, for each vegetation community, for each ecosystem function, in each landscape context. Table 7 shows the Functional Acre Uplift gained for every $100,000 invested in restoration, which is the estimated ratio of benefits gained per unit cost. (Please note: these two tables are based on data included in Table 1, not Table A1, and will not reflect changes made to the cost estimates).

VI. Tabs 4-9: Cost Estimates

Tabs 4 through 9 outline the estimated costs of restoring each of the five restorable vegetation communities. For each of the five habitat types we identified as restorable, we assumed the desired future condition to be a native riparian forest ecosystem (for elevations of 6 feet or higher relative to the river) or a native riparian shrub ecosystem (for elevations within 6 feet relative to the river). See full vegetation community descriptions in Appendix 2. Vegetation Communities Described in Reeves & Jones (2004).

The costs of implementing restoration projects to improve these restorable habitats to their desired conditions were estimated using the Financial Year 2015 cost scenarios provided in the NRCS Field Office Technical Guide (FOTG), as compiled on Sep. 9, 2014. (This information is available at http://efotg.sc.egov.usda.gov, in Section 1, Cost Data, Payment schedules, FY15 Practices Payment Scenarios.) The estimates reflect the total practice cost.

Referring to the NRCS cost estimate scenarios, we chose the practices we determined to be most appropriate to accomplish the restoration, given the descriptions and the typical topographic positions of each vegetation community. In general, we separated restoration into three discrete steps: 1) remove introduced species, 2) plant and establish native vegetation, and 3) conduct ongoing management. We chose one NRCS practice for step 1 (if necessary), multiple practices for step 2, and one practice for step 3 (if necessary).

Each vegetation community's tab is separated into two main sections. At the top are the NRCS practices we determined to be most appropriate, separated into the three main restoration steps.

- Column A allows you to turn **On** or **Off** each row. If you disagree with a specific practice being used, you can turn it **Off** by entering "0," and its cost will not be included in the total cost. Similarly, you can use this column to turn **On** practices that you think would be more appropriate. You can see a list of other related NRCS practices and their costs starting on row 19 (Restoration Menu). These are all currently turned **Off**.
- Column B and C contain the NRCS practice code and name
- Column D contains a description of the specific cost scenario
- Column E contains the unit size (acre, linear foot, etc.) that the cost relates to.
- Column F contains the cost per unit, as included in the NRCS total practice implementation cost estimates
- Column G contains the quantity of units on which to apply the practice. These cells automatically update based on the Site size (cell F14), which is recorded in acres. Please feel free to adjust this to see how the cost changes for larger projects.
- Column H contains the total cost associated with this practice (which is generally Column F multiplied by Column G). These costs are totaled at the bottom of the first section of the spreadsheet

Cells that are **shaded green** contain input values that any user can change; the calculations that depend on them will update automatically. Cells that are shaded blue contain calculations that update automatically based on these input values. Please focus your attention on turning on or off each row in Column A or adjusting the site size in cell F14.

Some restoration practices are more appropriate at specific elevations above the river level, and some project sites require multiple planting and establishing practices as a result. As an example, introduced riparian grasslands were generally found along the river bank, straddling the line at 6 feet relative to the river. We determined that close to the river (within 6 feet), planting willow cuttings would be most appropriate, whereas further up from the river (more than 6 feet from the river), planting small container trees and shrubs would be more appropriate. You can adjust how much of the project falls within 6 feet of the river in cell F15.

The cost information included in **Tabs 4-8** only refer to implementation costs. Costs associated with project planning and permitting are summarized and estimated in **Tab 9**. These cost estimates were based on the budgets of past restoration projects conducted along the Mokelumne River (in Reach 2 and in Reach 4), and information was collected from Audubon CA, USDA NRCS, and the San Joaquin County Resource Conservation District.

VII. Tabs 10-14: Environmental Benefit Estimates

Tabs 10-13 outline the estimated environmental benefits of restoring the vegetation communities identified as restorable in our study. These estimates were derived directly from data produced by applying the Riparian Habitat Quantification Tool to specific vegetation communities at actual restoration sites in the study area. This supporting data is included in **Tab 14.**

Tabs 10-13 include specific benefit information for Annual Grassland, Introduced Riparian Shrub, Introduced Riparian Forest, and Riprap vegetation communities, respectively. We did not have any calibration sites with conditions similar to the Introduced Perennial Grassland vegetation type, and therefore do not have specific benefit estimates. To approximate the benefit of restoring Introduced Perennial Grassland, we assumed the benefits to be similar to those of restoring the Introduced Riparian Shrub vegetation type.

Columns A-J are consistent throughout **Tabs 10-14**, and are defined as the following:

- Column A shows a unique identifier assigned to each vegetation polygon assessed using the Riparian Habitat Quantification Tool. A polygon is essentially an individual unit of area consisting of the same vegetation community.
- Column B shows the restoration site where that specific vegetation polygon exists. Our assessment includes information from seven recent restoration projects.
- Column C shows the "run" number corresponding to the number of times the Riparian Habitat Quantification Tool was run for that specific site. This variable does not apply directly to the tables, and is only included for identification purposes.
- Column D shows the polygon number corresponding to how each individual polygon was originally mapped at its specific restoration site.
- Column E shows the vegetation code corresponding to the specific vegetation present in that polygon.
- Column F shows which of the corresponding vegetation communities included in our assessment matches the vegetation code. Specific descriptions of each vegetation code can be found in the Riparian Habitat Quantification Tool User Guide, available on the Sustainable Conservation website.
- Column G, H, and I show the topographic attributes of each polygon
    - Column G shows the elevation of the polygon relative to the river (either *Above* or *Below* six feet from the river).
    - Column H shows the side of the river on which the polygon is located (*River right*, meaning the right-hand side of the river from the perspective of an observer facing downstream, or *River left*, which means the left-hand side of the river when facing downstream).
    - Column I shows the position of the polygon relative to a levee either *Inside* (between river and levee) or *Outside* (on opposite side of the levee as the river).
- Column J shows the size of the polygon (or group of polygons), in acres

Tabs 10-13 each have five main tables. In each table, the baseline and uplift values are shown for each of the four ecosystem functions measured by the Riparian Habitat Quantification Tool as a range between the low and high landscape contexts. As a reminder, the *landscape context* is considered *low* when only 30% of the surrounding habitat is intact, and *high* when 100% is intact. Also shown are Combined Riparian Scores (for both low and high landscape contexts), which are averages of the baseline or uplift for each of the four ecosystem functions measured.

Table 1 shows the **environmental baseline** as a percent of the potential ecosystem function possible for that specific polygon. The topographic attributes shown in Columns G-I are included to show the effects of geography on ecosystem function, in addition to vegetation type.

Table 2, directly to the right, is a companion to Table 1. This table shows the **environmental uplift** as a percent of the potential ecosystem function gained through restoration. These uplift values were calculated by subtracting the environmental baseline conditions of the restorable vegetation community (such as Annual Grasslands) from the environmental conditions of the desired future vegetation community (Native Riparian Forest or Native Riparian Shrub).

Table 3 shows the average environmental baseline and environmental uplift produced as a result of restoration. These average baseline and uplift values are shown both as a percent of potential, as well as in terms of Functional Acre Units. As a reminder, Functional Acre Units are defined as fully (100%) functioning areas (these cells are shaded red).

Table 4 and 5 show the average baseline environmental condition and average environmental uplift for each of the eight specific topographic combinations. These are included to capture the variation in baseline and uplift values based on topographic conditions, and could be helpful for conservation practitioners looking to address a very specific ecosystem function. Targeting a specific topographic context could allow for an even greater return on investment, but is very site specific and not as useful for a large watershed analysis.

Tab 14 includes the supporting environmental baseline data produced by applying the Riparian Habitat Quantification Tool to specific vegetation communities at actual restoration sites along the Lower Mokelumne River, using habitat information collected before restoration took place.

This tab also includes the corresponding environmental uplift values (Columns AH-AP), which estimate the environmental benefit gained by restoring each vegetation community. As a reminder, these uplift values were calculated by subtracting the environmental baseline conditions of the restorable vegetation community (such as Annual Grasslands) from the environmental conditions of the desired future vegetation community (Native Riparian Forest or Native Riparian Shrub, quantified using habitat information collected at sites after restoration took place). To ensure that the comparisons are as accurate as possible, we compared restorable vegetation communities to desired future vegetation communities at either the same polygon (pre- and post-restoration) or to a polygon with the same topographic attributes. The full methods used to calculate these baseline and uplift values are included in Appendix 1b. Estimating the environmental benefits of restoration.

- Columns K through O show the combined capacity score of the polygon. This “combined capacity score” combines the site capacity score with the project area capacity score (found in Columns Z-AF). For a full explanation of how to read and understand these scores, please refer to the Riparian Habitat Quantification Tool User Guide on the Sustainable Conservation website.
    - Column N and O show the combined capacity score for the Shade function, assuming a 60/40 split between project area and site capacity scores. Column N shows the value

assuming the rest of the site to be degraded, while Column O shows the value assuming the rest of the site to be restored.

- Columns P and Q show the percent of the surrounding habitat that is considered as intact for the maximum and minimum landscape capacity scores. As described above, the landscape context is considered low ("LS Low") when only 30% of the surrounding habitat is intact, and high ("LS High") when 100% is intact. The scope of the surrounding habitat that needs to be considered varies for each function.
- Columns R-Y show the final environmental baseline scores for each polygon for each of the four ecosystem functions.
    - Columns R-U show these the baseline values assuming a high landscape context
    - Columns V-Y show these the baseline values assuming a low landscape context
- Columns Z through AF show the supporting Project Area Capacity and Site Capacity scores that are used to calculate the Combined Capacity scores in Columns K-O. See the Riparian Habitat Quantification Tool User Guide for a full description of these values.
- Columns AH through AP include the corresponding environmental uplift values calculated by Sustainable Conservation.
    - Column AP shows the vegetation type identified as the desired future condition of that specific polygon, based on topographic variables.

VIII. Citations

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Appendices

Appendix 1. Methodology

Appendix 1a. Updating the Reeves & Jones (2004) vegetation map

Two large actions were taken to update the Reeves & Jones (2004) vegetation map:

1) Update polygons where vegetation had changed due to active restoration. To determine where restoration had occurred, we referred to the restoration sites that Stillwater Sciences used as calibration sites during their development of a riparian habitat quantification tool as part of the Mokelumne Environmental Benefits Conservation Innovation Grants (national and state grants). The vegetation classifications recorded in polygons in the calibration site shapefiles were used as the most up-to-date.
2) Perform a randomized spot check of the Reeves & Jones (2004) vegetation map in an attempt to gauge the degree to which vegetation changed since the original vegetation assessment in the early 2000s, and if vegetation did change, identify if any broad patterns of change applied, which would allow us to make changes at a broad scale

I. Updating polygons based on recent restoration:

1. After gathering the calibration site shapefiles from Stillwater Sciences, we made sure each had the same attribute columns. For those that did not, we added the fields in manually.
    a. Next, we moved the field placement, so that they matched across all the shapefiles
2. Then, we combined all of the Calibration site polygons into a single shapefile, using the "Merge" Tool, in the Arc Toolbox, Data Management (see here), to produce the file, "Calibration_Site_Merge."
3. Next, we used the "Intersect" tool (Arc Toolbox, Analysis tools, Overlay toolset, see here), to produce a layer that included all of the Calibration Site polygons that fell within the boundary of the Reeves & Jones 2004 Vegetation map.
4. Then, we cross-walked the calibration site vegetation classifications with the vegetation communities used by Reeves & Jones (2004). This allowed us to recode the polygons in the updated Reeves & Jones (2004) vegetation map shapefile using consistent nomenclature.
5. Finally, we updated the polygons based on the calibration site information.
    - Note: We realized that the majority of changes to these vegetation communities would have been due to proactive management, and therefore would not allow us to make any broad generalizations beyond areas at the calibration sites.

II. Performing randomized spot checking of the Reeves & Jones (2004) Vegetation Map:

1. First, we sorted the polygons in the Reeves Jones 2004 Veg Map by reach.
    - Then, we eliminated polygons in Reach 1, since we are not including Reach 1 in our analysis
    - We then assigned each polygon a random number, generated by Excel.

- We sorted these polygons by vegetation community and then by the random number, from smallest to largest.
- For vegetation communities we determined to be degraded (in need of restoration: Annual Grassland, Introduced Perennial Grassland, Introduced Riparian Shrub, Introduced Riparian Forest, and Riprap), we chose the first 25 polygons, to spot check to see if they have changed/improved
- For vegetation communities we determined not to be degraded (Native Perennial Grassland, Native Riparian Shrub, Riparian Willow Shrub, Interior Live Oak Woodland, Valley Oak Woodland, Riparian Willow Woodland, & Native Riparian Forest), we decided we were not as concerned with the possibility of degradation, and decided to spot check 10, in order to save time. Especially on restoration sites, we assumed that these types of habitats have been managed.

2. Next, we visually spot-checked each of the randomly selected polygons, to check that the current state matched the vegetation community as recorded. This visual spot-check was conducted using a combination of the Google Earth imagery (imagery current as of spring 2014) & ArcGIS World Imagery.
    - Some polygons were switched entirely from one community to another, while some polygons were split into smaller units, to be put into different communities
    - All polygons that were updated are marked as "1" in the "Updated_" column
3. All polygons that needed to be updated were re-coded in the appropriate vegetation community, under the field, "**New_Veg**"
4. Because we updated the size of some of these polygons, we had to recalculate the area of the polygons using the "Calculate geometry" function.
    - Two new fields were added, one showing area in ft^2 ("**NewArea_ft**") and one showing area in acres ("**NewArea_Ac**")
5. The old fields were left unedited, for reference. Please note that the short abbreviated vegetation community field "VEG_COM" was not updated, and is therefore no longer accurate. Please use the new polygon classifications listed under the field "**New_Veg**" as the most current vegetation classification. However, some of the old fields are still accurate and useful, particularly "**RIVER_REAC**," which displays in which reach the polygon resides.
    - Note: after conducting this randomized spot check, we were unable to confidently discern any pattern of change across these polygons. As a result, we could not make any broad generalizations, and left the rest of the polygons unchecked and unchanged. Overall, the polygons that were checked showed seemingly random and infrequent changes.

Appendix 1b. Estimating the environmental benefits of restoration

I. Estimating the environmental function of each vegetation community, based on Riparian Habitat Quantification Tool outputs at past restoration sites (conducted by Stillwater Sciences).

Goal: Develop representative riparian function scores for five[10] vegetation types and one mature riparian forest condition in order to estimate the difference in riparian benefits for typical sites that could be restored within the Lower Mokelumne watershed. To the extent possible, this will be performed using updated scores from 'calibration sites' (existing restoration projects along the Lower Mokelumne River) so that all before and after scores are computed using the final version of the tool.

Steps

Characterizing Topographic Positions

1. Identify four restorable vegetation types along Lower Mokelumne River:
    a. Introduced riparian forest
    b. Introduced riparian shrub
    c. Annual grassland
    d. Riprap
2. These will be 'restored' to a 'mature riparian forest or mature riparian shrub as appropriate': mature shrub within 20 feet of river's edge (low flow); mature riparian forest in areas greater than 20 feet from river's edge.
3. Describe typical topographic positions for each of the restorable vegetation types based on Reeves and Jones' (2004) vegetation map and other spatial data so that typical baseline conditions can be associated with similar 'calibration sites.' Topographic variables considered for each vegetative type using the riparian tool include typical position relative to 1) existing levees, 2) elevation above Mokelumne River using DEM or 2-ft contours to determine above or below 6-foot elevation, 3) north or south aspect, and 4) presence/absence of eroding river bank (*eroding banks not available as spatial data so not included in spatial evaluation*). The maximum number of actual distinct combinations of these topographic variables is **eight**.
4. Sustainable Conservation will find sites where there is an eroding levee near the river.
5. The typical topographic variables for each restorable vegetation type of interest will be used to find areas with similar topographic features at the calibration sites to serve as representative post-restoration equivalents.
6. Findings from this analysis were summarized and provided to Sustainable Conservation in the 'Lab Report' sent by 12/1/2014

Characterizing Uplift in Benefits with Restoration of each Vegetation Type

Seven pilot sites along the Lower Mokelumne River were used to run the Quantification Tool assuming restorable vs. restored vegetation cover. For each of the seven sites, the following steps were performed:

[10] No Introduced Perennial Grassland restoration sites (consisting primarily of *Arundo donax*) were available to include in our analysis at the time of this study. As a result, benefit estimates for Introduced Riparian Shrub habitats were used as a proxy.

1. Locate one or several contiguous polygons within the site that represents a consistent set of topographic positions.
2. Assign a vegetation type (restorable or restored) to that area and assign a 'run number'.
3. Assign appropriate restorable vegetation types (based on topographic position) to each area and assign unique run numbers to each
4. Assign appropriate restored vegetation types (based on topographic position) to each area and assign unique run numbers to each
5. Using the Mokelumne Riparian Benefits Quantification Tool developed for that pilot site, replace data in the veg tab with the assigned vegetation type and appropriate associated variables for each run. For polygons in the pilot area that are not included in the 'run', clear all data in the vegetation tab. The results will be tailored to just the acreage within the active polygons.
6. Make appropriate adjustments for new vegetation types to the Fish Field and Bird Field data sheets. Assume management for restorable includes pesticide applications and management for restored does not.
7. Record Project Capacity Scores and Site Capacity Scores for each benefit type in the summary spreadsheet for each run.
8. Combine these scores with the landscape priority score assuming degraded (30%) vs. fully restored (100%) landscape conditions.
9. Use the Mokelumne Benefits Shade-a-lator developed for each pilot site and replace the vegetation codes, per the restorable and restored runs to the Shade-a-lator.
10. It was not possible to 'clear' the other polygons within the pilot sites from the Shade-a-lator runs. Therefore, we converted the surrounding 'unused' polygons for each run to either restorable or restored conditions so that these could be combined with restorable or restored landscape priority scores.
11. In order to assume the surrounding landscape is degraded, we assigned the remaining polygons as 'annual grassland' vegetation type, and ran the Shade-a-lator.
12. Record results in summary sheet.
13. In order to assume the surrounding landscape was fully restored, we replaced the existing vegetation codes, outside of the polygons targeted in the run, either *Salix lasiolepis* (arroyo willow) within the first 20 feet from the low flow bank, or Mixed deciduous riparian forest for the remaining area. We then ran the Shade-a-lator and recorded results in summary sheet.
14. Report two shade project capacity and site capacity scores: 1) assuming rest of pilot site is restorable, and 2) assuming rest of site is in fully restored condition. Combine these with low and high landscape priority scores, respectively.

Developing Final Uplift Estimates

Benefits from theoretical restoration efforts can be calculated by comparing restorable vs. restored vegetation in paired runs (see columns AH-AO of Tab 14: Supporting Benefit Data).

II. Estimating environmental benefits as uplifts from baseline data

At this point, Sustainable Conservation took the raw data produced by Stillwater Sciences (see Tab 14), and consolidated it into more manageable figures to communicate the estimated benefits of restoring various habitat types (Tabs 10-13).

These raw estimates of the environmental condition of each vegetation type were displayed as the percentage of full function as quantified by each of the four ecosystem functions (riparian bird habitat, fish habitat, downstream flood attenuation, and stream shade), using two estimates of the surrounding landscape conditions (**High**, fully restored [100%], and **Low**, degraded [30%]). These polygons were categorized according to three topographic variables, with 8 distinct combinations:

- Elevation relative to river (Above or Below 6 feet from the river)
- Side of river (River right or River left)
- Position relative to levee (Inside or Outside)

Sustainable Conservation began by directly comparing the environmental conditions between restorable and fully restored vegetation types for pairs of polygons that matched in both location and size. The restored habitat type to which we would compare (either Native Riparian Shrub of Native Riparian Forest) was determined based on the topographic position of the polygon. In this way, we were able to calculate the percent environmental uplift produced when restoring a specific polygon from a restorable vegetation type to a restored vegetation type.

Next, we averaged both the (1) environmental baseline condition and (2) environmental uplift for each of these distinct polygons for each vegetation type we analyzed. To display these baselines and uplifts in terms of Functional Acre Units (defined as fully [100%] functioning areas) we multiplied the average percentages by the number of acres in each vegetation type. These baseline and uplift values are presented as a range for each ecosystem function (birds, fish, flood, and shade) based on landscape context.

In order to capture the variation in environmental baseline condition and the potential for environmental uplift at polygons with different topographic conditions, we also took the average baseline environmental condition and average environmental uplift for all polygons with the same topographic condition. These are shown in Tables 4 and 5 of each vegetation community tab (Tabs 10-13).

We also considered an additional method for calculating the total environmental baseline and environmental uplifts in terms of Functional Acre Units, which would have involved using the averages within each topographic combination to calculate the Functional Acre Units gained within each combination, and then summing them to produce the total uplift. We ultimately decided not to use this method because we lacked enough information for each distinct topographic combination for each vegetation type to yield a decent estimate. As a result, we would have been unable to estimate the uplift for 100% of the restorable area.

We did not have any calibration sites with conditions similar to the Introduced Perennial Grassland vegetation type, and therefore do not have specific benefit estimates. To approximate the benefit of restoring Introduced Perennial Grassland, we assumed the benefits to be similar to those of restoring the Introduced Riparian Shrub vegetation type.

Appendix 1c. Estimating the costs of restoring degraded vegetation communities

The costs of implementing restoration projects to improve the remaining area with degraded habitat to their corresponding desired future condition were estimated using the Financial Year 2015 cost scenarios provided in the NRCS Field Office Technical Guide (FOTG), as compiled on Sep. 9, 2014. This information is available at http://efotg.sc.egov.usda.gov, in Section 1, Cost Data, Payment schedules, FY15 Practices Payment Scenarios.

Referring to the NRCS cost estimate scenarios, we chose the practices we determined to be most appropriate to accomplish the restoration, given the vegetation descriptions and the typical topographic positions of each. In general, we separated restoration into three discrete steps: 1) remove introduced species, 2) plant and establish native vegetation, and 3) ongoing management. In general, we chose one NRCS practice for step 1 (if necessary), and multiple practices for step 2, and one for step 3 (if necessary). The estimates reflect the total practice cost.

Appendix 2. Vegetation Communities Described in Reeves & Jones (2004)

Restorable Vegetation Communities

Annual Grassland

Annual Grassland is open grassland primarily composed of annual plant species. Many of these species occur along roadsides, adjacent to and in agriculture crops, and as understory plants in Valley Oak Woodland and Native Riparian Forest vegetation communities. Annual grasses and herbs dominate in the ground layer. Typical species include ripgut, *Bromus diandrus*, soft chess, *Bromus hordeaceus*, foxtail chess, *Bromus madritensis*, filaree, *Erodium botyrs* and *E. cicutarium*, yellow starthistle, *Centaurea solstitialis*, goldfields, *Lasthenia californica*, lupine, *Lupinus bicolor*, oats, *Avena barbata* and *A. fatua*, rye, *Lolium multiflorum,* and mustards, Brassica sp. Other species identified in Annual Grassland along the lower Mokelumne River that are invasive, considered detrimental to native ecosystems, and may also harbor disease and pests harmful to agriculture include California burclover, *Medicago hispida*, common mallow, *Malva neglecta*, nightshade, *Datura sp., sowthistle*, *Sonchus sp*., and lambsquarter, *Chenopodium sp.* Emergent shrubs and trees may be present, and grass tends to be less than 1 m in height. This habitat is continuous and open. Composition of plant species may vary based on proximity to other habitats in the watershed. The most invasive wildland pest plant that occurs in this vegetation community is yellow starthistle. Annual Grassland comprises about 27.1% of the communities mapped along the lower Mokelumne River, with most (63%) in Reach One.

Introduced Perennial Grassland

This vegetation community is seasonally or permanently saturated with a shallow water table. Along the lower Mokelumne River this community is almost exclusively dominated by giant reed, *Arundo donax*. Another introduced perennial grass that may occur occasionally throughout the watershed, but was not extensive enough to map (less than 100 m^2) is pampas grass, *Cortaderia selloana*. Individual and small patches of giant reed, less than 100 m^2 in area were observed throughout the watershed. This vegetation community consists of grasses less than 1 m tall with open cover to grasses less than 8 m (26.2 ft.) tall with continuous cover. It comprises less than 1% of the communities mapped along the lower Mokelumne River, with most (65%) in Reach Four.

Introduced Riparian Shrub

This vegetation community/habitat association tends to be seasonally flooded or saturated. It occurs in floodplains along streams and rivers. Along the Lower Mokelumne River this community tends to be dominated by Himalayan blackberry, *Rubus discolor*, with occasional non-native perennial grasses (e.g. pampas grass) less than 1 m in height. Fremont cottonwood, white alder, box elder, elderberry, coyote brush, California rose, poison oak, or willows may be present. Emergent trees may also be present. Shrubs tend to be less than 6 m (19.7 feet) tall with continuous canopy and variable ground layer. Himalayan blackberry is classified by Cal-IPC (1999) as another one of the most invasive wildland pest plants in the state and is on the A-1 list of Exotic Pest Plants. This habitat/association tends to be found as an understory of the Native Riparian Forest. Introduced Riparian Shrub comprises less than 1% of the communities mapped along the Lower Mokelumne River with the most (63%) occurring within Reach One.

Introduced Riparian Forest

This habitat tends to be seasonally flooded or saturated and occurs in floodplains along streams and rivers. Along the lower Mokelumne River this non-native vegetation community is dominated by black locust, *Robinia psuedoacacia*, and/or tree of heaven, *Ailanthus altissima*. Eucalyptus may also be present, but does not occur in stands greater than 100 m^2. Fremont cottonwood, white alder, box elder, elderberry, coyote brush, California rose, poison oak, wild grape, or willows may also be present. Trees tend to be less than 30 m tall with continuous canopy cover, sparse shrubs and variable ground layer. Stands of black locust and tree of heaven were differentiated in the comments section of data sheets while mapping the vegetation. It comprises less than 1% of the communities mapped along the lower Mokelumne River with the most (64%) occurring within Reach One.

Riprap

This habitat classification is composed primarily of material dumped along streambanks and levees for stabilization. Material may include concrete, rock revetment, automobiles or some combination of all these materials. In some areas, Annual Grassland and/or Introduced Riparian Shrub may be growing over Riprap and was mapped as Annual Grassland or Introduced Riparian Shrub. Riprap comprises less than 1% of the area mapped along the lower Mokelumne River with the most (93%) occurring within Reach One.

Desired Future Vegetation Communities

Native Riparian Shrub

Native Riparian Shrub habitat is seasonally flooded or saturated. It occurs in floodplains along streams and rivers. This habitat tends to be dominated by elderberry, *Sambucus mexicanus*, coyote brush, *Baccharis pilularis*, California rose, *Rosa californica*, and/or poison oak, *Toxicodendron diversilobum*. Fremont cottonwood, *Populus fremontii*, white alder, *Alnus rhombifolia*, box elder, *Acer negundo*, or willows, *Salix* sp., may be present. Shrubs tend to be less than 5 m (16.4 ft) tall with continuous canopy and variable ground layer. It comprises about 1% of the communities mapped along the lower Mokelumne River with the most (80%) occurring within Reach Four.

Native Riparian Forest

Native Riparian Forest habitat tends to be seasonally flooded or saturated. It occurs in floodplains along streams and rivers. Native Riparian Forest is dominated by Fremont cottonwood, white alder, box elder, Oregon ash, walnuts, *Juglans* sp., and/or California sycamore. Elderberry, coyote brush, California rose, poison oak, wild grape, or willows may be present. Trees are less than 30 m (98.4 ft) tall with continuous canopy cover, sparse shrubs and variable ground layer. It comprises about 18% of the communities mapped along the Lower Mokelumne River with the most (54%) occurring within Reaches Two and Four.

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