Title
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PILOTING A MONITORING PROGRAM FOR CCC LWD PROJECTS

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ABSTRACT

This paper addresses the issue of monitoring Large Woody Debris (LWD) projects performed frequently by one of the state's most prolific restoration groups--the California Conservation Corps (CCC). Through its Salmon Restoration Program, the CCC has enhanced over 1,800 miles of stream in an effort to restore vital coho, chinook and steelhead habitat on California's North Coast; however, limited time, funding, and incentives have restricted monitoring of these projects to pre- and post- project photo-monitoring, and an account of the number and location of LWD structures placed at each project site. Monitoring future CCC LWD projects is essential to identifying and enhancing their effectiveness in restoring salmonid habitat. Opportunities at the CCC, including access to Watershed Steward Project members at at least two sites, trainings offered by project partners, and available survey equipment, as well as the desire to increase future project effectiveness make the establishment of a simple monitoring protocol feasible for this organization. Keeping both opportunities and constraints in mind, we have developed a monitoring protocol that allows the CCC to monitor changes in physical habitat characteristics often associated with salmonids--pool depth and frequency--to assess the effectiveness of installed LWD structures. The protocol consists of collecting long profile, cross-section, and LWD data in a sample reach for each project in three phases: pre-project, as-built, and post-project--with post-project data collected only after large storm events. We piloted this protocol on South Fork Cottaneva Creek, which already had benchmarks and a pre-project data set (obtained from the landowner, MRC) established, and revised the protocol based on our experience.

INTRODUCTION

Over the past 50 years, California's North Coast has seen a dramatic decline in salmon populations due to logging, loss of habitat, and over-fishing. Coho salmon are federally endangered in this region, while chinook and steelhead are threatened or endangered in nearby regions and are considered species of concern. The listing of these species has led to a large scale attempt by local, state, and federal agencies to restore salmon habitat, including the California Conservation Corps' 23 year old Salmon Restoration Program.

The California Conservation Corps (CCC) was formed in 1976 by governor Jerry Brown to "further the development and maintenance of the natural resources and environment of the State, and to provide the young men and women of the state meaningful, productive employment" (Library 2009). In 1980, The Salmon Restoration Project (SRP), a joint venture of the California Conservation Corps and the California Department of Fish and Wildlife (then Fish and Game), was authorized to "enhance and restore California's salmon and steelhead habitat, fully restoring the productivity of Chinook salmon, coho salmon and steelhead trout streams through habitat improvements" (CCC 2013). The primary focus of SRP work is the installation of in-stream Large Woody Debris (LWD) structures and re-vegetation of the riparian corridor to provide wood for future recruitment. They are generally identified by CCC Fish Habitat Specialists, the CDFG, local landowners, or local non-profits and then implemented by the CCC (Poteet 2013).

In the past 23 years, SRP projects have "improved" 1,800 miles of salmon habitat in both streams and estuaries and the planting of over 2 million trees. While this is extremely impressive, very few of these projects have been monitored to assess whether or not they are doing what they were designed to do, increase channel complexity and provide cover for salmon rearing. While funding is provided for project implementation, largely via the CDFW Fisheries Restoration Grant Program[1], very little money is available to monitor projects once they have been completed. Hence, CCC monitoring is constrained to pre- and post-project photos, and CDFW monitors only 10% of projects it funds; the CCC

[1] A funding mechanism established in 1981 "in response to rapidly declining populations of wild salmon and steelhead trout and deteriorating fish habitat in California." (Wildlife n.d.)

makes up only a portion of those projects. This lack of funding for more systematic, in-house monitoring of its work leaves the CCC with limited, anecdotal knowledge of the effectiveness of its work.

Given the scope of these projects, it is vital that the CCC gain a better understanding of how its in-stream LWD structures are functioning, so that it may maximize the effectiveness of its projects in the future.

We developed a pilot protocol to illustrate the potential of a future low-cost monitoring program that can be implemented by the CCC (or its WSP members) to assess pending and future in-stream structure projects. This simple protocol was designed to maximize existing resources, minimize the need for additional funding, and enhance the effectiveness of future projects through a better understanding of current project effects on physical habitat features. We implemented this protocol on South Fork Cottaneva Creek and to demonstrate the protocol's effectiveness and identify points of improvement for the plan.

THEORECTICAL FOUNDATION

Necessity

Riverine ecosystems are complicated and difficult to thoroughly investigate in one or two pre-project research trips. Furthermore, the dynamic condition of the river itself makes it difficult for restorationists to fully grasp the impacts their projects have on hydrologic and ecosystemic processes. Despite the enormous body of research on riparian and riverine restorations and their rationale, we still have limited knowledge of the restoration mechanism and its effectiveness in specific contexts. As Klein notes, "…many restoration projects are being implemented with minimal scientific context and that the high proportion of failed or ineffective projects is due to our current, insufficient understanding of the complex, dynamic processes that maintain a naturally functioning river corridor " (Klein, Alldredge and Goodwin 2007).

Well-designed monitoring programs that evaluate and report post-project successes and failures are rare, representing missed learning opportunities to improve future restoration practices (Klein, Alldredge and Goodwin 2007). Lack of monitoring of how we intervene in dynamic river systems may delay the restoration process or lead to uncertainty about the long-term effectiveness of current restoration practices (Kershner 1997)(Wohl, et al. 2005) (Bernhardt and Palmer 2007) (Henry, Amoros and Roset 2002) (Moerke and Lamberti 2004).

A monitoring program would allow the CCC to refine its restoration strategy to more effectively reach its primary goal: salmonid habitat enhancement.

Approach

Monitoring approaches differ from project to project based on the project's goals. Within the context of fish habitat restoration, monitoring falls into one of 3 categories (Table 1), the latter of which include long-term data sampling and analysis by monitoring experts or inspectors trained in various techniques. Though aspects monitored are distinct, structural characteristics are often substituted for functional characteristics to illustrate progress toward success where monitoring of functional characteristics is impractical. For example, large woody debris (LWD) is an important component of fish habitat and an element in channel forming processes (Roni and Quinn 2001) (Keller and Swanson 1979). Ideally, fish surveys would be performed to directly measure changes in abundance of a target species if that is the project's goal; however, this is not always possible. In these cases, the presence of LWD may be an indicator of increased habitat, but only when associated with overall increased cover, pool depth, and/or pool frequency (all necessary elements of juvenile rearing habitat) (Roni and Quinn 2001). Only by measuring changes in the channel form through long profiles and cross sections will these improvements become apparent.

Monitoring Aspect	Monitoring Object	Monitoring Approach
Site Characteristics	Structures built	Photos
Structural Characteristics	Stream channel morphology	Long Profile, cross-sections
	Sediment	Sample analysis
	Riparian vegetation	Sample analysis
	Percent canopy cover over stream	sampling stations/belt transects
	Presence and abundance of large woody debris	LWD survey
Functional Characteristics	Fish abundance	Sampling
	Aquatic macroinvertebrate abundance	Surber sampler or kick-net Sampling
	Bird abundance	Sampling stations
	Riparian trees and shrub presence and diversity	Document the production
	In-stream water temperatures	Document water quality

Table 1: Monitoring Types (Table adapted from NOAA Monitoring Characteristics - (NOAA n.d.))

Currently, project monitoring for the CCC is limited to photo-monitoring of all sites to illustrate that funding deliverables have been met. Additionally, a handful of projects are randomly selected for monitoring under the Fisheries Restoration Grant Program, which is carried out on 10% of FRGP projects (of which SRP projects are only a fraction of the total) (Poteet, 2013). The FRGP monitoring protocol focuses primarily on conditions immediately around installed structures and does not take into account changes in channel complexity between structures (Flosi, et al. 1998). While this data in aggregate has been useful in informing recent changes to types of LWD structures installed (the CCC is transitioning from projects that are heavily anchored to a combination of anchored and unanchored structures to allow for increased channel complexity), it provides little information about the effectiveness of individual projects in altering channel complexity.

Historical Background

In its first ten years of existence, the SRP focused primarily on stream clearing, with the goal of removing or modifying debris jams along 100 miles of stream each year (Lufkin 1991). The theory was that these debris jams, the legacy of heavy logging on the North Coast in the 1950s and 1960s prevented salmon and steelhead migration up natal streams. Though the CCC succeeded in its stream clearing efforts and purportedly opened many streams to fish migration, salmon and steelhead populations continued to decline (Flosi, Downie, et al., Salmon and Steelhead Habitat Restoration in California 1998). Studies of anadromous streams throughout the Northwest in the 1980s and 1990s disproved the hypothesis under which the CCC had operated in its first years and suggested that the presence of large woody debris in streams was vital to stream stability and the formation of adequate salmon habitat (Bilby 1984)(Andrus, Long and Froehlich 1988) (Keller and Swanson 1979) (Bilby and Ward 1991) (Bisson, et al. 1992). Consequently, in the last 20 years, the Salmon Restoration Project has shifted from stream clearing efforts to projects focused on reintroducing large wood to streams through the installation of LWD structures (based on DFG guidelines) and the planting of trees along the riparian corridor for future recruitment.

SRP projects exist within the larger context of watershed management and are generally carried out as one of many strategies to improve salmon habitat. For this reason, it is not our intent to critique the installation of LWD structures in terms of its effectiveness in long term restoration of salmon habitat but to provide a framework by which the effectiveness of this relatively short term[2] habitat solution (as acknowledged by restorationists) can be maximized.

[2] The development of a mature riparian canopy that provides wood for recruitment into streams can take 25 to 100 years, while LWD structures are predicted to last 20 – 30 years. These structures are designed to kickstart salmon habitat re-creation and will require maintenance or replacement before natural processes are able to take over. (BLM 2013)

SRP projects are designed to pursue one of two big picture goals: 1) Restore salmon spawning habitat; or, 2) enhance juvenile rearing habitat to increase the survival rate of juveniles.

MONITORING PROTOCOL

An effective monitoring protocol requires an understanding of the opportunities and constraints of the organization performing the monitoring, as well as the goals of the project to be monitored.

Several factors contribute to the lack of monitoring efforts generally, even in the face of its necessity:

- Reluctance to allocate funds for the necessary long-term commitment;
- Lack of incentives and standards for evaluating success;
- Perceptions of monitoring as intimidating and labor intensive;
- Limited information on how to implement a monitoring program;
- Inherent difficulties in isolating restoration effects in complex, dynamic biological systems (Kondolf and Micheli 1995)(Kershner 1997) (Klein, Alldredge and Goodwin 2007) (Palmer, et al. 2005)

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For the CCC, funding, incentives, and the difficulties in isolating restoration effects are the most pressing constraints to a monitoring program, in addition to the time available to develop such a program (Poteet 2013). However, the CCC-Fortuna center also possesses valuable resources that would make the implementation of a monitoring program less imposing than other organizations might find it. These resources include:

- the presence of an externally funded Watershed Stewards Project (WSP) member onsite
- access to local DFG training operations through the WSP member or the CCC Fisheries Intern program
- existing creek survey gear

- and the desire to improve their project effectiveness through more rigorous monitoring given the funding (Poteet 2013).

The Watershed Stewards Project is a statewide program that trains young adults in fisheries monitoring and restoration techniques. The twenty year old program began at the CCC-Fortuna Center and has maintained at least one member there ever since. This member, though usually untrained upon entrance into the program, has the opportunity to pursue multiple fisheries restoration projects, and could, given its prioritization, add project monitoring to their task list. In addition, the CCC often receives funding to promote two or more CCC members to the position of Fisheries Interns, during which time they work with DFG to learn and perform spawner surveys. These interns would be a valuable additional resource in a CCC monitoring program during the summer months. Along with WSP members placed at the local DFG office, CCC WSP members and Fisheries interns are trained in performing spawner surveys and habitat surveys by the CDFG at the beginning of each survey season. This provides the CCC WSP member with most of the necessary tools required to perform longitudinal profiles, cross-sections, and wood counts (personal experience). Any program implemented by the CCC would be based on the techniques learned through this process.

Project monitoring should occur in three phases: pre-project data collection, implementation and as-built data collection, and post-project monitoring.

Defining Goals and Re-Defining Success

Re-defining project success is essential to the success of a monitoring program. For most CCC projects, including SF Cottaneva Creek, this redefinition is fairly straightforward. It requires acknowledging already stated objectives, such as increasing pool depth and frequency, understanding the potential trameframe within which structures are working (response rate will vary with rain events), and committing, at least in-house, to pursuing that goal above and beyond funding deliverables. Once this has occurred, monitoring can begin.

While a future monitoring strategy may include a biological inventory, the current monitoring protocol will be limited to an assessment of three physical factors most often cited in CCC project proposals in order to maximize existing resources and get the program off the ground. Those factors are: increasing channel complexity, increasing the depth and frequency of pools, and increasing in-stream woody cover for fish. Physical factors are the target of this monitoring strategy because they often serve as proxies for biological factors, as noted above, and they require less frequent survey intervals; physical monitoring can be limited to pre-project, as-built, and post-event monitoring, while biological factors such as fish counts generally occur on a yearly or seasonal basis. Limited funding and time restrict the extent to which projects can be monitored, making physical factors an ideal step up from photo monitoring in the CCC monitoring protocol. Monitoring via the use of a long profile, channel cross sections, and an LWD volume assessment can demonstrate whether each of these objectives is met and can be carried out fairly efficiently.

The steps for the CCC Monitoring Protocol can be found in Table 2 below.

Timing	Step	Notes
Pre-Project	Define Objectives	Based on project proposal
	Identify monitoring reach	Part of project site
	Establish Benchmarks	Long profile and cross section; GPS each cross section and upstream/downstream long profile points. Establish in a permanently distinct location (ie: not in a location that will covered/altered by project work); mark vividly using paint or brightly colored, large pins); For cross sections, ensure that line of site from end to end is clear and that tap can be pulled straight in future surveys (potentially omit planting 10 feet around your cross section site for ease of access and implementation of survey).
	Long profile survey	(NOTE: If third person is present, can perform LWD survey at the same time as long profile)
	Cross section survey	
	LWD survey	Include: locations of all pieces of wood (natural and installed) along the long profile distance; length/diameter of each piece; number of the structure log is a part of; photo points upstream, downstream, and from opposite bank; GPS locations. CCC structures should be numbered by site, while natural structures/pieces should be numbered sequentially (ie: if you

		had 2 CCC structures, a natural jam, another structure and another jam, the sequence would read SITE 1, SITE 2, NAT1, SITE 3, NAT 2)
	Digitize Data	Record all data in project excel file to hold all future monitoring data.
	Organize Data	based on objectives for future comparison (create long profile graph, cross section graphs and LWD chart)
As-Built	Review pre-project data	including photos, GPS points, and graphs; print relevant information for reference in the field (ie: GPS points, notes on benchmark locations)
	Site Visit	If surveyor is different than the person who performed the pre-project survey, spend a couple of hours to get acquainted with the site and on-the-ground info before beginning survey
	Perform surveys as indicated in steps 5-8 above	
	Analyze data based on objectives	ie: increasing frequency/depth of pool; increasing amount of woody debris retained in stream, etc Create graphs and compare to pre-project data.
	Write monitoring report	Make notes about any important changes to channel form as a direct result of project implementation to keep in project file.
Post Project	Perform surveys and analyze data	See As-Built
	Identify strengths and weaknesses of individual sites	Relate changes in channel morphology (pool depth/location/frequency) to type of structure installed. Use photos to identify structure type (single-log, double-log, multi-log) and direction of wood.
	Use information to inform upcoming projects	Ineffective wood placement/groupings, most effective placements, etc

Table 2: Monitoring Protocol - Steps

Pre-Project Data

Pre-project data should not be collected until immediately prior to the start of project implementation. While in theory project design documents can be utilized to establish monitoring points prior to project implementation, our pilot site on SF Cottaneva Creek—which went from 20 log structures in the design phase (beginning at XS-1), to 65 structures beginning over 1000 feet downstream of the first cross section—clearly demonstrates that in-field adjustments often occur. For this reason, pre-project data collection should be carried out in the days immediately prior to the placement of large wood in the stream. In the case of SF Cottaneva Creek, this did not occur, as monitoring points and the initial survey were conducted independently of the CCC for different purposes. Where possible, the CCC is encouraged to utilize existing resources such as these monitoring points for their own comparisons, with approval from the necessary parties.

Whether the entire project or a reach of the project is monitored will largely be affected by available staff time and the extent of the project. For comparison, a trained three-person team can perform a 1,000 foot long-profile survey, and collect data on four cross sections and all LWD in the reach in one and a half days. Our work on SF Cottaneva Creek confirmed that this work load is feasible. It should be noted that changes in all three objectives can be easily identified in the 1,000 foot reach surveyed on SF Cottaneva Creek, though cross sections were not associated with specific structures. That said, in order to identify changes at any given structure, a cross section should be established immediately downstream of that structure.

Given the availability of time and manpower, it is recommended that at least 10% of the project be monitored via cross section and a 1,000 foot monitoring reach or 10% (contiguous) of the site extent be monitored via long profile (whichever is greater). 10% has been identified by the CDFG as a valid sample for surveys and monitoring (Restoration Manual).

If not already established, permanent monitoring locations using pins and colorful paint to highlight the location. Pins should be located beyond the project extent so that they will not be disturbed by project work. At least one pin should be located in an area that is not likely to change elevation so that future comparisons can be made. Pins should be used to establish the upstream and downstream extent of the long profile as well as to establish the right and left bank cross section boundaries. Cross section pins should be established outside of the channel above flood prone depth. Knowledge of how to determine this is gained through DFG training exercises. It may not be feasible given time and resources to establish a permanent benchmark with a known elevation; however, if permanent benchmarks are established using this method, relative elevations can be compared, which is the purpose of this protocol. Copious notes as to how to identify these benchmarks (accompanied by pictures of relevant landmarks if possible) will ensure easy identification by future monitoring teams.

Once the benchmarks are established, the monitoring team should immediately begin the survey, using standard long-profile and cross section protocols (monitoring team can be trained in these protocols at the local DFG office or by FHS). LWD monitoring should consist of diameter and length estimates of each piece of wood along the entire profile, the number of wood pieces per structure (and whether the structure is natural or manmade), the location of each piece of wood relative to the long profile, and photos of each structure taken from downstream, upstream and the opposite bank. Each of these items is typical information collected by the DFG in their own monitoring practices and will provide data on the volume of wood and its location in the stream. All wood and all structures should be accounted for in the LWD survey, as this will provide the most accurate understanding of changes in pool depth and frequency along the creek. This information will be related back to the long profile survey so that log locations can be compared to pool locations, and it will also be compared to as-built and post-project volumes to gauge the change in woody cover and pool formation as a result of the project. Data collected should also include information on the stream size, class, and flow volume, and should be categorized based on these traits so that future projects on similar creeks can be more easily compared. All data should be immediately entered into a project database for later comparison. Once pre-project data is collected, the project can commence.

As-Built Monitoring

The as-built monitoring data should be collected prior to the project's first winter, or before a major flood event, but no later than three winters after the project has been constructed (Flosi, Downie, et al., Habitat Inventory Methods 1998). This ensures that the data collected is representative of changes made to the creek bed as a result of the project and not changes in hydrologic conditions. Depending on how late in the year the project is implemented, the as-built monitoring surveys may be carried out by a different team than the pre-project monitoring. If this is the case, the new monitoring team should first review all project documents and monitoring data collected by the pre-project team before heading into the field. Surveys should again be performed in a systematic way, and data entered into the project database immediately after collection for comparison with pre-project information.

Post-project monitoring

Post-project monitoring should occur on an as-needed basis for at least the next ten years (or the extent of the landowner access agreement). If possible, an access agreement and monitoring period of 20 years should be negotiated. While five years is a typical monitoring window, this may not be enough time for the creek's morphology to respond to the structures, particularly if the structures are installed during a series of dry years; and, it does not allow for an understanding of if and how structures function through the end of their design life (20+ years) (Roni and Quinn 2001). Monitoring should occur after a heavy rain event, or every three years after implementation in order to identify changes. This monitoring should proceed following the pre-project data collection guidelines to ensure consistency. Data should be immediately entered into the project database and compared to pre-project and as-built results, and a report written up that identifies changes to the creek system.

Because this data is collected in-house, analyzed results can be immediately referenced to inform impending project designs. For those projects in the proposal phase, notes about what types of structures and locations of wood can inform the actual project design, while for those in the implementation phase, structures can be modified as they are being installed. This will require the guidance of an on-site Fish Habitat Specialist, who will utilize the results of the most recent surveys to inform the log placement. During the monitoring phase of the adapted project, notes about how and why a structure was placed the way it was (with reference to previous surveys) should be included in the project's monitoring database. Once this project enters the post-project monitoring phase, this information can be utilized to identify adjustments to structure type and wood placement were effective. For this strategy to work, CCC staff members must ensure that the surveys they are using to inform current projects are located in streams of similar flow, size, and class. This information is easily identified in DFG Habitat Surveys.

PROTOCOL PILOTING

To test our monitoring protocol, we worked on South Fork Cottaneva Creek. We chose this location because of our previous knowledge of the site, the recent installation of a series of CCC LWD structures there, and the prior establishment of a long term monitoring reach by landowner, which happens to fall within the CCC project reach.

Figure 1: Watershed Location

Watershed Overview

South Fork Cottaneva Creek is located in coastal Mendocino County, California (Figure 1). It is a tributary to Cottaneva Creek, and drains approximately 5.4 square miles to the Pacific Ocean. South Fork Cottaneva Creek has approximately 5.6 miles of blue line stream, which supports both coho salmon and steelhead trout. The entire watershed is owned and

Figure 2: Watershed Boundary (SF Cottaneva in aquamarine)

managed by the Mendocino Redwood Company for timber production (Stream Inventory Report: South Fork Cottaneva Creek 2008).

Site History

Mendocino Redwood Company Watershed Assessment

In 2004, the Mendocino Redwood Company, performed a watershed assessment of the Cottaneva and South Fork Cottaneva Creek watersheds to identify areas of mass wasting, surface and point source erosion (roads/skid trails), hydrology, fish habitat, amphibian distribution, riparian condition and stream channel condition (MRC 2005).

One long-term stream channel monitoring segment 995 feet in length was established on South Fork Cottaneva Creek to monitor changes in stream channel morphology as the result of restoration efforts in the watershed. These efforts, which continue throughout the Cottaneva Creek Watershed today, have primarily consisted of erosion control measures outlined in the Watershed Assessment. A longitudinal profile, as well as four cross sections, was surveyed to provide baseline data for future monitoring efforts, including detailed large woody debris counts along the entire profile. The cross sections were located along relatively straight reaches in the long profile and were surveyed from above the flood prone depth of the channel (MRC 2005).

South Fork Cottaneva Creek Habitat Enhancement Project

In 2012, the Fisheries Restoration Grant Program (FRGP) provided funding to the CCC to restore 2 miles of South Fork Cottaneva Creek as juvenile salmonid rearing habitat (see appendix). With the cooperation of the landowner, the CCC planned and managed the installation of 65 log structures to “increase stream complexity, improve pool depth and frequency, sort spawning gravels and provide velocity refugia for migrating salmonids” ((Goodfield 2011): A3). While these were the objectives of the project, success was measured by the number of logs installed and the appropriateness of the anchoring techniques used, not by changes in stream complexity, pool depth and frequency, or sorted gravels. According to Andrea Poteet, the Fish Habitat Specialist for the CCC-Fortuna, these are typical goals and measures of success for CCC SRP projects (Poteet 2013)

The presence of the MRC long-term monitoring reach along a segment of this restoration project provides an opportunity for CCC to examine the effects of their techniques and test out a potential monitoring plan without the expense that such a process would usually incur. The 2004 MRC data provided a pre-project baseline for stream conditions, while a survey performed by the authors prior to the project's second winter illustrates the as-built condition.

Site Application

A total length of 1,000 feet longitudinal profile and 4 cross sections were surveyed and illustrated along the South Fork of Cottaneva Creek, based on the MRC's established benchmarks. The volume and condition of LWD was inventoried along the established longitudinal profile.

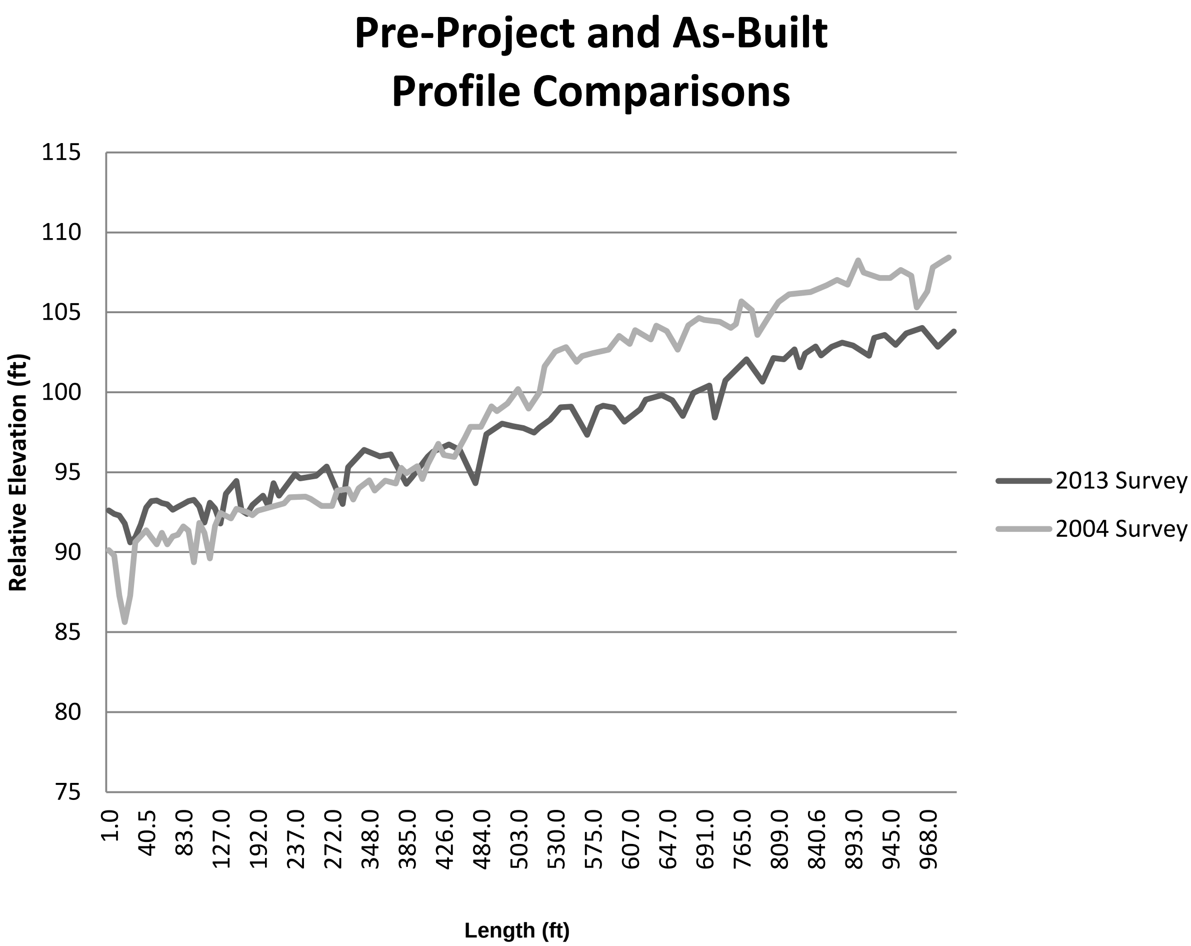


Figure 3: Longitudinal Profile Comparison

A comparison of our as-built long profile to the pre-project long profile indicates that indicates that most structures were located in pre-existing pools (see Figures 3 and 4 for the long profile comparison and LWD locations). No statement can be made about whether the as-built size and depth of pools was pre-existing or a result of the structures, because of the time lapse between pre-project data collection and the implementation of the CCC project.

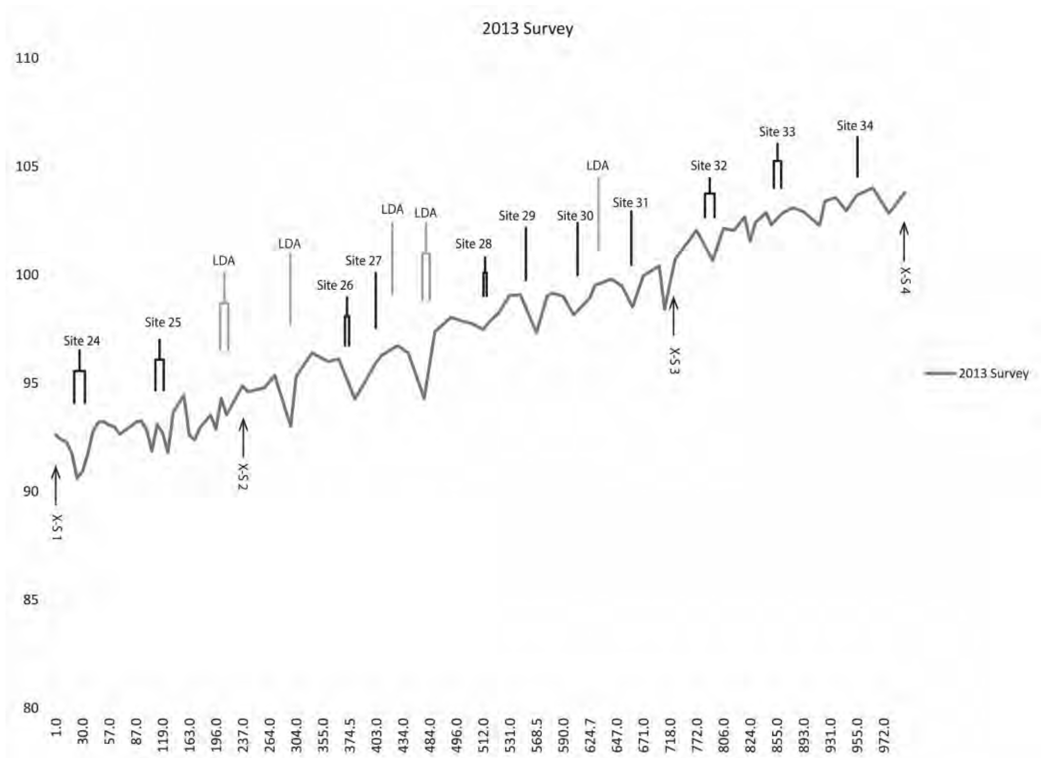
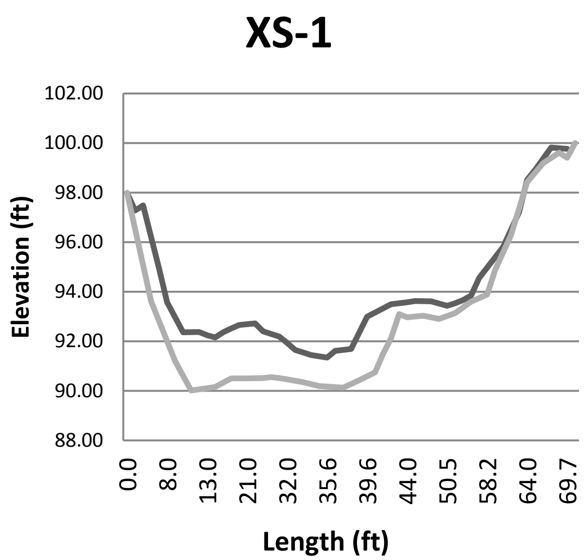
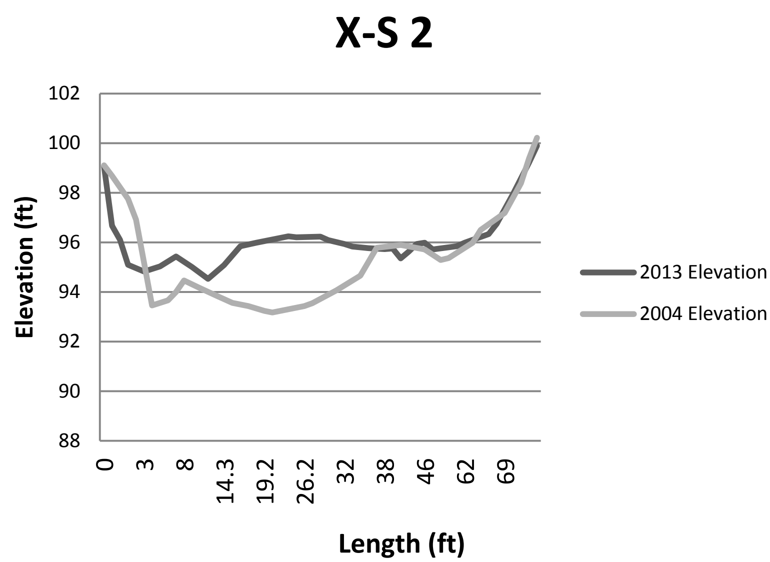


Figure 4: LWD and cross section locations

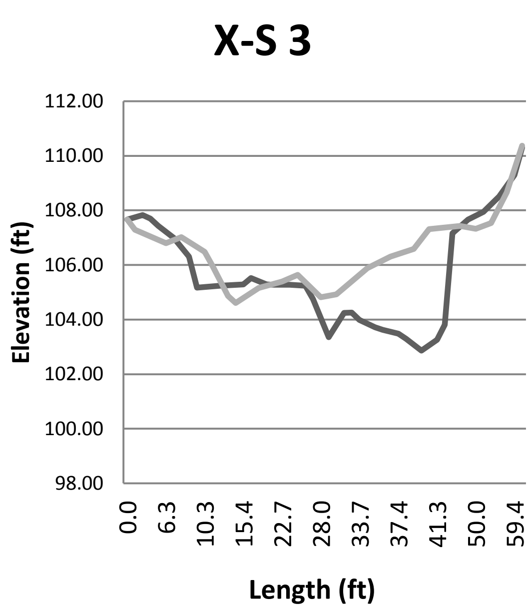
By comparing the 2013 survey and 2004 survey, we found that channel slope has decreased, indicating that this reach recently (or currently) underwent a significant morphological change. The downstream segment of the 2013 long profile was an area of deposition in the past 9 years. The depth of the most significant pools decreased and frequency of pools in general decreased from 2004 in this reach. The upstream portion of the reach, as defined by the transition point from aggradation to incision seen in the Figure 3, illustrates greater incision and an overall increased depth of pools. As stated above, we cannot conclude whether pool changes are a result of construction work or natural processes prior to structure installation; however, it is clear that the channel has undergone significant change in terms of gradient. This should be kept in mind when assessing post-project data. Interestingly, even with the changes in bed elevation, the location of 1/3 of previously existing pools maintained their location from 2004 to 2013.

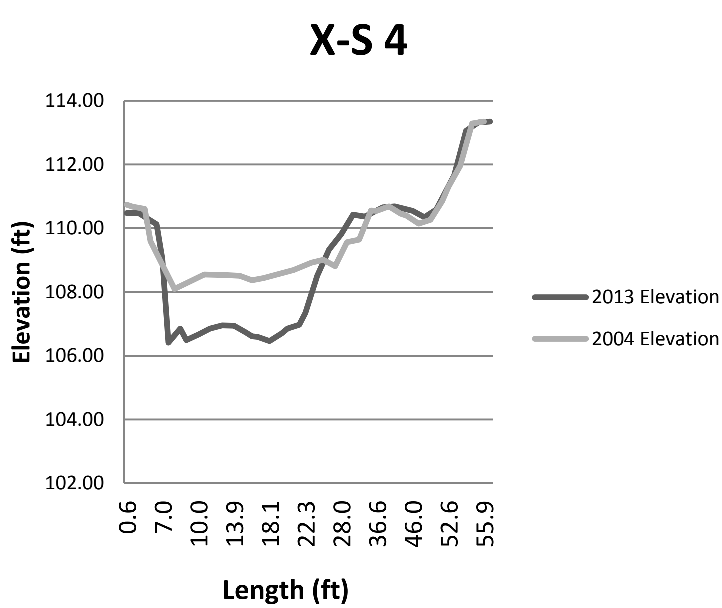




Figures 5 and 6: Cross Section Comparisons Illustrating Aggradation

Cross sections 1 and 2 demonstrate accretion of the channel bed, while cross sections 3 and 4 illustrate the shift of the main channel to a lower elevation (Figures 5, 6, 7, and 8).





Figures 7 and 8: Cross Section Comparisons Illustrating Incision

Our efforts to gather this data illustrated some of the pitfalls of monitoring efforts. First, we experienced difficulty in locating the most downstream benchmark, as the location was not GPSed and reference was not made to how far the benchmark was from the gate. Furthermore, the project proposal indicated that the CCC structures began at the downstream end of the long term monitoring reach, yet the built structures began nearly 1,000 feet downstream. From this exercise, we identified the need to set aside time to associate oneself with the project if you are to the site. Furthermore, lack of photo-monitoring by MRC made it difficult to know whether certain woody debris in the stream was present pre-project. We were only able to identify project sites post-survey, based on our copious photos, notes, and comparison to CCC photos. As-built photos should be carried with surveyors during post-project monitoring to reduce confusion. Once found, it was evident that MRC's benchmark marking technique (lots of paint and bright pins) was successful in making these points visible. Where feasible, this technique should be adopted by the CCC.

CONCLUSION

Ecosystems require long-term monitoring because they are complex and sensitive, and because they change slowly. (Frank J. Mazzotti, Nicola Hughes, and Rebecca G. Harvey) Generally, project monitoring should occur in three phases: pre-project data collection, implementation and as-built data collection, and post-project monitoring. Each of the phases will be implemented in sequence and be referred to for the next phase.

Through this case study—South Fork Cottaneva Creek—and research on the CCC assessment protocol, opportunities and constraints, we have highlighted a simple protocol designed to maximize existing resources, minimize the need for additional funding, and enhance the effectiveness of future projects through a better understanding of current project effects on physical habitat features.

An effective monitoring protocol requires an understanding of the opportunities and constraints of the organization performing the monitoring, as well as the goals of the project to be monitored. Our monitoring protocol provides the CCC with guidelines from the beginning of the project construction period to the long-term beginning of monitoring. Establishment of a long-term monitoring program is the necessary follow-up to assess success and determine if corrective actions are needed after the completion of the restoration construction, as well as to inform the construction of future projects.

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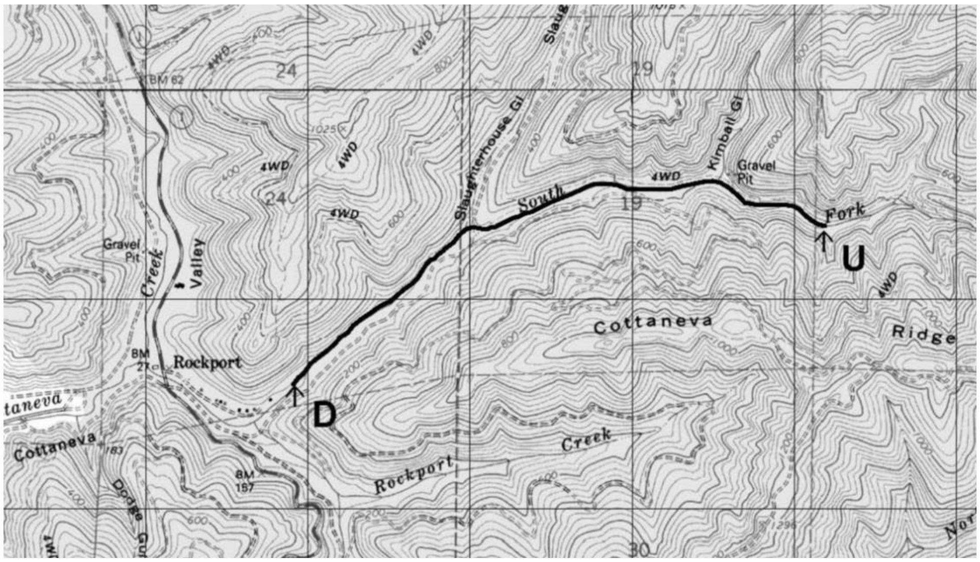
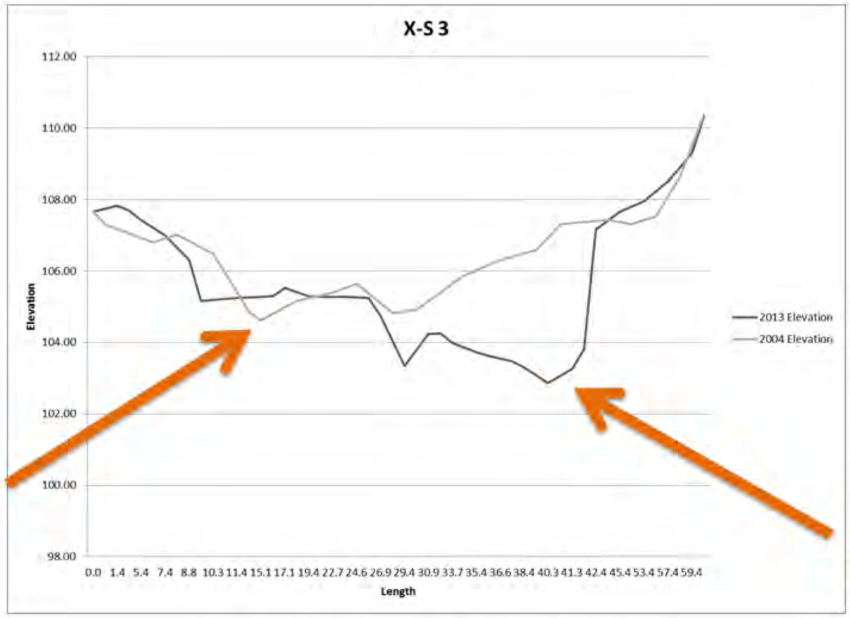
APPENDIX

CCC Project Site Extent (Proposed)



Long Profile Site Plan -

Cross Section With Photo



2013 X-S 3 (Looking upstream)

Example Project Photos

SITE 28

SITE 29

SITE 30