CHANNEL RESTORATION IN AN URBAN SALMONID STREAM

John McCullah, CPESC
Sacramento Watersheds Action Group (SWAG)
491 South Street
Redding, CA 96001
(530) 247-1600 (office)
(530) 247-1601 (fax)
john@watershedrestoration.org

Biographical Sketch

John McCullah is a Certified Professional in Erosion and Sediment Control. He received a BS degree from Humboldt State University in Watershed Management, with an emphasis in Watershed Geology. John is the founder and director of the Sacramento Watersheds Action Group (SWAG), a community-based, non-profit watershed action group. John is also a part-time instructor at Shasta College, teaching a Watershed Restoration class, and he teaches erosion control and soil bioengineering courses throughout the U.S. and Canada. John is President of Salix Applied Earthcare, a natural resource consulting firm in Redding, California. He is the author of Erosion Draw, a comprehensive manual of Best Management Practices, and also Bio Draw, a compendium of biotechnical soil stabilization practices.

ABSTRACT

In 1997 the Sacramento Watersheds Action Group (SWAG) conducted an assessment of the Sulphur Creek Watershed, a tributary to the Sacramento River. The analysis included documentation of land uses, an inventory of erosion and sediment sources, an analysis of riparian conditions and stream habitat, and a preliminary hydrologic analysis. The watershed analysis revealed that extensive dredger mining, road building, and railroad construction within the Sulphur Creek watershed - combined with dam releases which caused backwater conditions at the mouth of Sulphur Creek - have resulted in channel degradation and severe deterioration of fisheries and wildlife habitat. The erosion inventory for this analysis was an important step in making recommendations for watershed restoration projects.

The erosion inventory indicated that streambank erosion within the lower reaches of Sulphur Creek (also the location of the Redding Arboretum) is the primary source of sediment negatively impacting adjacent spawning areas. Near the confluence with the Sacramento River, a 200 m (600 ft) segment of Sulphur Creek became a depositional area for sediment. A median sandbar resulted from the combined effects of these sediment inputs and the backwater from the River. This caused the channel to "jump" over into an open meadow, forming a high vertical bank that was eroding at an alarming rate. Using the watershed analysis as a basis, SWAG, with the assistance of Shasta College students, embarked on a project to return the stream to its "historic" channel. The project was to be implemented as a community-based, worksite learning opportunity for the Shasta College Watershed Restoration and Heavy Equipment Operations classes.

This paper discusses the design, implementation, and results of a channel re-alignment project within the Sulphur Creek Watershed. This project involved the removal of a median sandbar, reshaping an eroding vertical bank, and realignment of approximately 200 m (600 ft) of Sulphur Creek. The channel was reconstructed in a meandering alignment while the banks were stabilized with Biotechnical Erosion Control techniques. Fish habitat features were installed, such as boulder clusters, root wads, riparian vegetation, and spawning gravel (which was uncovered during excavation of the sandbar). The dynamics of the new channel changed dramatically during the wet winter following the realignment. These changes have led to unique results as the channel reaches equilibrium.

The total cost for this project was originally estimated at $53,540. However, through extensive volunteer efforts supported by the local college and in-kind contributions, the project was completed with only a $3000 mini-grant.

Keywords: bioengineering, streambank stabilization, biotechnical, channel design, watershed restoration, riparian, habitat

BACKGROUND

Sulphur Creek is a seasonal urban stream located in Redding, California. The lower reach of Sulphur Creek is located within the Redding Arboretum on the River. The confluence of Sulphur Creek and the Sacramento River is immediately upstream from some of the most productive spawning areas of endangered runs of Chinook salmon. This reach of the Sacramento River in Northern California is known as the "Redding Redds". The mouth of Sulphur Creek is also near the northern entrance to the Turtle Bay Pedestrian Bridge, an unusual harp-shaped suspension bridge that is currently under construction. Once completed, the bridge will offer a link from the new Turtle Bay Museum complex to the educational natural resources within the Arboretum. Sulphur Creek provides spawning and rearing habitat for Chinook salmon, steelhead, and rainbow trout, and an urban setting offers the unique opportunity for public viewing of these salmonids.

PROBLEM ANALYSIS

The lower segment of Sulphur Creek is greatly influenced by backwater effects from the Sacramento River. When the Shasta Dam is discharging 1200 m^3/sec (40,000 cfs) or higher, Sulphur Creek forms a backwater "lake" from the mouth to approximately 200 m (600 ft) upstream. It is highly likely that over the last two decades a period of high water coincided with a period of high sediment discharge within the Sulphur Creek watershed. This large sediment discharge most likely came from the excessive streambank erosion through the Arboretum area as a result of the historic stream diversions through dredger tailings. The large discharge of sediment was then deposited as the current velocities slowed in the backwater area. This deposition caused a large median sandbar to be formed.

Over the ensuing years conditions were apparently favorable for the establishment of willow, wild grape, non-native blackberry, and other vegetation on the sand bar. The vegetation, with their strong root systems, reinforced the median bar and made it resistant to erosion. During subsequent years, high, flashy discharges within Sulphur Creek (possibly influenced by urbanization) coincided with relatively low flows within the Sacramento River. During these periods, Sulphur Creek had sufficient stream energy to downcut and incise the median bar. However, with the vegetation strongly reinforcing the sand bar, the stream energy was focused onto the right bank (if looking downstream), resulting in the erosion which formed the high vertical bank along this area of Sulphur Creek.

Figure 1. The high vertical bank and backwater effect.

In 1997, SWAG, Shasta College, Turtle Bay Museums, and the Redding Arboretum on the River implemented an emergency streambank stabilization project with the aid of a National Fish and Wildlife Foundation grant along this reach to 1) immediately protect historic oak trees that were being undermined and 2) protect the toe of the eroding bank by using biotechnical erosion control techniques such as vegetated deflectors and vegetated geoberm revetments. The project successfully demonstrated the use of biotechnical methods with rootwads, vegetated rock deflectors, and Salix spp. (willows) as an alternative to traditional hard armoring such as riprap and gabions. The Continuous Berm Machine (CBM) was also used to construct vegetated geoberms with brushlayers to protect the bank between the deflectors.

In 1998, SWAG applied for and received a $3,000 mini-grant awarded by the Cantara Trustee Council for installation of in-stream fish habitat improvement structures in this reach of Sulphur Creek. However, while the streambank stabilization effort was successful in stopping erosion at the toe of the vertical bank, monitoring of the completed project revealed that although the 20 foot high bank was no longer being undercut, it was still actively sloughing due to frost wedging and soil saturation. Large chunks of topsoil were still heaving off into the creek below. Other observations affirmed that this section of the channel between the right bank and the aforementioned median bar was preventing the stream from achieving its full potential with regard to natural floodplain processes, and ultimately spawning and rearing habitat. In addition, the reach was classified as an F3 channel (Rosgen Stream Classification System). F3 channel characteristics are not conducive to installation of in-stream fish habitat structures, in most cases. The backwater effect coupled with the somewhat unstable conditions of the F3 channel made selection of habitat structures difficult. *This stream reach still did not have a natural or stable alignment or cross-section, and before additional habitat structures or riparian vegetation could be positioned, the channel needed to be aligned into a more natural sinuosity.*

SOLUTION

There was much discussion concerning the proposed design of the structures being considered. Because of the unique sediment and flow dynamics of this area of the creek, it was difficult selecting a structure(s) that would be compatible with the existing geomorphology. For this reason, an alternative plan of action was developed and was approved by the project manager from Cantara.

The alternative plan not only provided better fish habitat, but also achieved other important objectives relating to water quality, public safety, and education. This proposal involved removal of the median sandbar, a slight realignment of the channel, reshaping of the high eroding streambank, installation of streambank habitat structures, and planting riparian vegetation. The realignment included meanders, flood terraces, pools, and habitat features consistent with the design stream type. The unstable right bank was considered unsafe to visitors and was still a large source of sediment as soil continued to slough off into the creek. Realignment and re-sloping of the bank would reduce both the safety threat and erosion.

SWAG applied for an EPA "5 STAR" grant to fund this work, realign the stream, and provide a more natural channel base for installing habitat structures. The $3000 received from the Cantara Trustee Council was added as a partnership fund for a cash/in kind contribution. With the $20,000 requested from the 5 STAR Program, the partnership funds from Cantara, and matching contributions from Shasta College and other volunteers, the total cost of this project was estimated at $53,540. Unfortunately, SWAG did not receive this grant.

However, through volunteer efforts supported by SWAG, Shasta College, and Turtle Bay, the project was implemented in October 1999 without the grant. The only part of the project plan that was found to be impossible without funding was the complete re-conformation of the high vertical bank. With the aid of the Shasta College Watershed Restoration students and Heavy Equipment students, the rest of the plan seemed feasible to complete with volunteer labor. The $3000 contribution from Cantara would be used by the project contractor, Shasta College, for equipment fuel. Despite short time constraints, all additional needed permits were acquired within a 30 day period.

PROJECT GOALS

The objectives of the project were as follows:

- Rebuild the vertical right bank to a stable slope and as high as possible using the material excavated from the median sandbar, and revegetate the bank with riparian and native plants.

- Realign and reconfigure the stream reach to a stable alignment, meander, and cross-section, and restore natural floodplain processes.

- Install stream habitat structures and revegetate the riparian area.

- Provide educational and interpretive opportunities on salmonid habitat, stream restoration, and natural resource management.

The project was designed to accomplish these objectives by re-locating the stream away from the eroding stream bank. The new alignment was designed and constructed using natural channel design principles to create a vegetated meandering alignment, a stable natural cross-section, and various fish habitat features. The designed stream channel was located approximately 10 m (30 ft) east of the present channel.

The most significant goal of the project was to restore the proper stream function and form along this critical reach. Another primary objective of this project was to provide educational opportunities in stream restoration and natural resource management. To accomplish this objective, the project utilized the Shasta College students and instructors for both project design and construction. Also volunteering were students from Sequoia Middle School, who assisted with planting and other project tasks. According to the revegetation plan, students and volunteers would continue to plant riparian vegetation throughout the project area as needed. A monitoring plan was also developed, and the success of the project would be monitored for several years.

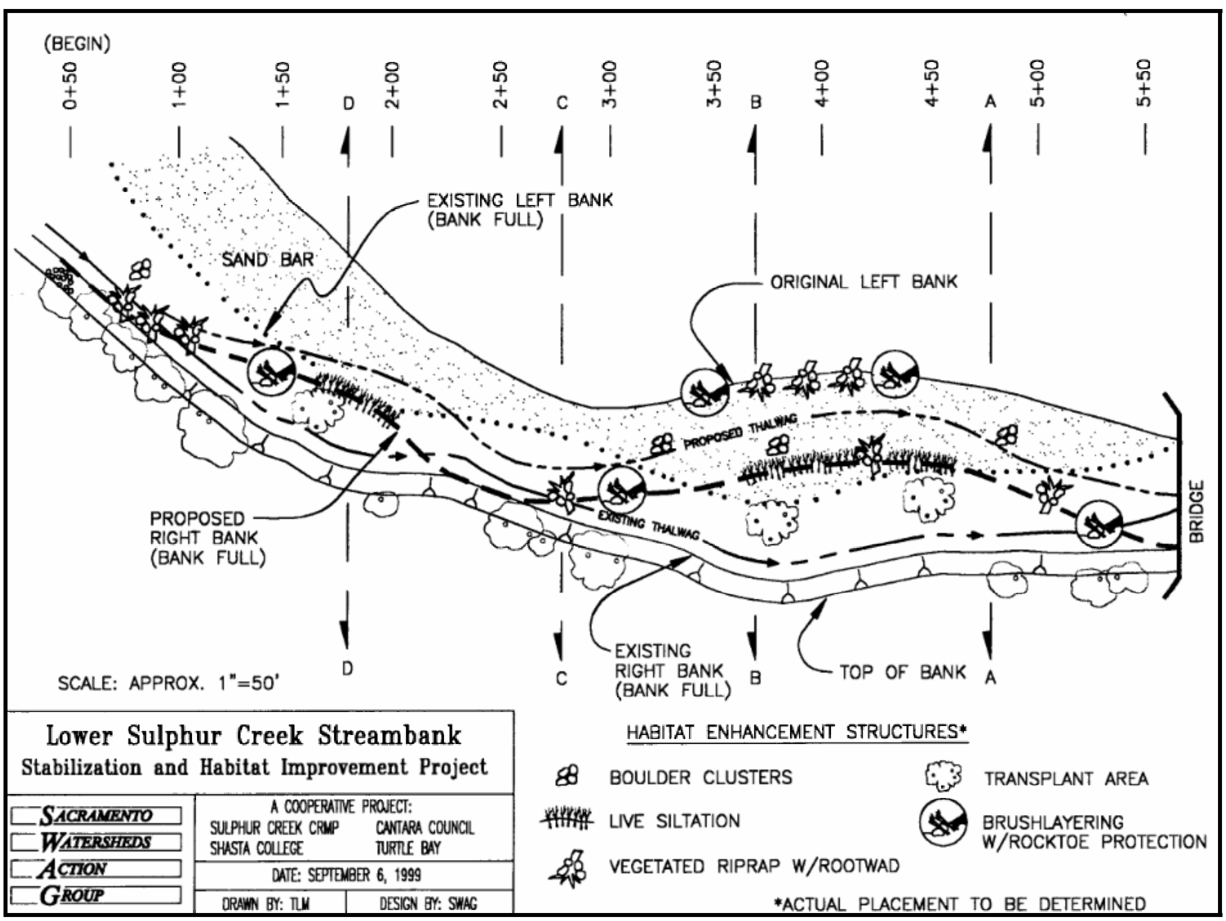


Figure 2. Restoration Plan.

RECONNECTING THE FLOODPLAIN

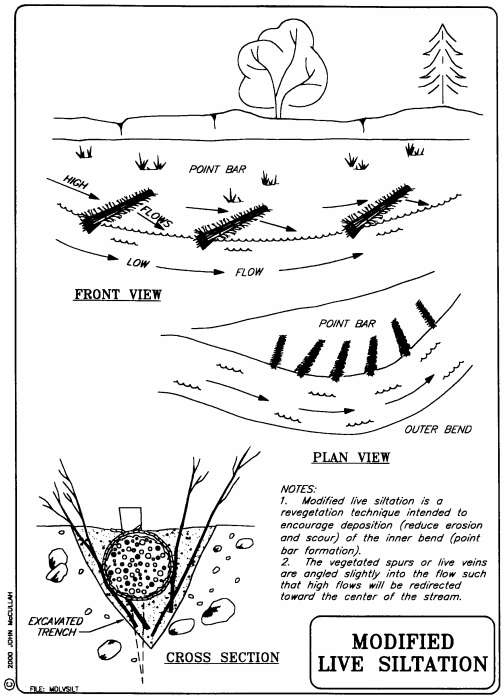
The streambed was dry during the channel reconstruction. A D-5 bulldozer, a backhoe, and a 2 cy loader were used to shape the channel, reconstruct the bank, and place the heavy biotechnical structural components (boulders and rootwads). Shasta College Heavy Equipment students demonstrated their skills by successfully removing the sandbar and moving the material up against the eroding streambank, forming a new bank. The new bank was shaped and graded to a 4:1 slope. In some areas, there was not enough material to completely rebuild the vertical bank all the way to the top. It was determined that the bank would be finished at a later time, with additional funding. Vegetation and boulders from the previous toe protection project were salvaged in order to place on and within the loose excavated material. The project provided an opportunity for the college students to perform actual landform restoration work using heavy equipment, while also learning about the delicate nature of stream ecosystems.

The backhoe was used to dig large holes over 2 m (6 ft) deep in the channel until the water table was reached. Large diameter willow and Populus spp. (cottonwood) poles (which were salvaged on site) were placed in these holes. This biotechnical revegetation technique, called "pole planting", ensures that the basal ends of the live poles receive good contact with the vadose zone and water table in the soil, so irrigation is not required in the dry summer months. This technique was also combined with rootwad revetments, which direct high-energy flows away from the new banks, and also create scour pools and fish habitat. A total of six rootwads were installed for this project. The rootwads were obtained from a subdivision development, and the trunks were not long enough to key into the banks. The short trunks (boles) were anchored using only rocks and live pole cuttings.

Figure 3. During the channel construction, holes were dug deep in the channel in order to plant the live poles into the vadose zone.

Figure 4. After - almost a year later, the banks are revegetating well.

Only natural materials such as the rootwads, rock, and willow and cottonwood poles were chosen to protect the banks along the restored channel reach. In-stream structures such as vortex weirs and boulder clusters had been considered, but depositional features (central and transverse bars) are common in F3 type reaches related to the high sediment supply (Rosgen, 1996). The extensive use of in-stream structures was rejected because of the expected sediment supply and the probable deposition during the backwater periods. As a trial, one boulder cluster comprised of four 500 kg ($^1/_2$ ton) granite boulders was constructed in mid-channel.



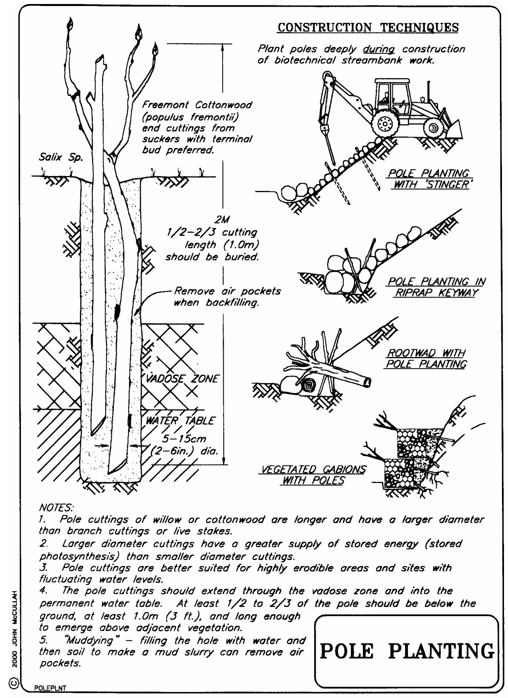


Figure 5 and 6. Modified Live Siltation and Pole Planting typical biotechnical drawings (Bio Draw 1.0).

Watershed Restoration students constructed four "modified live siltation" structures. Modified live siltation is a revegetation technique intended to encourage deposition at the inner bend of a channel and aid in the formation of point bars. Additionally, individual student projects were designed and implemented using techniques the students learned in class. These bioengineering projects included a brush mattress, a brush box, and the installation of biodegradable erosion blankets, which were through-planted with Carex spp. (basket sedge) transplants.

The earthwork for the project was completed within two weeks during the month of October, 1999. The project reach remained dry and the work was completed before the expected November rains. Approximately 900 cm of material was removed from the sandbar and used to reconstruct the right bank. During the excavation of the sandbar, which was thought to be the location of the original stream channel, old spawning gravel was uncovered and left in the newly exposed streambed.

Revegetation Plan

The reconstructed right bank and other areas that were disturbed needed ground cover for erosion control and stabilization. The area needing seed, mulch, and revegetation with native species was approximately .15 ha. The majority of the area was seeded at 45 kg/ha with the native grass Blue Wildrye (Elymus glaucus). Blue wildrye is a fast growing bunchgrass with a large, deep root system. This cool-season grass begins new growth in the fall, even before the rains begin. Blue wildrye is an excellent grass for reseeding burned and disturbed areas. The area was seeded with other grasses native to the Arboretum such as Slender Hairgrass (Deschampsia elongata). Certified weed-free wheat straw mulch was applied at a rate of approximately 3750 kg/ha (1 ½ tons/ac) and at a depth of 30-40 cm.

After the initial seeding of native grass species for erosion control, SWAG and the Arboretum sponsored several community-oriented “planting days”. On one of these “planting days” over 80 community members volunteered. These volunteer crews planted native grass plugs and native riparian and upland species that were donated from the Arboretum and local agencies.

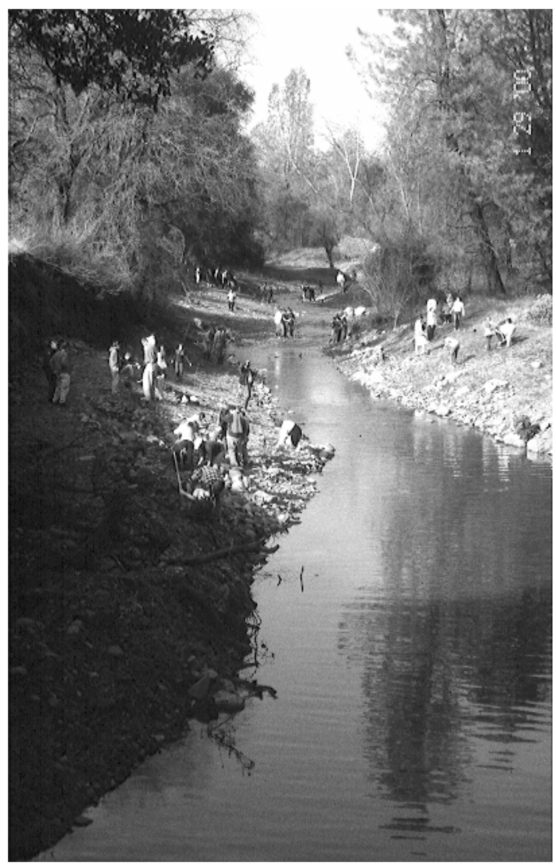


Figure 7 and 8. Before and After. The left photo shows the channel before reconstruction. The right photo shows the channel shortly after project completion, with volunteers planting riparian vegetation.

A 10-ft swath of fill soil directly under (parallel to) some areas on the right bank only received seed and mulch. These areas will later be built up using soil wraps, or filled and graded to a slope consistent with the natural contours of the streambank. Brushlayers of willow and cottonwood species will be placed between soil layers as the bank is constructed to add further soil stabilization. Once this upper portion of the right bank is completed, native tree species such as valley oaks may be planted here to eventually provide an overhead canopy that will shade this stream reach.

CONCLUSION

This project resulted in the restoration of stream function and form for over 200 m (600 ft) of Sulphur Creek. The stream is no longer straight, and the high right bank is no longer delivering sediment to the "Redding Redds". The channel is still incised within the alluvial valley but within that area there are now two gentle meanders with riffle and pool features. Because the natural gradient and substrate has been restored, the channel is now more accessible to juvenile salmonids which migrate downstream during seasonal low flows, and structures along the bank now provide resting areas during high flows. During the winter of 1999-2000, the stream "settled in", scour pools formed as intended, and many other changes occurred in the channel.

The removal of the excess sediment within the streambed resulted in channel adjustment approximately 200 m upstream from the restoration reach. The stream "head cut" through previously embedded bed materials, and this change in the channel led to the formation of gravel bars. The composition of the bars is desirable spawning material. Because the aggraded streambed was lowered during restoration, the backwater from the Sacramento River remains in the lowest portion of the project reach for a longer period during the dry summers, and this also aids in the escapement of salmon juveniles. Streamside vegetation is quickly establishing now that more water is available during the summers.

Ideally, the entire sandbar should have been completely removed. However, a small section of the sandbar was left in the upper portion of the project reach due to a combination of time constraints, lack of funds, and the presence of mature cottonwoods nearby (there were concerns that disturbing the soil too close to the cottonwoods would damage their root systems). The stream has subsequently incised the left bank of the sandbar. This section of sandbar will probably continue to erode as the stream reaches equilibrium. Both bends in the completed channel have scour pools and much habitat complexity among the vegetated riprap and rootwads. There is overhanging vegetation and cover, and the different species of willow and other native plants have created a diversified riparian habitat.

The boulder cluster was subsequently buried by sand and gravel. The boulders did not encourage scour nor did they provide any habitat value. As expected, the backwater effect coupled with the sediment load caused the boulder cluster to behave more like a dam, forming a gravel bar both upstream and downstream.

The cross-overs occurred where they were expected. The meander that was designed for the channel worked well, and the rootwad and vegetated riprap structures along the streambanks were also accurately designed. The elevation of the rootwads with the water level coincided with critical fishery periods in this seasonal stream.

At one section of the stream, there was approximately 10 m (30 ft) of visible bank erosion. This was not the result of improper alignment of the channel, but was the result of insufficient bank protection in this section. During one of the organized “planting days”, volunteers built a 10 m long (30 ft) brush mattress to protect this bank. However, the mattress was not properly secured at the upstream portion to contend with high flows. The flows got around behind the mattress and the entire mattress was ripped from the bank, a common predicament if a brush mattress is not firmly secured. However, a 3.3 m (10 ft) long brush mattress that was constructed by Watershed Restoration students on the opposite bank did very well, surviving extremely high velocities, with abundant growth of willows. This brush mattress was specifically secured to existing vegetation on the bank, and firmly secured to the bank so that the high flows would not scour behind it.

Figure 9 and 10. It is sometimes difficult to envision the dynamic changes that will occur after channel restoration in a seasonal stream, such as the formation of point bars. It is interesting to realize that while the gravels composing the point bars will move through the system, the point bars will still remain. These two photos show the changes that occurred in the new channel after the first large storm event.

Revegetation Success

Supplemental irrigation was not available for the project, and summers in Redding are typically very hot and dry, with no rainfall. As a result, almost all container plants that were planted high up on the banks in hot, exposed areas failed, with the exception of a few drought-tolerant species. The majority of the rooted container plants (cottonwood, elderberry, and upland species) had higher survival rates in partially shaded areas. Contrary to expectations, willow container plants did not have a higher survival rate than willow stakes, although all seemed to survive better in shaded areas rather than hot, exposed areas. The deeply planted live pole cuttings and brushlayers were very successful, with a 90% success rate. These were planted deeply into the vadose zone. It was also interesting to note that willow cuttings and basket sedges had survived over a month of complete inundation from the backwater. Almost all of the cottonwoods (poles and container plants) that were inundated under the backwater were eaten by beavers.

Two of the modified live siltation structures failed when the 10 m (30 ft) section of bank scoured, but two persisted and are growing vigorously and behaving like small vegetated bendway weirs. These structures survived the first season, although they were inundated for at least a month by backwater, they withstood an estimated 4 m^3/sec (12 cfs) velocities, and they were buried only about .3 m (1 ft) into the channel. The experimental brush box, which consisted of live stakes and dead brush, was partially washed away, although what remained was growing well.

The native grasses achieved about 70% cover and were going to seed after 1 year. There were not many weeds amongst the grasses. The basket sedges were also establishing well, and have withstood extremely high velocities. The biodegradable straw erosion control blankets actually did biodegrade in one season. The basket sedges planted in the blankets did not survive, but this was probably due to the dry location on the upper left bank. Cattails and rushes are naturally revegetating the stream channel.

The stream is now more accessible to visitors since there is now a gently sloping right bank where there was once an unstable vertical bank. The left bank is also more accessible now that the non-native blackberry growing in the sandbar has been removed. Students from kindergarten to college will be able to view the project (and migrating salmonids) and hear presentations from Turtle Bay Museum guides on the various aspects of stream restoration and natural resource management.

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