Send your completed paper to Sandy Rutter at rutter@asabe.org by ***new extended deadline***
**May 18, 2008** to be included in the ASABE Online Technical Library.

Please have Word's AutoFormat features turned OFF and **do not include live hyperlinks.** For general information on writing style, please see http://www.asabe.org/pubs/authguide.html

This page is for online indexing purposes.

## Author(s)


| First Name | Middle Name | Surname | Role | Email |
|---|---|---|---|---|
| Carolyn | Michelle | Jones | ASABE Member/ Design Engineer | carolyn.jones@ca.usda.gov |


## Affiliation


| Organization | Address | Country |
|---|---|---|
| USDA NRCS | 1303 Jefferson Street, Suite 500B<br>Napa, CA 94559 | USA |


## Author(s) – repeat Author and Affiliation boxes as needed--

| First Name | Middle Name | Surname | Role | Email |
|---|---|---|---|---|
| | | | | |

## Affiliation

| Organization | Address | Country |
|---|---|---|
| | | |

## Publication Information


| Pub ID | Pub Date |
|---|---|
| 08 | 2008 ASABE Annual Meeting Paper |



The authors are solely responsible for the content of this technical presentation. The technical presentation does not necessarily reflect the official position of the American Society of Agricultural and Biological Engineers (ASABE), and its printing and distribution does not constitute an endorsement of views which may be expressed. Technical presentations are not subject to the formal peer review process by ASABE editorial committees; therefore, they are not to be presented as refereed publications. Citation of this work should state that it is from an ASABE meeting paper. EXAMPLE: Author's Last Name, Initials. 2008. Title of Presentation. ASABE Paper No. 08----. St. Joseph, Mich.: ASABE. For information about securing permission to reprint or reproduce a technical presentation, please contact ASABE at rutter@asabe.org or 269-429-0300 (2950 Niles Road, St. Joseph, MI 49085-9659 USA).

2950 Niles Road, St. Joseph, MI 49085-9659, USA
269.429.0300 fax 269.429.3852 hq@asabe.org www.asabe.org

***An ASABE Meeting Presentation***

***Paper Number: 08***

# Dry Creek – The Removal of a Barrier to Fish Passage and Restoration of a Stream in Napa County, California

**Carolyn M. Jones, Agricultural PE, Civil PE**

USDA NRCS, 1303 Jefferson Street, Suite 500B, Napa, CA 94559, carolyn.jones@ca.usda.gov.

**Written for presentation at the**
**2008 ASABE Annual International Meeting**
**Sponsored by ASABE**
**Rhode Island Convention Center**
**Providence, Rhode Island**
**June 29 – July 2, 2008**

***Abstract.*** *Habitat for our native fish species has been limited since the dam building era of the 1950s and 1960s. Dry and Hopper Creeks are tributaries to the Napa River and both comprise some of the highest quality anadromous salmonid habitat on the Pacific Coast. With the cooperation of vineyard landowners, Napa County Resource Conservation District, USDA NRCS, the California Department of Fish and Game, and other partnering agencies, a concrete flashgate dam structure that prevented the upstream movement of Chinook and steelhead salmon was identified as a major barrier to fish passage in the Napa River watershed and was removed. Prior to removal, a series of treatments were designed and in the summer of 2007 the dam was replaced with vortex boulder weirs, riprap along the bank toes, and brush mattresses on the banks. After a representative first storm season, the project has performed well.*

**Keywords.** Streambank revetment, salmonid, fish passage, stream, weir, vortex weir, willow, brush mattress, soil bioengineering, USDA NRCS, restoration, dam removal, stream training.

The authors are solely responsible for the content of this technical presentation. The technical presentation does not necessarily reflect the official position of the American Society of Agricultural and Biological Engineers (ASABE), and its printing and distribution does not constitute an endorsement of views which may be expressed. Technical presentations are not subject to the formal peer review process by ASABE editorial committees; therefore, they are not to be presented as refereed publications. Citation of this work should state that it is from an ASABE meeting paper. EXAMPLE: Author's Last Name, Initials. 2008. Title of Presentation. ASABE Paper No. 08----. St. Joseph, Mich.: ASABE. For information about securing permission to reprint or reproduce a technical presentation, please contact ASABE at rutter@asabe.org or 269-429-0300 (2950 Niles Road, St. Joseph, MI 49085-9659 USA).

## Introduction

Dry and Hopper Creeks are tributaries to the Napa River and together comprise some of the highest quality anadromous salmonid habitat on the Pacific Coast. With the cooperation of vineyard landowners and partnering agencies, a flashboard dam structure that prevented the upstream movement of Chinook salmon and steelhead fish was removed. The structure was replaced with a series of vortex boulder weirs, riprap at bank toes, and brush mattresses on the banks in the summer of 2007. After a representative first year storm season, the project has performed well.

## Salmonid Habitat on the Pacific Coast

The Napa River and its tributaries are considered to be high quality habitat and 14 native freshwater fish species call the reach home, two, of which, are salmonids. Chinook salmon (*Oncorrhynchus tshawytscha*) travel upstream in fall to spawn. Steelhead (*Oncorhynchus mykiss*), otherwise known as anadromous rainbow trout, are listed as a threatened species and migrate upstream between December and March. (Koehler, 2008)

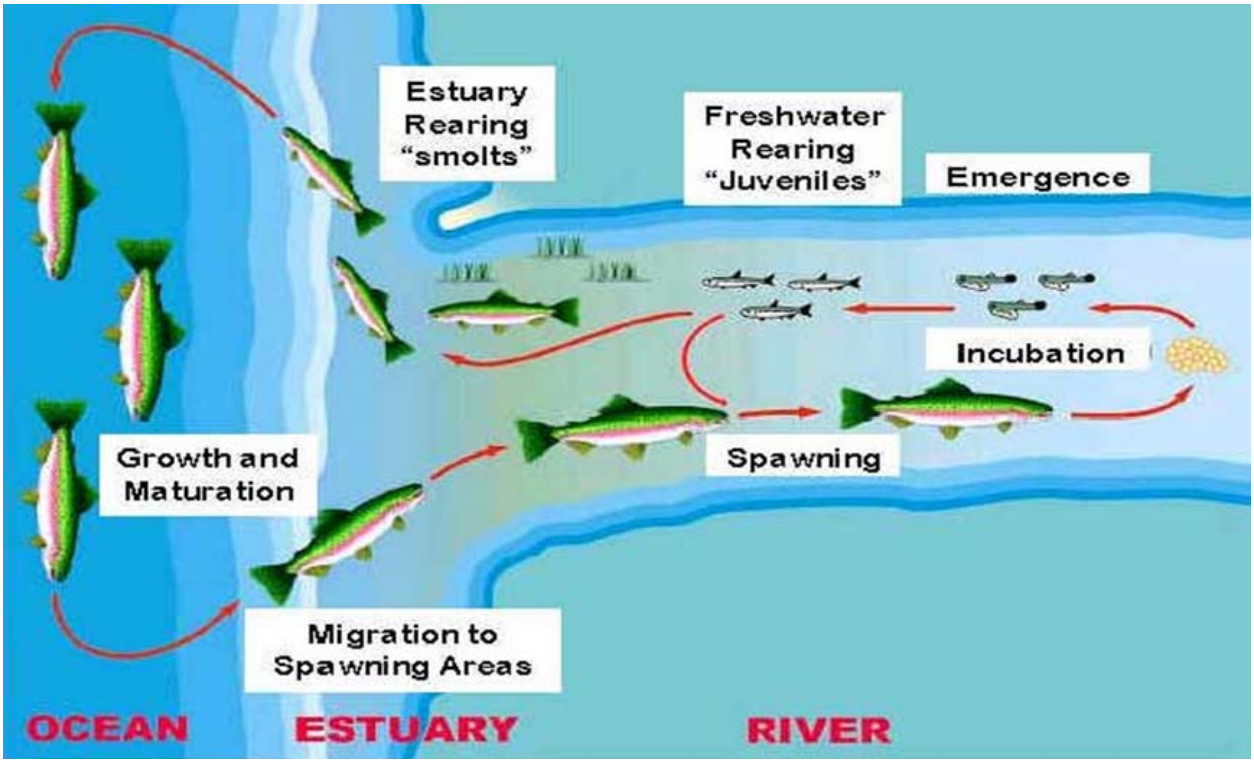


Figure 1. The Salmonid Life Cycle.

Figure 2. A Chinook salmon (*Oncorrhynchus tshawytscha*).

Previously when barriers have been identified, measures were taken to help fish get past them which usually involved installation of fish ladders. Unfortunately, the fish ladders in this system only flowed when the reservoir was full and, hence, did not serve a portion of the fish population. When the ladder was flowing, fish had to navigate to it and then work their way up the frothing structure which must have been difficult.

Figure 3. Looking upstream at the Dry Creek Dam while the flashgates are down and holding back water. Note water flowing through the fish ladder on the lower left.

## Napa River Tributaries, Dry and Hopper Creeks

The Napa River flows south into the San Pablo Bay, through the San Francisco Bay, and into the Pacific Ocean. The Napa River watershed contains over 800 miles of blue-line streams, of which, 16.9 miles usable by steelhead lie upstream of the confluence of Dry and Hopper Creeks where the dam existed. The dam received water from a 17,000 acre (27.8 square miles) watershed. Dry Creek happens to be a unique stream in the Napa River Watershed. The upper watershed lies parallel to the Napa River and flows at a low gradient in a very long, cool, damp, shady redwood forest. Because of these conditions, fish habitat in the upper watershed exists year-round in the spring fed stream. It then flows from the foothills through the valley floor that consists mostly of winegrape vineyards.

In November 2007, Napa RCD Senior Biologist Jonathan Koehler summarized Napa RCD fish habitat surveys and Friends of the Napa River (FONR) snorkel counts. From these surveys, he identified 8.8 miles of high quality salmonid rearing habitat in Dry Creek, 13.1 miles of potential steelhead rearing habitat including the four main tributaries of Dry Creek (Segassia Creek, Wing Canyon, Montgomery Creek, and Campbell Creek), and 16.9 miles of stream channel expected to be used by steelhead for migration, spawning, and rearing upstream of the dam.

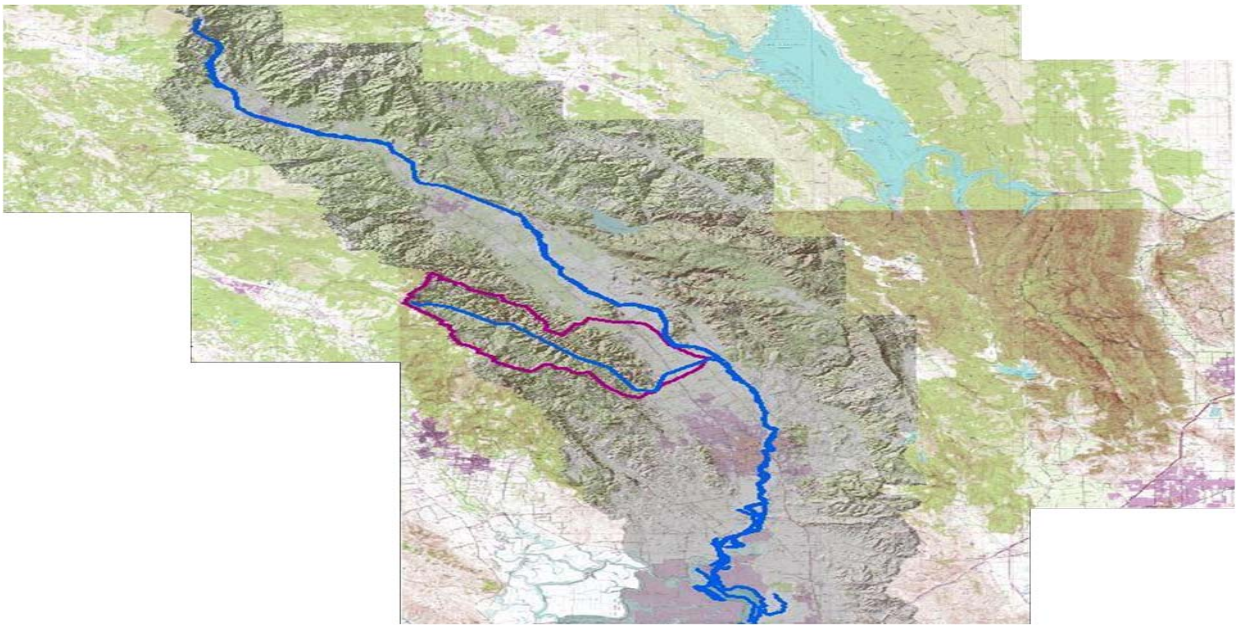

Figure 4. An orthogonal view of the Napa River Watershed. The watershed feeding the Dry Creek Reservoir is outlined in purple. The blue line within it is Dry Creek. The blue line continuing up the valley is the Napa River and drains to the San Pablo Bay at the bottom of the picture. Note that Dry Creek lies very low in the Napa River watershed.

## Anatomy of the Existing Dam and Bridge

Water from the 17,000 acre (27.8 square miles) watershed was retained behind the dam at the confluence of Dry and Hopper Creeks periodically between January and April. During below-freezing nights, water pumped from the reservoir into sprinkler systems prevented frost damage on the neighboring winegrape vineyards.

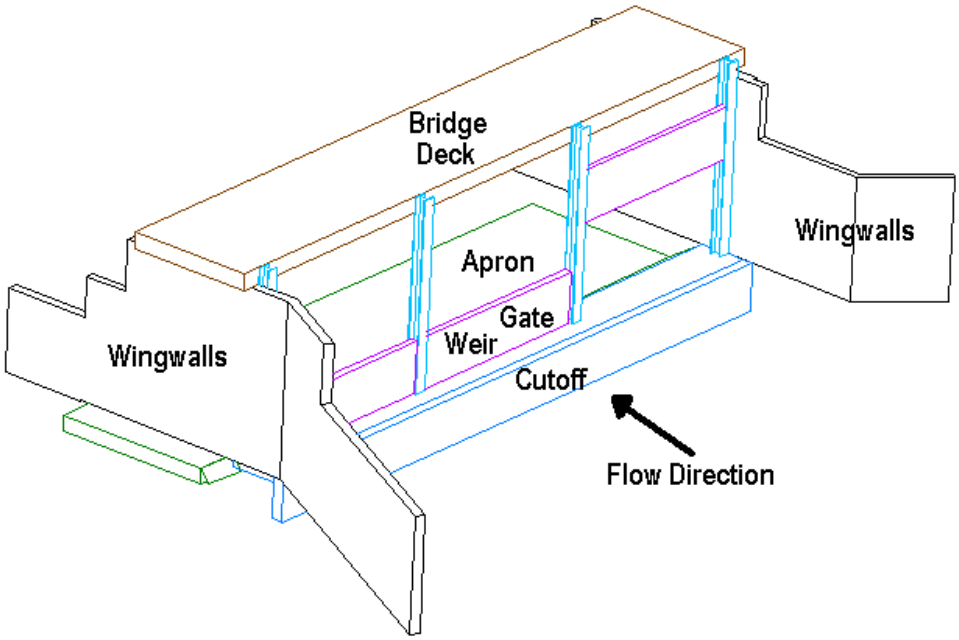


Figure 5. Wireframe depiction of the dam structure on Dry Creek (without the fish ladder).

Figure 6. Looking upstream at the dam structure on Dry Creek originally constructed in the 1960s. Note that the I-beams that supported the flashgates have been cut in this picture.

The primary purpose of the dam was frost protection. When valley floor temperatures drop below freezing in late winter, one way to prevent frost damage to the young shoots on the grapevines is to sprinkler irrigate the vines. The protection takes two routes; irrigation water that is warmer than the air helps to circulate the cold air near the ground surface and any water that

freezes on the vines releases heat in the process of freezing which warms and protects the vines.

Downstream of the apron, a plunge pool developed annually during large storms in conjunction with a downstream gravel bar as sediments were transported past the structure. Upstream of the structure a gravel bar developed and continued to increase slowly over the life of the structure. At the confluence, the bar acts as a floodplain when flows exceed the 2-5 year storm interval and will probably always exist as part of the functioning system.

Figure 7. Aerial view of the site prior to dam removal.

## Project Goals

Primary project goals were to improve fish passage for anadromous salmonids (steelhead and Chinook salmon), stabilize eroding banks and channel thalweg, and enhance and restore the riparian corridor.

## Project Timeline

2001 – Napa County Resource Conservation District (Napa RCD) habitat assessment and stabilization plan.

2002-2003 – Napa RCD applied for California Department of Fish and Game (DFG) funds and NRCS Wildlife Habitat Incentives Program (WHIP) cost-share funds. Neighboring landowners installed alternative frost protection measures.

2004-2006 – Napa RCD and DFG identified dam removal for fish passage as a top priority; Philip Williams & Associates (PWA) completed a feasibility study; Terra Firma completed a topographic survey that was combined with an NCRCD longitudinal profile.

2006-2007 – NRCS completed design with review by technical team and partners; Napa RCD completed California Environmental Quality Act (CEQA) documentation and permitting; Heide & Williams demolished the structure and completed rock and grading construction; California Conservation Corps (CCC) installed willow treatments.

2007-2008 – Monitoring.

## Feasibility Study

### *Hydrology*

Philip Williams and Associates (PWA) used a USGS Regional Regressional Analysis method adjusted with real-time stream gage flows resulting in the values below (Table 1).

Table 1. Combined peak discharge from PWA's adjusted USGS Regional Regressional Analysis.

| Storm Frequency (years) | Design Peak Discharge (cfs) |
|---|---|
| 2 | 1,775 |
| 5 | 2,917 |
| 10 | 3,497 |
| 25 | 5,071 |
| 50 | 5,590 |
| 100 | 6,033 |

### *Sediment Transport*

PWA used topographic information from the Terra Firma survey and a longitudinal profile by the Napa RCD to assess sediment transport. They concluded that absent a grade control, channel incision is likely but that the risk of downstream aggradation associated with removing the structure and releasing sediment is minimal. (PWA, 2006). This demonstrated that the installation of some form of grade control advisable.

### *Alternatives Presented*

PWA identified a number of conceptual-level alternatives that required further design calculations and consideration to arrive at a complete and constructible design. The primary concepts were:

1. Treatment of the existing structure by removing the lower apron, integrating rocks into the created void, notching the lip of the sill to support low-flow fish passage, and removal of the abutments for replacement with biotechnical bank stabilization structures.

2. A rock ramp fishway, a coarse bedload (large rock) ramp graded to simulate a rocky stream bed with larger boulders and woody debris to create pools of low velocity and low turbulence which allow fish to move progressively up the ramp while also providing cover and temporary holding spaces as well as a stabilized channel grade.

It was concluded that bank stabilization would likely be required at the site of removal for the existing bridge abutments and on steep banks along the existing channel alignment. Use of biotechnical approaches integrating structural features (e.g., rock toes) with vegetative features

(e.g., soil lifts, willow barbs, etc) were deemed desirable. Appropriate supporting structures could be applied to help retain, or train, the channel in its new alignment including barbs, armored bank toes, constructed riffles, etc.

## Salmonid Passage Criteria & the Vortex Boulder Weirs

National Oceanic and Atmospheric Administration's National Marine Fisheries Service (NOAA NMFS) has criteria for fish passage stating that the maximum hydraulic drop for adult salmonids shall not exceed 1 foot and a minimum 2 foot deep pool be provided as resting spots for the fish, as well as launching space for successful jumping and passage of the weirs. Additionally, they require that velocities be limited to 1 to 2 feet per second for short distances at 10% exceedance flow of 198 cfs in this case. The exceedance flow is calculated using the equation

$i_x=0.01(n+1)$ Equation 1.

where i is the peak discharge, x is what percentage of the year the flow is exceeded, and n is the number of days of stream gauge data available.

Table 2. Annual exceedance values based on NOAA NMFS criteria.

| Annual Exceedence, x (%) | Design Peak Discharge, i (cfs) |
|---|---|
| 1 | 874 |
| 10 | 198 |
| 50 | 22 |
| 95 | 1.1 |

Based on these criteria and guidance set forth in the California Salmonid Stream Habitat Restoration Manual (Salmonid Manual) (CA DFG, 1998), a number of options were available to provide salmonid passage and also retain channel stability. Since the properties of the existing concrete were unknown and it was determined that the velocities and shear stresses in the system could be withstood by bioengineering techniques, it was decided that the existing structure was to be removed. Vortex Boulder Weirs were chosen as they met our criteria.

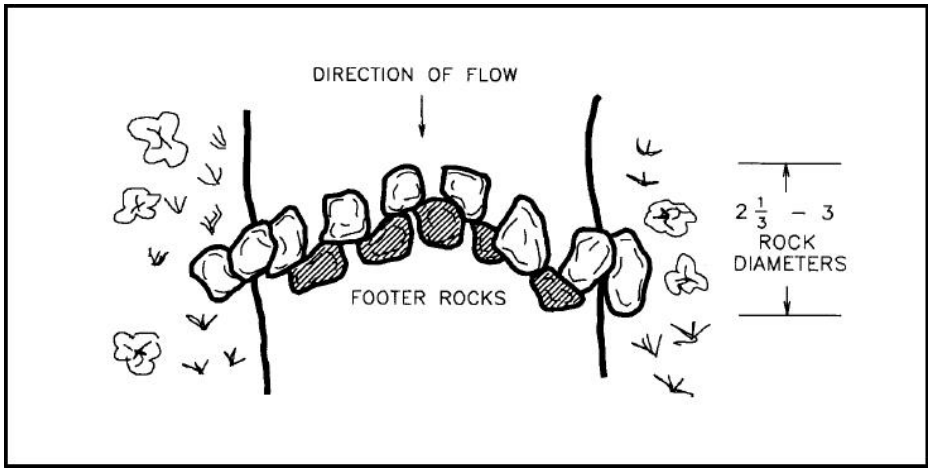


Figure 8. Vortex boulder weir plan view (CA DFG, 1998).

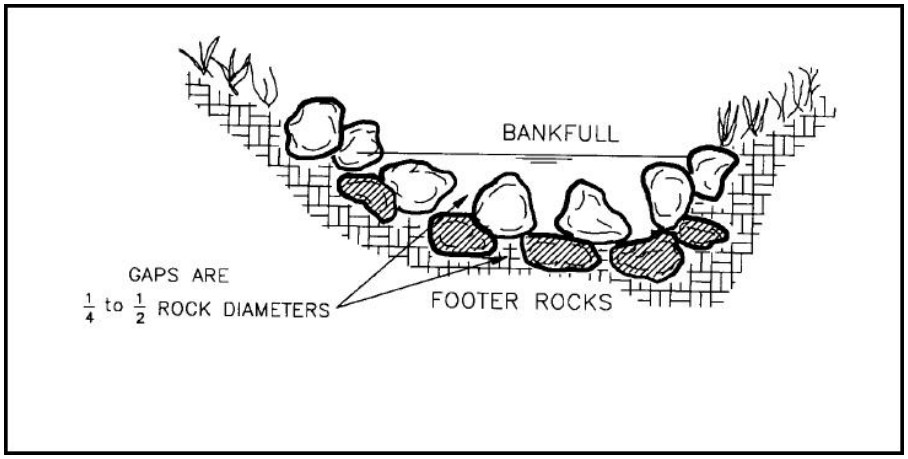


Figure 9. Vortex boulder weir cross-section (CA DFG, 1998).

The V-shape of these structures gave them strength. Forces acting on the upstream rock at the center of the weir were transferred through the adjacent rocks and ultimately into the banks. We opted not to include spaces between the rocks to add to the contiguous nature of the structures. Additionally, the nature of a gradation of rock riprap helped to fill in those gaps and more successfully transfer those forces.

The V-shape of the weirs required less hardscape (rock riprap) than other alternatives, used only natural materials, and focused high flow energies into the center of the stream. When constructed, the alignment could be carefully placed to direct all flows to the preferred location and train the stream thalweg into a more favorable path. This reduced the impact of high energy flows on the banks, giving the bioengineered measures a better chance at success.

Flow concentration created a scour zone downstream of the weir at the center of the V which became the jump pool required by the Salmonid Manual. Each weir would also be passable during a wide range of flows.

The change in grade between the creek centerline and the daylight point of the weirs on the banks allowed a large range of flow volumes, including smaller flows, to be concentrated into the center of the channel. The weirs had to be designed and installed so that the jump height didn't exceed approximately one-half foot, the maximum allowable for juvenile passage. Given that our work was focused on just over 100 feet of the channel bottom, the weirs were spaced every 50 feet and differed in elevation by about 6 inches. The weirs were designed to contain a 2 to 5-year flow and the toe riprap was constructed to the 2-year storm elevation.

The draft version of NRCS' recently released Stream Restoration Design Handbook (USDA NRCS, 2007) was consulted for rock stream barb design to size the vortex weirs because they act as two stream barbs meeting at the center of the channel. The resulting design rock gradation was a $D_{100}$ (maximum rock size, 100% of the rocks are that diameter and smaller) of 36 to 44 inches though a $D_{100}$ of 48 to 54 inches was installed. All weir rock and rock riprap had to conform to the Rock Riprap (907) specification which requires rock to be angular and dense (specific gravity of 2.65 or greater) (USDA NRCS, 2007). Much of the strength of a rock weir structure lies in proper rock gradation. Large rocks take large forces but the smaller rocks wedged between them help to lock the structure in place, transfer forces, and prevent piping.

## Streambank Soil Bioengineering Field Guide for Low Precipitation Areas & the Brush Mattresses

A HEC-RAS™ model was created using AutoCAD™ and EaglePoint™, the Terra Firma topographic survey, and the hydrology values that PWA provided. Based on the hydrology, the channel flows full during a 100-year storm which was used as the design storm, resulting in a design storm velocity of 7.5 fps and shear of 1.2 lb/sq ft. Because the allowable shear for a brush mattress is 6.5 lb/sq ft, the allowable velocity and shear for willow stakes is 9.2 fps and 2.0 lb/sq ft respectively, and the allowable shear for a fascine is 2.1 lb/sq ft, a system of the three treatments was chosen for the site.

Brush mattress installations use four components: willow posts, a mat of willow branches, jute rope, and a willow fascine. Willow posts of 3-4" diameter are augered into the bank in a grid. They must be installed with the cut end down for proper root establishment. Between those posts a mat of ½ to 1 ½ inch diameter willow branches are laid along the banks. A natural rope, such as jute, is then used to secure the branches to the bank by cross-hatching the grid both diagonally and horizontally using the willow posts. Finally, fascines, 12 inch bundles of branches made of the same branches used for the brush mattress, are laid horizontally across the bottom ends of the brush mattress to press them into the earthfill. Some degree of growth is expected from each of the willow treatments. To retain some flow capacity after the willows will have bushed out in the future, the toe riprap was carried up the banks to the 2 to 5 year flow depth.

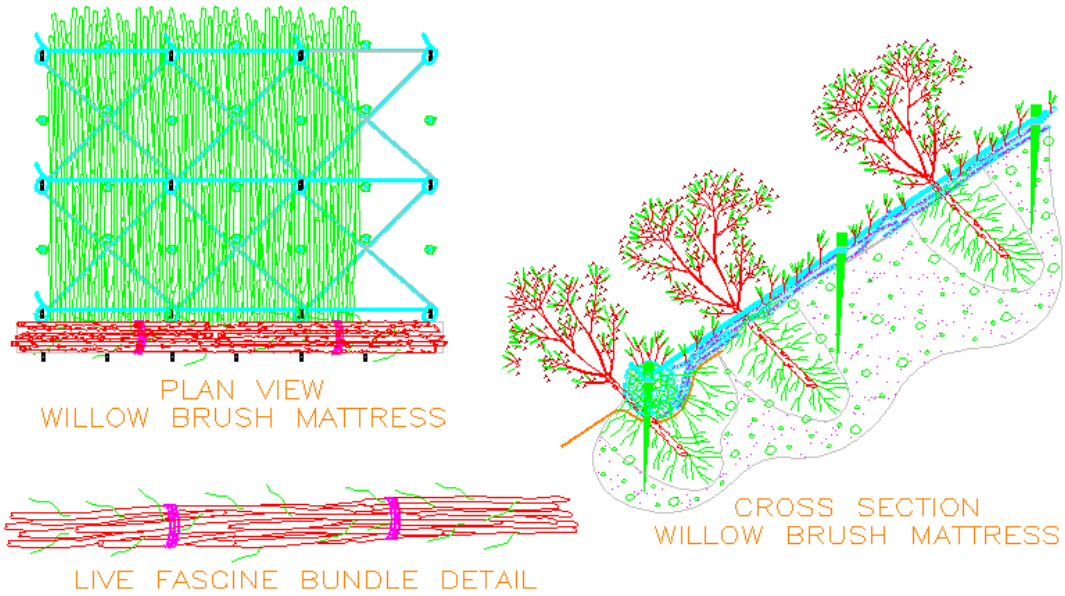


Figure 10. Willow brush mattress construction. Note that willow posts will not be leafed out nor rooting at the time of construction.

## Installation

On August 16th, 2007, a pre-construction meeting was held between the landowner, NRCS, the Napa RCD, the contractor and sub-contractor, and permitting agencies. The design documents and construction safety guidelines were reviewed and discussed.

On August 27, the contractor, Heide and Williams, Inc., went to work demolishing and disposing of the old dam structure. The appurtenances were cut off of the railcar bridge and apron using a cutting torch and then the bridge was stripped of its wooden planks. At that point, the railcar was light enough to be lifted from one end to drop it down into the channel, onto the apron where it was cut apart and hauled out of the channel via an existing access ramp between the two creeks. They then went to work jack-hammering the concrete wingwall out on the south side and stockpiling broken concrete and other debris on the apron at the north side where they could load it into trucks. As the apron and pilings were removed, rebar was cut, and concrete came out, the channel slowly began to look more natural. And while trucks were being loaded with debris for disposal, the process of grading the banks began from downstream up. Once the whole structure was removed, the toe rock was installed up to the location of the downstream weir. Then the downstream weir was installed and toe rock and weirs were continued upstream so that the contractor was always working their way out of the channel.

Figure 11. November 15, 2007 after construction. Note the two V-shaped weirs daylighting into existing trees.

During field staking, we opted to daylight the weirs into existing trees on the banks, which prevents flanking during high flows and can help take the forces transferred from the center key rock into the banks and the trees. To prevent the weirs from being compromised, they were keyed into the banks by about five feet so that the plunge pool wouldn't undercut and launch or dislodge the foundation boulders. Additionally, it was crucial to be sure that there were enough small rocks in the gradation to fill in the gaps between the larger rocks. This prevents piping and, in the end, the structure from being compromised.

Figure 12. September 24, 2007 during construction. Note the fascine lying horizontally across the bottoms of the willow brush. The brush had to be compressed tightly while being tied down to the posts.

The first step of installing the brush mattresses was to auger holes into which the posts would be driven. Augering is necessary for willow post installation. If the posts are installed into an excavated trench, they will likely be eroded out since a trench is an easy path for water to take. Once the grid of posts were installed, willow branches were laid down and compressed. We could have used finer branches but since the supply was limited, we used what was available of the allowable species, Red willow (*Salix laevigata*) and Arroyo willow (*Salix lasiolepis*) (Blake, 2007). Locally available Sandbar willow (*Salix interior*) was not used because it tends to migrate into the center of the stream where it creates the sandbars for which it is named.

After the installation of the fascines, the last step was to “salt” soil over the brush mattress. The scattered earth helped to fill in the spaces between the brush with soil to aid in brush growth.

Construction was completed by October 15$^{th}$, 2007.

## Performance & Lessons Learned

Based on rain gauge data available on the Napa Valley Regional Rainfall and Stream Monitoring System (Napa Onerain), the rainfall depth on January 4$^{th}$, 2008 corresponded with that of a 25-year, 24-hour storm in the Dry Creek watershed. The runoff and stream flows observed that day matched that predicted by the HEC-RAS™ model during the same 25-year storm flow. Water flowed about 3 to 4 feet from the top of bank during the peak of the storm runoff.

Figure 13. January 4, 2008 storm flow in the project reach, approximately 25-year storm. Flow is 3-4 feet from the top of bank.

Monitoring after that storm identified a small amount of damage to the project including a small amount of displaced brush from the south side brush mattress and some settling of the toe riprap on the upstream end of the north side rock toe. Neither of these are seen as detrimental but rather as lessons learned. The riprap toe was actually extended further upstream near the end of construction because there was rock left over. Though the left over rock was slightly smaller than optimal, we expected it to have adhered. It settled somewhat but the settling was minor.

Figure 14. March 13, 2008, looking downstream.

While the brush mattresses were well installed, it is recommended that a month or two post-construction and prior to the storm season, the brush mattresses should be inspected and re-tied down. Despite proper irrigation and initial tie-down, the brush can be expected to “relax” down into place after construction is complete. Additionally, the effects of solar exposure and project maintenance (including irrigation) can cause breakage in the tie-downs making another pass and/ or a tightening crucial for optima project success.

Irrigation is also crucial to the success of bioengineered structures both prior to the rainy season and for the subsequent few summers. While visible growth of the willow posts is not expected,

it's necessary to keep the willow material damp to keep it alive and to allow the vegetation to begin establishing the root matrix that will support the earthen banks in the long term.

While so much attention is put on vegetation, similar attention needs to be put on imported earth backfill and straw mulch. They must both be inspected by an agronomist or soil conservationist to ensure that what is being brought on site is weed-free to prevent the competition by advantageous invasive plants with the intended vegetation.

## Benefits and Next Steps

Local bank stability has been enhanced by grading and the protection of banks by the brush mattresses. Monitoring has shown that there was a release of accumulated sediment from upstream of the structure, though it was limited, and not considered to be detrimental.

Riparian health has been improved by the establishment of favorable native plant species that create a more contiguous corridor for native wildlife travel and migration. Additionally, the removal of non-native plants, such as *Arundo donax*, an invasive bamboo-like grass, and *Vinca major* and *minor*, hosts to Pierces Disease, which is a serious threat to winegrape vines has benefitted both native habitat and the neighboring vines.

The partnership of seven local, state, and federal agencies and private landowners has proven successful. There is hope and current work being put into developing a streamlined, coordinated riparian restoration permitting program to further incentivize the restoration of riparian corridors in the Napa River watershed. Additionally, this has been an excellent opportunity for landowner education both through partnership and use of the site as a demonstration project for future potential projects both for fish passage and for bank and channel restoration.

In that light, the Napa RCD has identified, as priorities, several barrier removal projects throughout the valley that will enhance the habitat available to economically and ecologically significant salmonids.

The Napa RCD is also continuing to research and develop opportunities for further upstream and downstream restoration work including additional invasive plant removal, native plant establishment, and alternatives for addressing the head-cut that is slowly eroding its way up from the Napa River.

## Project Costs and Funding

Table 3. Costs.

| **Item** | **Cost** |
|---|---|
| Planning & Permitting | $ 52,900 |
| Implementation/Construction | $ 190,400 |
| Administration | $ 48,100 |
| ***Total*** | ***$ 291,400*** |

The project was funded through NRCS' Wildlife Habitat Incentives Program (WHIP), a California Department of Fish and Game (DFG) Fisheries Restoration Grant, and a San Francisco Regional Water Quality Control Board (RWQCB) Grant with monetary contributions from the landowner. Additionally, the neighboring landowners committed early in the process to discontinue pumping from the reservoir for frost protection and installed alternative frost protection measures in place of sprinkling with reservoir water. Some vineyard blocks were equipped with fans and others were provided water from an off-stream reservoir. These changes represent a considerable contribution and commitment to the project.

## Partners & Support

Table 4. Partners.

| Partner | Support |
|---|---|
| Napa County Resource Conservation District | Lead Agency, Project Coordinator and Administrator |
| Katherine Hall Wines | Private Landowners |
| USDA Natural Resources Conservation Service | WHIP Funds, Engineering & Design |
| CA Department of Fish & Game | Fisheries Restoration Grant, Permitting, Design Review |
| San Francisco Bay Regional Water Quality Control Board | State Bonds and CWA Funds for Feasibility Study & Planning, Permits |
| CLSI Napa Green Fish Friendly Farming | Funds, Planning Oversight & Input |
| NOAA National Marine Fisheries Service | Permitting, Planning Oversight & Input |

## Conclusion

The project goals of improving fish passage, stabilizing the streambanks and channel thalweg, and restoring the riparian corridor have been met.


### *Acknowledgements*

Once again, this project could not have been completed without the hard work of our partners listed above. Technical oversight, support, and review by Marcin Whitman of the California Department of Fish and Game, Marianne K. Hallet, PE, of the California State Office of USDA NRCS, and David Robledo, PE of the Salinas Area Office of USDA NRCS. Quality construction can enhance the results of a good design. The cooperation and quality construction of local contractor Heide and Williams, Inc. and the exceptional efforts of the California Conservation Corps (CCC), Napa Center have been greatly appreciated and contributed to the success of this project.


## References


Blake, P. 2007. *Guidelines for Harvesting Live Willow Materials in Riparian Areas*. Napa, CA: USDA NRCS Napa Field Office.

California Department of Fish and Game (DFG). 1998. *California Salmonid Stream Habitat Restoration Manual, 3rd Edition (http://www.dfg.ca.gov/fish/Resources/HabitatManual.asp)*. California Department of Fish & Game.

Ecotrust, and Friends of the Napa River (FONR). 2002. *Results of Hankin-Reeves standard uncalibrated Oncorhynchus mykiss survey of Napa River tributaries.* Portland, OR.

Hoag, C., J. Fripp. 2002. *Streambank Soil Bioengineering Field Guide for Low Precipitation Areas*. Aberdeen, ID: USDA NRCS Plant Materials Center.

Koehler, J. 2008. *Salmon and Steelhead in Napa County* (presentation). Napa, CA: Napa County Resource Conservation District.

Koehler, J. 2007. Personal e-mail regarding Dry Creek and Hopper Creek Salmonid Habitat. Napa, CA: Napa County Resource Conservation District.

Napa County Flood Control and Water Conservation District. 2008. Napa Valley Regional Rainfall and Stream Monitoring System. Available at: http://napa.onerain.com. Accessed January 2008.

NOAA National Marine Fisheries Service, Southwest Region. 2001. *Guidelines for Salmonid Passage in Stream Crossings (http://swr.nmfs.noaa.gov/hcd/NMFSSCG.pdf)*: Santa Rosa, CA.

Philip Williams and Associates, Ltd. (PWA) 2006. *Preliminary Report on Fish Barrier Removal Alternatives for a Sill Structure on Dry Creek, Napa County, CA (PWA Ref. # 1828)*. San Francisco, CA.

Terra Firma Survey, Inc. 2006. *Cross Sections for Dry Creek Seasonal Dam Removal*. Saint Helena, CA.

USDA Natural Resources Conservation Service (NRCS). 2007. *California Field Office Technical Guide (http://efotg.nrcs.usda.gov/CED)*: United States Government Printing Office.

USDA Natural Resources Conservation Service (NRCS). 1990. *Engineering Field Handbook (http://www.info.usda.gov/CED)*: United States Government Printing Office.

USDA Natural Resources Conservation Service (NRCS). 2007. *Stream Restoration Design Handbook, NEH-654 (http://policy.nrcs.usda.gov/viewerFS.aspx?id=3491)*: United States Government Printing Office.

USDA Soil Conservation Service (SCS). 1978. *Soil Survey of Napa County, California (http://websoilsurvey.nrcs.usda.gov/app/)*: United States Government Printing Office.

## Appendix or Nomenclature

Anadromous – a fish that migrates from the ocean into fresh waters to spawn or reproduce.

Apron – the wide, flat section across which the water flows when the flashgates are raised and on which water falls when the flashgates are down blocking flow. The apron prevents a pool from being scoured out which could undermine the structure, negating the purpose of the weir. The high water velocities and long, shallow flow across the apron are preventative to fish migration. Flow on the apron surface was shallow and very spread out making the swim-ability very poor. Additionally, the two-foot, 45 degree drop at the upstream end increased the difficulty of passage.

AutoCAD™ – a design, drafting, modeling, architectural drawing software.

CLSI – California Land Stewardship Institute.

Cutoff – the section of concrete below the ground surface that stabilizes the structure, preventing it from rotating or sliding downstream. It also prevents water from traveling under the apron.

$D_{100}$ – the diameter of the largest particle of the sample in question. One hundred percent of the sample is this diameter or smaller.

DFG – The California Department of Fish and Game (http://www.dfg.ca.gov/)

EaglePoint™ – a civil software add-on that works with AutoCAD to create civil-based drawing results.

Flashgates – the steel plates that are supported by I-beams. The I-beams sat vertically between the railcar bridge and the concrete apron. When the flashgates were down, the dam held water for frost protection.

Head-cut – a vertical drop in the bed of a stream channel, also known as a nickpoint.

HEC-RAS™ – a River Analysis System (RAS) software designed by the U.S. Army Corps of Engineers that perform one-dimensional steady flow, unsteady flow, sediment transport/mobile bed computations, and water temperature modeling. (http://www.hec.usace.army.mil/software/hec-ras/)

NOAA NMFS – National Oceanic and Atmospheric Administration's National Marine Fisheries Service, also known as NOAA Fisheries (http://www.nmfs.noaa.gov/)

Railcar bridge – a bridge deck created by removing all but the floor of a rail car.

RWQCB – Regional Water Quality Control Board

Stream barb – a constructed, upstream-facing projection placed along the outside bend of a curve in a stream to direct or train flows toward the center of the channel and deflect energy away from the toe of the outside bank. Stream barbs are usually constructed of rock.

Thalweg – the lowest point in a channel cross section, also known as the flowline.

USDA NRCS – United States Department of Agriculture's Natural Resources Conservation Service (http://www.nrcs.usda.gov/)

Vortex weir – a constructed, upstream-facing, v-shaped weir that focuses flows and flow energy to the center of the channel. Vortex weirs are constructed of rock.

Weir – an instream blockage that holds back water to control channel grade or for storage. In this structure, I-beams supported steel plates that held back water for frost protection.

Wingwalls – the abutments of the concrete structure that prevent water from traveling around the intended pathway. They retain the banks adjacent to the apron and often support a bridge deck like the railcar used in this case.