Environmentally Sensitive Streambank Stabilization Techniques

Geyserville Bridge and the Russian River - 5 Years Later

Alternatives to Riprap

In early 2000, the Transportation Research Board (TRB) received requests from their members for more research on alternatives to riprap. The TRB, comprised of member State DOTs had issued a "problem statement"; Are there any alternatives to riprap that DOT engineers can specify with confidence?

Apparently many State and Federal highway engineers were having problems acquiring and complying with environmental permits on highway projects adjacent to streams and rivers. Rock, riprap, gabion baskets and other typical engineering structures were criticized by resource agencies for not providing adequate aquatic habitat. Therefore they were demanding more bioengineering or soft engineering elements. However, within the engineering community there is considerable skepticism regarding the performance of these measures, especially when subjected to flood event magnitudes considered in typical DOT designs for bank protection.

In 2002, the TRB and National Cooperative Highway Research Program (NCHRP) issued an RFP for research and development of guidelines and design criteria for methods determined to be "environmentally-sensitive". The 3-year research, conducted by Donald Gray, Doug Shields and myself was reported and published as NCHRP Report 544 – Environmentally Sensitive Channel and Bank Protection Methods (McCullah and Gray, 2005). Over 50 Environmentally Sensitive Streambank Stabilization (ESenSS) methods were identified and presented in an extensive guidance manual, published on CD and using html. The designer or regulator can 'surf' through the information by using a browser. The manual included design considerations, design criteria, typical drawings (in AutoCad and Microstation formats), construction specifications, costs and much more.

Above: The site in October 2014, after 4 years. Below: Looking downstream prior to starting project. Channel avulsion sent the thalweg toward the right descending bank.

Highway 128 Geyserville Bridge Project, Russian River

This article will investigate and evaluate how the redirective and bioengineering methods have worked on this project and what are some of the lessons learned. The critical element of this project was to protect the upstream abutment of the new bridge, constructed three years previous. The design concept presented involved redirecting the stream thalweg with the best alignment possible given the existing environmental constraints. A significant constraint was the Federal regulators would not allow the gravel bar "to be touched". This was understandable, as historic gravel removals may have contributed to the disequilibriums. And there was not a lot of time for more studies.

The project quite possibly holds a record for the speediness of getting permits. It was designed and permitted in less than one month as it was imperative that the project be complete when the salmon were expected to make their spawning runs in October. The project used ESenSS as the basis of design which included the following; 1) 5 Rock Vanes, 2) a new bankline delineated by 300 ft. of Longitudinal Stone Toe, 3) 300 LF of Live Siltation, and 4) a low flood terrace built at an estimated bankfull stage elevation and planted with willow and cottonwood poles.

David Yam, Branch Chief, Office of Water Quality with Caltrans District 4 was the Project Manager. District 4 Hydraulics ran the analytics and approved the concept design. Caltrans had some experience with redirective methods having designed Bendway Weirs on Cedar Creek in District 2.

The project was constructed under an emergency contract and Ghilotti Construction completed the work in about 30 days. The Russian River is one of the most critically sensitive salmonid streams in California, therefore there were always several environmental and stormwater monitors on site. One of the most critical elements, making this project possible from an environmental permitting standpoint, was the use of self-launching (poorly sorted, well graded) rock to build the structures. Also the fact that the biotechnical elements, especially Live Siltation, are effective immediately and get stronger with time, e.g., self-mitigating.

How Well Will The Techniques Work?

There were 3 major concerns over this design. First, the main question posed by professionals involved in this project was how the structures will function during high water. A common concern was; how can the low Rock Vanes survive and provide their re-directive function when the expected floodwater surface elevation might be 6-12 ft. over the structures? The project was also completely visible due to the webcam installed. As you can imagine, there were constant comments, feedback, and certainly a fair share of "doomsday prophesies" and yet the project proponent and design team stayed on course.

Google view taken pre-project 2010, Red line is toe of old bank which was protected with riprap until 2003. Bank migrated over 60-feet is 7 years.

The LST was made wider to provide a 'feeder' access for rock.

Clean self-launching rock, installed by skilled operators assured no turbidity issues.

The primary reason that the project worked is the nature of the redirective method. Vanes or bendway weirs point upstream and are designed to have flows running over them, like an airfoil. The pressure gradients can therefore turn the vectors of high velocity away from the banks. If the structure were pointing downstream it would, in fact, turn the flows into the bank. Redirective methods are actually a way to manage the thalweg.

No Destruction of Channel Bottom and Minimal Turbidity

This is an area where ESenSS methods are very beneficial when acquiring permits. The use of well-graded and clean stone precludes the necessity to dig scour trenches. The quality and quantity of stone is designed to provide "sacrificial stone" – rock that will self-launch into any scour holes that may occur. If the designer determines that scour is likely, then he/she can specify more rock, stacked up at angle of repose that will self-launch into the scour as needed.

After building and monitoring projects in Canadian Rockies, California, and New Zealand using "clean stone" we have found that structures CAN be built in sensitive rivers with little to no sediment or turbidity resulting. However these sensitive projects do require strict rock specification adherence and skilled equipment operators.

When the stone is very well graded, with small fractions (1"-3/4") it is also called "self-filtering stone" (D. Derrick, personal communica-

Above: Project completed on October 11, 2010. Here terrace has pole plantings (willow and cottonwood) installed and counted. Note the poles are over 9-ft tall.

The site has experienced several floods. This flood is in March 2011.

Live Siltation installed deeply in trench - self-filtering rock used to control turbidity.

tion) and can also preclude the need for filter fabric. The typical riprap design requires a scour trench, lined with geotextile, then filled with riprap or RSP. This type of construction is likely to degrade the existing substrate and cause significant water quality issues that are difficult and expensive to mitigate. Scour trenches also fill with water, making it difficult to properly place filter fabric, and dewatering can require additional permits. In some locals the assembly and maintenance of isolation techniques or diversions can be more costly than the actual stream repair.

Secondly, nother common concern was how would the relatively small rock gradations survive the anticipated tractive forces? This project, maybe for the first time on a big river in California, demonstrated the use of very well graded stone, referred to as self-launching rock, in the design and construction of low rock toe protection and the rock vanes. Generally here in the west, the stone is uniformly sorted and pretty big rock. Often the RSP is comprised of two gradations, big and medium, e.g., 1T and 1/4T stone. In contrast, self-launching stone is comprised of big rock graded down to small rock, with many gradations in between, e.g., 1T, 1/2T, 1/4T, 12", 6-9", 3", and ¾". Self-launching is possibly a misnomer as this leads some to think the rock is designed to travel downstream. This is not so. Self-launching stone is designed to "reposition", it shifts and settles and ultimately locks together. This locking together concept is important to visualize. Large angular rock is properly placed is a way to maximize contact points. But several large 1T angular rocks can only have three or four contact points between each other. Envision now the amount of contact points from a well-graded mix of angular rocks. See www.watchyourdirt.com for a recently completed project on a Malaysian river, Sg. Pedu, which required such well-graded stone specifications. Once the rocks settled and shifted, the "whole became stronger than the parts".

Third, and finally, is the question of "Will the high flood waters impinge on the outer, right-descending bank as it did before the redirective vanes were installed?" and "Will the bank continue to erode and will the riverbank migration continue to threaten the Geyserville Bridge abutment?".

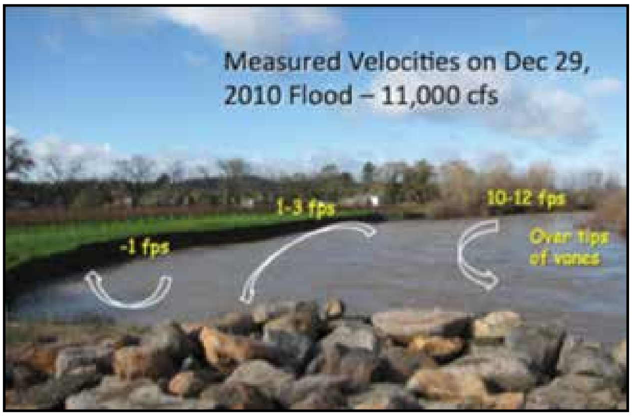
To answer this concern one must see the distribution of high velocities after the redirective vanes were built. The high velocities, which were once impinging and concentrated at the outer bank, are now focused at the tips of the vanes. And then the velocities within the redirective field to the once eroding bank are less then 2-3 fps, even during flood flows. Another way to say it is we effectively moved the thalweg away from the bank.

Also, we installed Live Siltation and other 'roughness' factors, which will dissipate erosive energy, and slow velocities as the floodwaters rise to occupy the flood terrace.

As the four years of photos show, the tips of the vanes did lose or "sacrifice" some stone to scour. Probably 25% of the installed vane length is gone. However the channel bottom and thalweg have adjusted and dropped nearly 5-ft. It is important on this aggrading river reach, which is susceptible to depositional avulsion, that the channel be somewhat constricted and move bedload through. With the strongly built LSTP, remember it also served as a haul road, and the well-established willow "hedge" it is unlikely that the rivers thalweg can shift or move, once again, toward the bank.

Lessons Learned / Wish List

Caltrans District 4 was willing to look at innovative and environmentally sensitive approaches to solving the problems at hand.



The vanes moved the high velocities off of their tips, even though there was 9-ft of water over them. There was 1-3 ft./sec velocities near the bank.

After 15 days the flood receded and no erosion had occurred.

They took some risks while doing due diligence in design and mitigation. There were so many constraints on this project, yet the District persevered and produced a project that has proved to be quite successful.

If I were to design a similar project today I would build the vanes with a wider cross section and wider footprint. This would add more sacrificial rock to the structure. In fact, this site could have benefited with less constraints so we could have pushed the thalweg even further out. This redirection would give the river a much better alignment with regards to the bridge. Bendway Weirs may have been a better choice for the redirection and they certainly would best for a longer structure.

Only about 50% of the pole plantings on the flood terrace survived. The upstream section of the terrace got high velocities that either killed or uprooted the plants. Many of the cottonwood poles broke as they are much more brittle than willow.

An alternative method for planting the flood terrace would have been to open slit trenches, oriented perpendicular to the flood flows. These slits are quickly made with an excavator with a large bucket. Work starts downstream and backs upstream as work proceeds. As the operator is holding the slit trench open a worker can install several branches into the trench and the bucket is then carefully pulled out. This method would be a modified live siltation array with the branches pointing downstream.

The project limits and Caltrans ROW was only 300-ft upstream. This was a very short distance to turn such a large powerful river. It would have been beneficial to have a Bendway Weir or two upstream in order to nudge the thalweg over sooner. Floodwaters hit the upstream edge of the LSTP with a lot of force and the first upstream vane has to do a lot of work.

NCHRP and TRB have recently developed a second research project, NCHRP Project 24-39, headed by Ayers and Associates, which is intended to collect more empirical data and present it in a new report focused on an evaluation of flume trials and more seasoned a case studies. Some of this information was reported in *Land and Water*'s March/April 2014 issue – "What I've Learned About Streambank Stabilization". **L&W**

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For more information about this project or others visit the archive at www.watchyourdirt.com, or you might consider attending one of David Derrick or John McCullah's courses. To inquire about upcoming courses, contact John at john@salixaec.com.

The Shasta College Erosion Control BMP Summit, is in Redding, CA on May 1 and 2nd. One day classroom with 2nd day in the field at SC Erosion Control Training Facility. The ECTC is featured in Dirt Time videos and is home of Mt. McCullah, where we will spray hydromulch, install silt fence by slicing, construct a Skimmer Pond and so much more. Contact jeni@salixaec.com for more information.

Keywords/Definitions

Redirective Techniques - discontinuous, transverse structures that redirect (shove, push) the impinging, high velocities away from the bank and toward the middle of the channel, e.g., rock vanes, bendway weirs

Thalweg Management - see above

Self-Launching Rock - poorly-sorted rock, specially-designed rock gradation to eliminate need for excavation scour trench

LSTP - longitudinal stone toe protection

Live Siltation - willow branches installed at bankfull discharge elevation and oriented out into stream for additional "roughness"

Pole Planting - method for planting willow and cottonwood poles (greater than 6' long cuttings)

Biotechnical - the use of biologic and structural components in a mutually-reinforcing manner