2011 AEG ASABE-ISELE Conference
Anchorage, Alaska
Performance of ELJs in Washington State-Post Project Appraisal
by
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Understanding cause and effect
In rivers, by understanding cause and effect we can do a pretty robust synthesis of performance!

Have a seat Jack. What I am about to tell you might come as a big surprise.
Post Project Appraisal Team

- Fluvial Geomorphologist – W. Barry Southerland, USDA-NRCS-WNTSC
- Fluvial Geomorphologist-Engineering Geologist – Frank Reckendorf
- Fish Habitat Biologist-Mark Schuller, Retired
  November 2006
- Stream Mechanics Engineer-Dean Renner, USDA-NRCS, Olympia, WA
Why a study on ELJs?

- It is an important technology that re-infuses wood components into stream corridors. Wood, an important fish (aquatic) habitat component, is sorely lacking in many systems where it was once abundant and natural.

- NRCS wants to know about the physical performance of these structures and did they meet the objectives of the stated project goals.

- Request was generated from the Washington NRCS State Conservation Engineer and State Conservationist - December 2005 – To conduct an assessment in order to appropriately and confidently recommend this practice to address specific streambank erosion concerns.
Why study?

- ELJs have been implemented since the mid 90s (Over 14 years) (2010). What have we learned from successes and losses and how can we better apply this technology to our NRCS client base and other interested shareholders? Over $110 million of WA State- SRF (Salmon Recovery Funding) Board monies have been spent.

- Are there significant design components that will help us adapt this technology in higher risk landscape settings?

Team Criteria for Post Project Appraisal

- Did the structure address the primary physical goals & objectives stated for the project-on the permit?
- Projects had to be five years or older and exposed to floods above bankfull Q (channel formative flow)
- Projects had to be identified as Engineered Log Jams either on permit or design.
- Projects had to include streambank protection as one of the primary goals.
Types of Anchors as described in Stream Habitat Restoration Guidelines, WDFW, USFWS, WDOE

1. **No anchors** -- where wood is supplied to the stream and allowed to be naturally stable or, as conditions develop, moved by the flow.

2. **Passive anchors** -- where the weight and shape of the structure is the anchor, and movement at some flow level is acceptable (includes ballast).

3. **Flexible anchors** -- such as tethering the structure so there is some degree of movement flexibility with varying flows.

4. **Rigid anchors** -- holding the logs permanently in place with no movement allowed.
Project Stages

- **Stage 1** – assemble team, conduct initial assessment, gather information relative to projects, exam goals and objectives, reconnaissance of structures, field visits for 5 years to identify physical strengths and weaknesses of structures relative to streambank erosion and absence of structure or significant reduction in size of structure since time of installation, streambed and bank materials, scour (pool) depth, examination of aerial photos before and after installation, contact local entities and sponsors, exam peak flows since installation, on-site stream velocity at point of flow convergence. Discuss feasibility of Stage 2 study.

- **Stage 2** - Stream morphometry – dimension, pattern, and profile, more in-depth bank and bed stratigraphy, more in-depth look at velocity distribution, hydraulic geometry and bedload competence (incipient motion), particle size distribution. Interview designers-installers, study project costs. Proceed with Stage 2 based on Stage 1 findings.
ELJ Post-Project Appraisal Locations

- **Cowlitz River** near Packwood
  - Private Landowners

- **Cispus River** – U.S. Forest Service - Near Randle

- **North Fork of the Stillaguamish** above C-Post Bridge – Private owners and Pilchuck Tree Farm

- **South Fork of the Nooksack** Sierra Pacific Industries Tree Farm

- **Elwha River** – Elwha Tribe Private and Tribal Lands

- **Hoh River** next to Hoh Rain Forest Road - Jefferson Co Dept. of Transportation & NPS
Upper Cowlitz River near Packwood

- **RM 121** – Reach Length 1380 feet
- **Drainage Area** – ~260 mi²
- **Funding** – Private Landowner and NRCS
- **Completion Date** January 1996

**Objective(s):** Streambank protection & creation of deep pools at each ELJ w/ associate environmental benefits.

**Type:** Passive Anchor

- **Number of ELJs** - 3
- **Number of Logs** – 200 total

1996 – 30,020 cfs- Five weeks after const. – 20Q – LP III
1997 – 21,000 cfs, 5.2Q,
1998 – 15,800 cfs, 1.9Q
1999 – 23,900 cfs, 7.4Q – All three ELJs lost
2002 – 17,400 cfs, 3.5Q

Previous to installation damages from the high flows:
- LP III- 32, 900 cfs – 25Q,
- BFQ ~9000 cfs
Upper Cowlitz Project

Findings - ELJ Installation

Loss of 7 acres of floodplain since installation
• 300 feet of lateral recession since installation
• Channel Slope .0035 ft/ft – (1996)
• Channel bed $d_{50} = 51$mm $d_{84} = 98$mm (1996)
• Streambed scour, bedload transport, aggradation
• Streambank stratigraphy (lateral accretion-fine textured over vertical accretion-gravel course textures.
• $Rc/Wb kf = 1.9$, $Rc/Wb kf$ values less than 2.5 has high tightness of curvature – (R.A. Bagnold, 1966 & others) a.k.a. tortuosity.
Upper Cowlitz Aerial Photo-2006

Flow

1994 Channel Boundary
1994 Channel Bank
PHOTO BASE 2006
Cowlitz ELJs -2007

Right streambank several years after loss of ELJ #2

6 Foot Global Flow Probe
ELJ Cispus River Appraisal Study Site

- **Cispus River** — U.S. Forest Service Project  RM – 17.2 to 20
- **Drainage area:** 250 square miles
- **Funding:** SRF Board & BPA through Lewis Co. Conservation District
- **Objectives** — Streambank protection for Forest Service Road 23 and Bridge of FS Road 28 & salmon habitat improvement
- **Project completed**  Summer 1999 Sites B & C, 2001 Site A
- **Floods:**
  - 1999: 8840cfs – 4.2Q
  - 2002: 8480cfs – 3.9Q
  - 2003: 14800cfs – 19Q
  - 2006: 6440cfs – 2.3Q
  - **BFQ est. 3500 – 4000 cfs**

USGS Yellowjacket Gage 14231900:
- 250m² – 11 years of record

N46° 26’ 41.2”  W 121° 50’ 24.7”
Cispus ELJs

- Number of ELJs Constructed – 12
- Number of logs – 1400
- Passive anchor

Problems Cispus

- Response to high flows of 2003 - 19Q, In that event a significant amount of alluvial fill used for ballast was removed from all sites A, B, and C but particularly A & B, ELJ A1 lost, A2 at risk
- Channel migrated away from habitat on 10 out of 12 ELJs
- Sedimentation – aggradation along ELJ
The channel along site C is not connected to the main channel at lower flows. Site B is connected at high flow.
Cispus River Site B

Rip Rap to protect key of B1

This Secondary side channel received aprox. 20% of flow.

(Source-USFS)

Presently no flow at bankfull and below

10/2006

Cispus ELJ - Passive Anchor

Flanking on backside of ELJ - B1. Example of at-risk.

~ 3 feet in 06 runoff – common scallop patterns between structures. Streambank erosion between B1 and B2.
North Fork of the Stillaguamish

- **RM- 21-22**
- **Drainage Area** – 115 square miles
- **Funding** – SRF Board
- **Completion Dates**: Summer, 1998 first 5, second 3 – 1999
- **Objectives** - Create and enhance holding pool habitat for summer chinook salmon.
  Streambank Protection – limit erosion along a 250 m of bank.
- **Number of ELJs** – 5 – 1998, number of logs – 550.
- **Number of ELJs** – 3- 1999, cabled only at front of key members and sill log.
North Fork of Stilly

- Flood discharges and erosion

At USGS gage 12167000 near Arlington (262 mi²) we have had at least 7 high flows above bankfull (channel formative flow) since installation.

2003 and 2004 had 43 & 20 Q event ranges LP-III dist.

Slope: 0.26% or 0.00257 ft/ft

- Rc/Wbkf 6.6 for jams 3, 4, and 5
- Rc/Wbkf 2.7 for jam 1
- Passive Anchor style – some cable used for maintenance
NFS - ELJ #3 before and after 2006 high flow

August, 2006 ELJ #3

October, 2007 ELJ #3, Gone
NFS ELJs 6, 7, and 8 all on point bar (opposite eroding bank)

Jams 1, 3, 4, and 5 directly associated with streambank protection. Jam 2 was apex center jam diverting most flow to left, channel has shifted right. Channel and jams 6, 7, and 8 were constructed on point bar. ELJ 6 is gone in 2011. ELJ 7 at risk.

Left Bank with ELJ

Right Bank across from ELJ 7

No Connectivity to low flow channel
South Fork Nooksack

- RM 19-21
- Drainage Area – 74 square miles
- Funding – SRF Board
- Completion date summer, 2000 – 1.5 miles treated.
- Objectives: salmonid habitat improvement and streambank stability
- 6 ELJs, ELJs 3 and 5 streambank log jams, ELJs 1, 4, and 6 – split flow jams. ELJ 2 side trib. bank jam – 200 large primary members and ?? racked members – no pylons – Cost $850,000
- Floods: 2002 – 13800 5Q
  2003 - 6020 1.2Q
  2004 – 18500 17Q
  2005 – 12600 4Q
  2006 - 7560 1.4Q
- Estimated BFQ – 4950 to 6250 cfs
South Fork of the Nooksack

- Old compacted lacustrine bed material along streambank and below coarser alluvial armor. Bed and local streambank armor is high in glacial, and glacial fluvial transported granitic material that is erratic in this watershed. Paleo-channel formed in a much higher fluvial geomorphic regime.

Most ELJs Footer material and sill logs are in- clay portion of bed.

- Slight - Radius of Curvature to bankfull width – Tightness-of-Curvature - Rc/bdw  Ranging between 4.8 and 6.6

- Excellent physical site for ELJs

- Water surface gradient: 0.005 ft/ft - .006 ft/ft

- No pylons used in design – Passive Anchor Style- only passive anchor style site to completely survive high runoffs!
South Fork of Nooksack

Flow

1994 Channel Boundary
1994 Channel Bank
PHOTO BASE 2006
Glacial erratic rocks & other course rock over old paleo lacustrine setting

Bed material makes a significant difference on stability
Elwha River – Elwha Tribe, Clallam Co.

- RM – 1.9
- Drainage Area: 313 Sq. Miles including two dams (Elwha and Glines Dams)
- Funding – SRF Board
- Objectives: salmonid habitat improvement and streambank protection
- 6 ELJs: 99-2, 99-3, 99-4, 99-6, 00-2, 02-4
- 3 ELJs performing, 3 gone
Elwha

- Rc/Wb kf: 2.5-2.6 ft/ft
- High Flows
  - 2002 – 25,700 cfs 10Q
  - 2003 – 29,700 cfs 18Q
  - 2006 – 26,000 cfs 10Q
- Rigid anchor style with cable
- Salmonid Habitat Restoration
- Streambank Protection
Elwha Left Bank

- In 2007 (5 runoff seasons) ELJs began to shift and wash out.
- In 2010-2011, ELJs 99-4, 99-6, 00-2 were not present,

ELJ - #99-4 w/ cable 2010 - Gone

1999

2006

1999
Upper Hoh River Site near Hoh River Rain Forest

- RM- 23.5
- Funding SRF Board
- Objective(s) Salmon habitat improvement & streambank protection* (Also mitigation for rip-rap)
- ELJs 1, 2, and 3 installed in 2003, 2 washed out in 2003. Some root wads downstream that are remnants of three wash outs.
- Gage drainage area - 253 mi²
  Gage is 7 to 8 RM downstream

2003, 30900 cfs – 2Q
2004, 62100 cfs – 25Q
2005, 32700 cfs – 2.2Q

- Combination of Passive & Rigid Anchor Style ELJs

• As stated by Jefferson County Road Department and Planning (Sponsors).

BFQ ~ 25,000 cfs

N47° 48’ 59.49 ”  W 124° 08’ 10.37”
Upper Hoh Road Site

October 2005
Remnants of washed out root wads

We have learned from this project and others that tight \( \frac{R_c}{W_{bkf}} \) are very critical to stability. **Extreme tortuosity:** \( \frac{R_c}{W_{bkf}} = 1.4 \) to \( 1.6 \) at time of installation. Most extreme of nearbank stress of all ELJs assessed.

If you must have river disturbance and short-term sedimentation to install ELJ key for scour depth this cannot be compromised in permit.
Field observations of identified concerns

- **Rc/Wbkf** – **Tightness of curvature** value i.e. tightness of turn and increased shear in the nearbank area on meander bend log jams. Flow convergence into key of meander bend style log jam resulting in flanking is common. **Rc/Wbkf values below 2.4-2.6 ft/ft multiple nearbank shear points are common and nearly all ELJs are gone.** Below 2.5ft/ft all are gone.

- **Height of log structures relative to bankfull Q elevation & the associated floodplain entrenchment characteristics** – this impacts the intensity of flow convergence on the log structure key at various flood stages.

- **Appropriate ballast and early loss of alluvium fill** when alluvial fill is the principle ballast tool.
Concerns Continued

- Flow- how they perform at the 1.1Q, 5Q, 10Q, 20Q, 50Q, and 100Q. What are the expectations? Should there be expectations when streambank protection is an identified objective? **Shifting objectives-Post Construction!**

- Shifting objectives-Post Construction!
  - Substrate and geologic-geomorphic conditions, i.e. was there significant depth of scour impacting stability?
  - Meander geometry – do we really know the influence of ELJs on meander geometry?
  - Unrealistic constraints, like on the Hoh, imposed upon designers/installers by permitting agencies often impact structural integrity of ELJs. We cannot design by consensus, that compromises design. Permit reviewers need to keep structure stability in context of hydraulic-geomorphic setting.
  - Buoyancy issues at high flood stage in nearbank high shear area. No sites existed on seasonally freezing conditions!
Forty percent of bend Jam Type ELJs are gone after 5 years of monitoring. Sixty percent of bend jam style ELJs exposed to main channel flows- are gone. $R_c/W_{bfk}$ is a critical component.

<table>
<thead>
<tr>
<th>ELJ Sites</th>
<th># of ELJs</th>
<th># of bend jam ELJs*</th>
<th># of ELJs Lost</th>
<th>Exposure to Flood(s)**</th>
<th>Return Int.</th>
<th>$Q_{\text{Max}}/Q_{\text{BKF}1.1-1.2}$</th>
<th>Tortuosity Rc/Wbkf</th>
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<td>12</td>
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<td>64</td>
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* ELJs lost due to exposure to flood(s)**

** Magnitude of flood(s)**

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* ELJs lost due to exposure to flood(s)**

** Magnitude of flood(s)**
Conclusions - Summary of Projects

- Of (38), 66% are still present. Most have been through high flow events.
- Of the 26 structures remaining there are 4 at risk e.g. substantial erosion scour & potential flanking.
- Of the 26 remaining structures: 14 have convergent low flow conditions. 3 were constructed on a point bar, 4 are apex bar jams, 6 other.
- South Fork of the Nooksack had the best match between stated objectives and results.

$Rc/W_{bkf}$ (curvature tightness) is a major factor regarding loss, avulsion, number and kinds of structures needed.

Based on stage 1 findings – ELJs placed in banks for protection are highly susceptible to avulsion and secondary flow currents at the key
Appreciation to:

- Elwha Tribe – Mike McHenry and Participating Crew
- Wildfish Conservancy – Mary Lou White
- Nooksack and Lummi Tribes – Greg Dumphy and Mike Maudlin
- USFS – Cowlitz Ranger District – Terry Lawson and Ken Wieman
- Jefferson County Road Department – Mark Thurston and Bruce Laurie
- Cowlitz site- Tim Lofgren and Greg Arkle
- Kristi Yasumiishi – Autocad Specialist - NRCS
Thank you
“Nos eat fructus ex nemus at alius por nos have sero.”
Questions?