Upper Green River Timber Pile
Anchored Engineered Log Jams:
Successes and Challenges

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Presentation Overview

- Project Purpose
- Project Setting
- Design Development
- Construction
- Pre-Post Construction Comparisons
- Conclusions
Upper Green River Project Area

RM 64: HOWARD HANSON DAM

RM 84: LESTER TOWN SITE
Project Purpose

- **MITIGATION**: City of Tacoma and USACE plan to increase size of reservoir to store water for municipal and industrial use.
  - Higher pool will kill riparian vegetation and destroy fish and wildlife habitat.
  - Must be in place before additional water can be stored.
  - Fish passage through dam is largest restoration effort in watershed.
Setting, Climate, and Hydrology

- West slopes Cascade range
- Closed watershed, jointly managed
- Impacted by past logging activities
- Marine influenced: cool and wet (heavy rain)
- Annual average stream flow ranges from 300-1100 cfs
- Floods occur November through February
- November 2006 event broke all-time storm totals for rainfall, but ranked 4th largest flood.
- Howard Hanson dam controls almost 50% of basin, providing significant flood protection for the Seattle metro area

Geology

- U-shaped valley
- Volcanic rocks predominate
- Some older sedimentary rock exposed in places
- Glacial/fluvial deposits on valley floor
- Isolated bedrock outcrops
Humphrey Site, Near RM 71

Welcher’s Field Site Near RM 74
North Fork Green River

Good news!...old piles spotted at Maywood Site near RM 75
6-mile Washout Site near RM 82

Lester Reload Site, near RM 84
Design Process

- Field-proof previous studies and conceptual designs first
- Refine site objectives based on existing conditions
- Analyses (suitability, design flood, risk, H&H, etc.)
- Site selection
- Hydraulic design
- Only 95% plans and specs
- Tech review and refinement
- Design for Construction

Analysis...The Fun Part!

- Site Suitability/Geomorphology
- Constructability
- Risk
- Hydrology and Hydraulics
  - How much data do we need? Can we get LiDAR?
  - Models? Schedules? Stream gages?
- ELJ Stability
  - 50-year design flood, 1.25 minimum safety factor of design
  - This is a low safety factor—projects are likely to fail during the design flood
Hydraulic Design

- After calibrating hydraulic model,
- Compare hydraulic profiles for base and with project conditions (model as obstructions, roughness, and ineffective flow)
- Assume debris dimensions—better yet, measure them in field
- Estimate scour depths—better yet, measure them at existing jams
- Determine anchor requirements
- Refine location, size, and design as needed

Critical Design Assumptions

- Protecting water quality in Class AA river requires minimizing excavation
- Need for longer term performance requires engineering
- Install habitat in wide area to affect reach scale change, and take advantage of chance
- Small structures will get big with time and self stabilize
- Geomorphically flat and wide reaches will be natural deposition areas, and will thus be suitable for ELJs, and pile driving
Rapid Hydraulic and Geomorphic Suitability Assessment

- Quick GIS/Hydraulic Analysis
- Slope breaks
- Bankfull width vs. Floodplain width
- Depth & Velocity
- Presence/Absence of woody debris
- Etc.
When looking for opportunities, LISTEN TO NATURE

RM 2: Upper North Fork Green River
RM 74: Welcher's Field
RM 64: HHD
RM 70: Humphrey
RM 75: Maywood
RM 81: Lester Road MP 5.5
RM 82: Lester Road MP 6
RM 84: Lester Reload
RM 80: Hot Springs Hotel
Project Challenges

- **Water Quality**
  - Strict water quality permit requirements (no more than 5 NTU above background)
  - Difficult to meet if in-water excavation required

**Impact = 3 - 10 x background NTU!!!**

![Graph showing turbidity levels with labels](image)

**Figure 33. Green River Pilot Project Turbidity Monitoring**
Project Challenges, Continued

- **Feasibility:**
  - No local pile driving contractors had experience in this type of river
  - Do we have a project?
- **Geology:**
  - Almost no subsurface data—Where is bedrock?
- **Design:**
  - USACE had not designed large engineered logjams or managed a restoration project of this scale
  - Relies on un-proven concepts

**Risk**

- Dynamic river with history of damaging floods
- River processes never fully understood
- Wood foundations and structural members will degrade with time
- Risk analysis indicated that infrastructure could accommodate failure of structures without significant consequences
- Design smaller structures with lower safety factors to conserve materials (living trees)
Risk Alleviation: Maywood Pilot Project

- Goals:
  - Determine if pile driving feasible at representative site
  - Get physical data to refine design parameters
  - Field test plans and specs
  - Learn from river

Maywood Pilot Project - February 2005, after flood
Maywood Pilot Project Results

- 10 of 10 piles driven to or below 12’ minimum depth, no piles more than 18’
- Water quality impacts minimal
- Heavier driving equipment should be specified
- Designs needed to shift scour away from piles
- Debris accumulation and pool formation rapid

2005 Project

- 10 Sites spread out over 20 river miles
  - 29 Pile anchored ELJs at 8 sites
  - 141 driven timber piles
  - 6 Boulder/ballast anchored ELJs
  - 9 loose wood jams
  - 96 loose logs with rootballs
  - Beaded ponds
- ~$1,000,000
- 2 months to construct
Typical Construction Sequence

- Build access roads
- Drive Piles
- Build Jams
- Clean Up Site

Upper Green River Pile Driving

- North Fork
- Humphrey
- Welcher’s Field
- Maywood
- Hotsprings
- Lester Road MP5.5
- 6-mile washout
- Lester Reload
- Bio-diesel hammer
- 60-ft tall crane
- Service truck
- Crew of 4

Generous clearances and gentle grades needed to accommodate crane.

Hotsprings RM 81

Welcher’s Field, RM 74
• Untreated timber piles
• “Class A”
• 30-40 ft long
• 13”-18” diameter butts
• Banded tops
• Pointed tips with driving shoes

Pile staging area, Welcher’s Field, RM 74

Preparing the tip
Stream crossings at low speed generate low turbidity

Welcher’s Field, RM 74

However, at high speeds, it’s a different story!

Humphrey Site, RM 71


- Piles difficult to keep vertical
- Throttle down drop height of hammer to limit skewing
- Throttle up drop height to get through dense layers
- Driving effort is high in course bed rivers

**Pile Depths Can Be HIGHLY Variable**

Designs must be able to accommodate REALITY.
Pile Depths Can Be HIGHLY Variable

### 2005 PILE DATA

<table>
<thead>
<tr>
<th>Description</th>
<th>Number</th>
<th>% of total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tota piles driven</td>
<td>141</td>
<td>NA</td>
</tr>
<tr>
<td>Piles not driven to minimum depth</td>
<td>11</td>
<td>8%</td>
</tr>
<tr>
<td>Piles driven above minimum Depth</td>
<td>130</td>
<td>92%</td>
</tr>
<tr>
<td>Piles driven to design depth</td>
<td>49</td>
<td>35%</td>
</tr>
<tr>
<td>Piles with split tops or skew</td>
<td>39</td>
<td>28%</td>
</tr>
<tr>
<td>Piles Broken During Installation</td>
<td>3</td>
<td>2%</td>
</tr>
</tbody>
</table>

Designs must be able to accommodate REALITY

Smaller bed material equaled design depth!

Hot Springs Site, near RM 80
…But not 500 ft downstream???

Hot Springs Site, near RM 80

We have a problem…rock encountered at < 10 ft

Humphrey Site, RM 71
Implement Additional Stability Measure—Pre-drill to Design Depth

Pneumatic down-hole hammer drill bit
Drilling is efficient, but, holes start to fill in with gravel. Rock dust turns to slurry if water encountered...

Only 2 of 8 piles successfully placed in pre-drilled holes—We abandon pre-drilling.

Tough Luck!
Pile tops split about 28% of time due to heavy driving conditions, (215-1,034 blows to depth)

Partly combusted fuel, lots of “precipitation”

100% Bio-diesel required

Water Quality Protection
Running out of piles and improvising...

...Unfortunately

...It didn’t work.
2005 Water Quality Data

- Only two exceedances above background
- Pile driving considered successful BMP

![Water Quality Impact During Construction, 2005](image)

Water Quality Impact During Construction, 2005

![Chart showing water quality impact with two samples exceeding 5 NTU limit](chart)

2 of 167 samples exceeded 5 NTU limit
PRE-POST CONSTRUCTION COMPARISONS

- RM 80, 6-Mile Washout
- RM 70-71, Humphrey Site

Successes: 6-Mile Washout

- Forest Service Road eroding for several years
- Slope ~ 0.4%
- Width ~ 150 ft
- Q 2 ~ 4,400 cfs
- Q 100 ~ 23,000 cfs
- Goals
  - Increase pool area by adding ELJs and LWD
  - Reduce bank erosion
  - Maintain existing habitat
6-Mile Washout, 2002

Washout

Type 2 ELJ

Type 1 ELJ

Meander jam

6-Mile Washout, 2005 Project
6-Mile Washout, 2005 Project

Open areas to trap mobile wood

Remains of old revetment used to anchor logs

6-Mile Washout, 2005 Project
6-Mile Washout, 2005 Project

Thalweg shifted, large pool formed

6-Mile Washout, 2006
6-Mile Washout, 2006

Deposits on outside of bend

6-Mile Washout, 2006

Flow returns to center of channel perpendicular to logs
35

6-Mile Washout, 2007

Pool area increasing?

Deposits on outside of bend increasing

6-Mile Washout, 2005-2006

Large pool

New gravel bar

Large pool

100 Feet
Erosion rate reduced. Deposits on outside of bend

Channel shift to inside of bend

No failures in November 2006 event

**6-Mile Washout, 2005-2006**

**Challenges: Humphrey Site, RM 70-71**

- Slope ~ 0.5%
- Width ~ 175 ft
- Q 2 ~ 8,800 cfs
- Q 100 ~ 34,000 cfs
- Goals
  - Increase pool area by adding ELJs and LWD
  - Increase channel length
Humphrey Site, 2005 Project, Type 1 ELJs

Gravel storage

Low-tech, No lashings

Nice pool

Humphrey Site, Type-1 ELJ 2006
2007, Where did the Type 1 ELJ’s go?

Humphrey Site,
Type 4 ELJ,
2007
Significant aggradation and meander migration

Project Performance Trajectory

• Good-76% of pile based structures are intact and functioning, despite major flood event
• Significant amount of geomorphic response has been observed
• Rough estimates indicate that pool area mitigation targets may have been met
• Except in one case structural failure was partly attributable to shallow pile depths
• Dynamic debris loading appears to be an issue for small structures
Conclusions

- Pile driving generated very little turbidity and can be considered a BMP for ELJ work
- Timber pile driving is possible in steep cobble/boulder bed rivers, BUT
- Need to account for uncertainty in subsurface
- Flexible design/build approach needed
- Geomorphic responses are variable and rapid
- Jams act as roughness elements and obstructions—response can be reach-scale and is hard to predict
- Projects will be require more monitoring to validate design assumptions

Thanks!

- City of Tacoma
- CDM Constructors
- McDowell Northwest Pile Driving
- Bremeyer Logging
- American Pile Driving Equipment
- Washington Department of Fish and Wildlife
- Washington Department of Ecology
- Muckleshoot Indian Tribe
- Tetra Tech ISG
- HDR/Geo-Engineers
Helpful Design and Planning Resources

• Stream Habitat Restoration Guidelines (SHRG) September 2004

• Integrated Streambank Protection (ISPG) Guidelines April 2003
  – Washington Department of Fish and Wildlife
  – Washington Department of Transportation
  – Washington Department of Ecology
  – http://wdfw.wa.gov/hab/ahg/