Functional requirements and design parameters for restocking coarse woody features in restored and enhanced wetlands.

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ABSTRACT:
For many years landowners, biologists, engineers and others removed large woody materials such as logs, rootwads and stumps from wetlands, floodplains, and streams of the western United States and Canada. By the early 1970's scientists and engineers began to recognize the critical roles that wood plays in the life cycle of fish, amphibian, small mammal and bird species. Removal of wood greatly decreases the carrying capacity of wetlands and streams for many of the species currently protected under the Endangered Species Act. In recent years, creation, restoration and enhancement of wetlands has become common practice. Little consideration has been given to woody debris and other structural habitat in wetlands. This paper discusses functional objectives, common constraints, and design parameters for restocking woody habitat features in wetlands. Examples of completed projects from ELWd Systems are used to illustrate design parameters.

Background

In recent years, the ecological significance of wetlands has come to the forefront of conservation efforts throughout the United States. Wetlands have not always been looked upon as valuable and productive resources. In the past, wetlands were viewed as vast wastelands that only provided a breeding ground for mosquitoes, flies and unpleasant odors (Payne). Many people felt that wetlands were places to be avoided or better yet eliminated. It was common practice to drain and fill wetlands for other uses, such as farming or urban development. The federal Government even encouraged land drainage and wetland destruction through a variety of legislative and policy instruments (Dahl, 1997). These attitudes and practices have contributed to an estimated loss of more than half of the wetlands that once flourished in the United States (Dahl, 1997).

Destruction of wetlands for agricultural uses, urban development, and changing land use practices has drastically depleted the abundance of wetlands. Eighty-one percent of the terrain that originally supported bottomland forests (forested wetlands) in the United States has been converted to other land uses (Clewell, 1990). Farmers found that wetlands offer rich organic soil that provides their crops with the nutrients needed to produce blockbuster harvests. Urban sprawl has also played its part in diminishing wetland acreage. Urban development consumes wetland habitat and isolates the remnant wetlands, making it difficult for wildlife species to move between wetlands. Kunz et al. (1988) observed in Washington State that the highest number of wetland impacts coincided with the counties of highest population and proximity to water bodies. Prior to wetland mitigation practices, cities were free to expand at will with no regard to wetland habitat destruction. These practices caused an estimated loss of 550,000 acres of wetlands each year from the mid-1950's to the mid-1970's (Office of Technology Assessment, 1984).

Overwhelming losses of wetlands throughout the United States has lead many wetland advocates to call for increased wetland restoration and creation in many states. Given the loss of wetlands within the Pacific coastal zone, the relative isolation of wetlands, and the frequency of catastrophic events, the remaining systems gain importance for their rarity, rather than their abundance (Onuf et al. 1978). Wetlands provide critical habitat for species during specific history phases, e.g., larval stage, breeding, nesting, and wintering. One cannot measure value simply by determining productivity or contribution to the food chain, but must consider that many species have been eliminated or severely reduced in number due to lack of wetland habitat during certain periods of their life history (Josselyn, 1990). Destruction of forested wetlands has also jeopardized many functional services they once provided, including: timber production, flood abatement, food chain support, improvement of water quality through nutrient and pollutant filtering and organic mater transformations, sediment retention, wildlife and endangered species habitat and others (Clewell, 1990).

Over the last three decades there has been increasing awareness that wetlands are valuable areas providing important environmental functions (Dahl, 1997). Wetlands provide a number hydraulic, biochemical and habitat functions (Table 1). Along with these functions, wetlands have many important recreational benefits as well. A growing number of users include: bird watchers, photographers, outdoor enthusiasts, artists, teachers, fishermen, and hunters. Local and Federal Laws such as the Emergency Wetland Resources Act of 1986 have helped to reestablish and protect wetlands throughout the United States. The U.S. Fish and Wildlife Service (1991) has estimated that about 90,000 acres were added to the Nation's wetland inventory between 1987 and 1990.

Table 1: Functions of Riverine Wetlands (Adapted from Brinson et al., 1995)

Hydraulic	Provide Dynamic Surface Water Storage - Long-term water storage - Subsurface storage of water - Energy dissipation - Moderation of groundwater flow and discharge
Biochemical	Provide Nutrient Cycling - Removal of elements and compounds from water - Retention of particulates and sediment from flood flows - Export organic carbon to water
Plant Habitat	Maintain Characteristic Plant Communities Maintain Character Detridal Biomass
Animal Habitat	Maintain Spatial Habitat Structure Maintain Interspersion and Connectivity Maintain Distribution and Abundance of Vertebrates and Invertebrates

Due to staggering losses in wetland area since the arrival of European settlers, restoration efforts have begun to take place across the United States. Because some wetland basins are better candidates for restoration than others, guidelines for prioritizing sites is needed. In addition to selection criteria, design guidelines must also be established.

Function of CWD in Wetlands

In areas that traditionally had a lot of forested and semi-forested wetlands, coarse woody debris plays many important roles. Coarse woody debris (CWD) helps facilitate many of the functions native wetlands provide. Table ____ details many of the functions of CWD in forested wetlands.

Table___: Functional roles of CWD in wetlands

Small Animals	Large Animals	Plants	Geomorphology	Hydrology
- Sites for Nests, dens, and burrows - Hiding cover for predators - Protective cover for prey - Lookouts for predators and prey - Travel-ways across forest floor, snow, etc. - Refugia during hot/dry and cold/wet weather - Cache and feeding space	- Shelter from inclement weather - Shelter from predators - Den sites - Provides a place for concentration of prey - Ants and termites provide food for woodpeckers and other birds	- Carbon source for microbial food web - Fungi and other microflora provide protein for small mammals - Holds moisture plants need during dry summer months - Provides substrate above the water table for plant and fungi colonization	- Stores sediment - Stimulates terracing of slopes to store fine organic debris, water and minerals - Improves shoreline stability	- Increases water storage/ infiltration - Absorbs water energy during high water events - Decreases risk of flash floods - Filters particulate and organic matter from the water

Often overlooked in wetland restoration is the need for complexity and structure. Many restoration and enhancement designs neglect the functional roles woody structure plays in these systems. The design of wetland rehabilitation projects is often very good at including plant and landscape features, but often overlooks the need for woody structure. Factors, including limited access, inability to use machinery, and threat of habitat destruction by heavy equipment can play a role in limiting CWD placement in wetland areas. Other inhibitors to placing CWD, including past plantings or rehabilitation efforts, can be a significant factor in the decision to continue wetland enhancement or abandon ideas for placement of woody features. The problem with this solution is that it may be years or even decades before many of the important functionalities down wood provides in wetlands are achieved. These constraints are a major reason for the lack of CWD in previously enhanced wetlands.

What is CWD?

Stumps, snags and down logs are the three main types of coarse woody debris found in wetlands. Stumps are typically 2-6 feet tall and snags are greater than about 8 feet. Down woody debris Although functionality begins at around twelve inches in diameter, pieces down to three or four inches in diameter are considered CWD. Large logs are those greater than twenty inches. Bull et al. (1999) suggest that minimum diameter should be fifteen inches in diameter at the large end to be of use to small mammals.

In response to the obstacles restricting CWD placement in wetlands an engineered alternative has been developed to supplement the wood supply until riparian and wetland plantings can deliver woody material on their own. This newly engineered solution allowing CWD placement in restored wetlands provides an opportunity for increased enhancement and immediate functional returns without degrading the wetland. **Appendix 1** gives a detailed description of the design processes used to create an engineered CWD alternative to native CWD.

Assessment of Installed Projects

ELWd Systems has recently completed projects installing a total of 67 engineered woody debris structures in wooded wetland and wetland pond areas. These two projects can be viewed as models for future work in enhancement of coarse woody features in wetlands. Project sites have been visited frequently since installation for monitoring, visual inspection, project completion, and photographic records.

The Magnusson Wetland project included thirty-two ELWd® habitat structures. Historically this site was a forested wetland within the channel migration zone of Newaukum Creek. For most of the past century, the site has been maintained as pasture and hay land, which is now being planted with native trees, shrubs, ferns, etc. as off-site mitigation for development within the city business area. The functional objectives for adding woody structure to the wetland include: (1) perches for ground-nesting birds, raptors, and small mammals; (2) nesting and cover for amphibians, birds, and small mammals; and (3) nurse logs for semi-aquatic vegetation to increase biodiversity on the site. Nine of these structures are upright stump replacement structures and the remaining twenty-three were installed as nurse logs. These structures were packed with a compost soil mix and planted with native plants. The structures were placed in low areas and small man-made ponds to provide habitat in seasonally ponded places. An ongoing monitoring program is currently being developed to look at survival rates of natives planted within the nurse log structures versus those not planted in nurse logs.

The Golden Gardens Park project included twenty-five ELWd® hollow log structures and one prototype floating raft. Twenty-three of the structures were used to line 150 linear feet of bank along the pond margin to inhibit the severe erosion caused by wave action and waterfowl. The hollow ELWd® structures were placed end to end, filled with rock and a compost soil mix, anchored in place with Duck-Bill™ drive anchors, and planted with native wetland and aquatic plants as a bioengineering alternative to other bank hardening methods. The remaining two ELWd® logs and the floating raft were tethered to buckets filled with gravel and floated in the pond as complex refuge and basking areas for amphibians, turtles and waterfowl in the wetland pond area.

The Davis wetland is part of a watershed restoration and demonstration project. The nine ELWd® structures were installed in the wetland as a demonstration of wetland restoration products from ELWd Systems. Other portions of the demonstration include products for river restoration, fire rehabilitation, lake and pond enhancement and pond margin erosion control. Structures in the wetland will provide habitat for amphibians, overwintering sites for small mammals, and perches for birds. One of the structures is a nesting stump designed to provide nesting habitat for larger birds such as geese, other waterfowl or raptorial birds. The other eight structures were a random mixture of upright stumps and horizontal logs. The logs were placed in one of three ways. Some were filled with compost and planted with native plants, others were filled with wood chip for amphibian habitat, and the remainders were left hollow for small mammal nesting and refuge sites.

Conclusions

Engineered CWD has proven to be a functionally effective means of restocking coarse woody features in wooded wetland enhancement and restoration projects. After initial evaluations of the 67 ELWd® structures it seems that they have made an immediate impact on the ecological health of the wetland systems. Observations of turtles, birds and amphibians using ELWd® structures for refuge, basking, and perching shows that immediate positive impacts can be made in wetlands with minimal physical impact on their fragile environment.

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Appendix 1: Design of Engineered Large Woody Debris

The Appreciative Design process (Dooley and Fridley 1996) was followed to create a CWD solution that may be preferred for many stream, wetland, lake and upland situations. Appreciative Design is a structured process to search for a best-set solution to technical and organizational problems. The Appreciative Design process is a significant extension of the hierarchical axiomatic design methodology of Suh (1990; 1995). Suh's axiomatic design was modified through the addition of stakeholder ownership of constraints (McIntyre and Higgins 1989), and includes many features of the Soft Systems Methodology developed by Checkland (1990).

In order to perform identified functional requirements, any specified native or engineered CWD solution would need to have design attributes such as the following:

- Cross-section and length that are proportional to historic and native wood
- High surface roughness, crevices, and crannies
- High physical surface roughness to trap sediments, debris, etc.
- Maximum surface area to cross-section area ratio
- Natural appearance after placement to blend with the wetland scene
- Natural appearance of components and debris when the structure fails, breaks-up or decays

In addition to physical parameter constraints there are a number of stakeholders who contribute constraints to the design process. Such stakeholders are termed "constraint owners."

Client Constraints

- Competitive installed cost compared to native CWD
- Low cost for placement (less equipment rental cost is better)
- Lasts long time (lower maintenance cost is better) (lasts until riparian silviculture begins to deliver)
- Applicable to sites with difficult access and are sensitive to the use of large equipment (install with hand crews is better)
- Placement does not damage the wetland ecosystem (lower risk of damage is better)

Fisheries Enhancement Contractor Constraints

- Manufacture from readily available materials (smaller diameter components is better)
- Low tech manufacture (product value does not warrant expensive manufacturing process)
- Easy to train crews to install (lower information content is better)
- Minimize risk liability claim from high water failure in flashy systems (less risk of damage to property & public works)

Volunteer Coordinator Constraints

- Maximum number of structures per grant dollar (lower requirement for rental equipment and operators is better)
- Need to separate volunteers from mechanized equipment operations (install with all hand labor is best)
- Maximize volunteer participation in meaningful part of projects (volunteers putting structures in wetland is better than volunteers doing cleanup after machines do the habitat work)

- Easy logistics to prepare for volunteer events and work days (stage kits of lightweight materials is better)

Environmental and Recreational Special Interests

- Materials are all organic and similar to native materials
- Avoid steel, plastics and other unnatural materials
- Structures look like they belong in the natural environment (better aesthetics)
- Debris from failed structures looks natural in the wetland environment

Materials Supplier Constraints

- Utilize non-merchantable or low value raw materials
- Utilize readily available raw materials

Regulator and Public Agency Constraints

- Natural materials (no car bodies, concrete, tires, asphalt, etc.)
- Does not increase flood height (less flood impact is better)
- Does not increase risk to public works (bridges & culverts) over native CWD risks (lower risk is better)

The current design of engineered large woody debris as manufactured by ELWd Systems company is an "optimal" solution to the design problem as characterized above. The fundamental element of an ELWd® brand engineered CWD structure is to create a hollow cylinder by assembling even numbers (pairs) of small diameter logs into a hollow tube or truncated cone (Dooley 1998; Dooley and Paulson 1998). The central cavity inside the ELWd® structure can be filled with wood chips or compost to provide habitat and support plant growth.