BIOENGINEERING REVIEW OF THE PACIFIC NORTHWEST THAT IS APPLICABLE TO CHENA RIVER WATERSHED WHITE PAPER DRAFT

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For

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ACKOWLDEGMENT

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PURPOSE AND GOALS

The purpose of this document is to provide a summary of the literature provided to Tanana Valley Watershed Association based on a literature search pertinent to this White Paper. The paper highlights key ideas, concepts, and information needed for future bioengineering projects.

DISCLAIMER

The document as follows is not from an exhaustive literature review but of a comprehensive literature compilation. This is document is intended for information purposes.

INTRODUCTION:

DEFINITIONS:

Specific keywords or terminology are often associated with river ecology and bioengineering. Riparian zone, or riparian area, as mentioned above, is the interfaces between land and riverine systems. An extension of this area from the channel's banks toward the valleys that often experience flooding are considered floodplains, which formed from a meander that erodes sideways of the land as it travels downstream. The lands of which water drains off of and into bodies of water enclose riparian zones and floodplains to form its watershed.

If this network was to include living organisms – plants, animals, microbes – the classification would be much larger of a community interacting with its nonliving, or abiotic, components to create an ecosystem. The energy that flows from an ecosystem is sourced from the sun. The interactions of the community provide functions called ecosystem functions that capture the exchange of energy, nutrients, and processes biomass. Biotic, or living, entities establish complex interdependencies in or with ecosystems that are coined emergent properties, which are unpredictable when considering just one component apart from the whole. Ecosystem functions include nutrient cycling, soil development, and microregulation as with water budgeting. The services provided from these functions that benefit mankind, such as products like drinking water and processes like decomposition. Four distinct groups separate categorical ecosystem services into provisioning, regulating, supporting, and cultural. The protection and maintenance of such services are critical to organismal survival.

Thus, managers may see the need for returning riparian areas or watershed into their former state, or repair their conditions, in order to recreate ecosystem services. In restoration of riparian areas, which is of interest in this paper, benefits also occur for salmonid communities and aquatic inhabitants like insects and plants, or conditions such as water quality and bank stability. Many techniques are available to promote habitats, bank stability, and alleviate erosive forces or erosion. Often plantings of trees, or grasses, are used in restoring banks to stability and habitat improvements that tends to be characterized as vegetative restoration, or soft banks. When structures, concrete, or large rocks predominantly dominate restoration efforts for erosion control, it is called bank armoring, hardening, or hard banks. Bioengineering is the mixture of hard and soft bank that enables the incorporation of techniques that take in the nature of stream dynamics while providing bank stability, habitats, and reduction of erosion. Bankfull relates to evidence of full stream height along the banks, width from bank to bank;

active channel refers to the point indications, usually vegetation, arises at height along bank or width from margins from bank to bank. These terms are used throughout the document.

PURPOSE OR SCOPE OF REVIEW:

The objective of this document is to provide a conclusive and supported portrayal of the information on various topics in order to allow the best decision on management to be made. The purpose is to guide decisions and improve the assessment, evaluation, and monitoring steps of the future bioengineering projects among the Chena River Watershed. Although information is collectively from locations within the USA and internationally, the main goal is informative instead of origin-specificity. Many useful and relevant information is provided in the Appendix.

BACKGROUND:

Streams connect and combine with various other waterbodies to create drainage catchments, or watersheds, that interact and depend on surrounding landscapes. The floodplains, stream margins, and vegetation along streambanks along with their root mass collectively provide shade canopy, bank stability, water purification, and habitat through downed trees, logs, and twigs (Clewell and Aronson, 2007; NOAA 2011, Iowa, 2006). The vegetation not only attributes to bank stability via roots but also reduces water flow through absorption of water as it approaches the catchment as an ecosystem function.

Restoring vegetation on streambanks is a common practice for this reason. It promotes habitat and enhances functionality of the stream in natural communities. In urban streams, however, bank stabilization and management practices incorporate hardening of banks opposed to vegetation because planners or management often do not want roads or houses to be undermined from the shifting channels (Clewell et al 2007, NOAA 2011, Iowa 2006). Thus, planting are not strong enough to face river movements and associated erosion, bank collapses, or bank undercutting of fast dynamic waters. Hence, vegetation is often incorporated with some degree of structure implementation through rocks or stones. Water quality is also emphasized in overall approaches to restoration and bank stability. The algae, moss, macrophytes, and insects that decompose leaves, wood, and dead organisms provide services and contribute to such nutrient cycling of the stream systems (Clewell et al 2007, NOAA 2011). This assists in water quality and stream health.

Chena River Basin is of particular interest for central Alaskans as an excellent focal example of what northern pacific communities face in challenges and restoration efforts. A concern of water quality and fish abundance, primarily chinook salmon, is in part due to early spring break-up. This earlier ice melt drastically contributes to runoff and pollution. In the face of increasing urbanization and development as well as the challenges of public education that are common in all parts of Alaska, many of these services and stream habitats have become impaired.

The idea of ecosystem service is applicable to salmon who are important nutrient fertilizers of the Pacific Northwest waterways and riparian areas. Salmon life history contributes to energy flow and nutrient cycling, especially within their natal freshwater streams. As Schindler et al. (2003) metaphorically states the services of nutrient cycling is a conveyor belt. In the process of decomposition of salmon, the nutrients released are ingested by both terrestrial and aqueous communities, which allow for growth. Anadromous (of freshwater spawning) salmon act as environmental engineers due to their redd digging that changes the pattern of water flow, alter stream bed composition, and disrupts bethic communities (Schindler et al., 2003). At times of flooding, salmon carcass adds nutrients within riparian zones, which is also available in marine or coastal zones as with an example of Californian wine country rivers (Schindler et al., 2003; Merz et al., 2006). Native riparian grapes are affected economically by dwindling salmon populations at all stages of their life cycles by the impairment of riparian health (Merz et al., 2005). This can be analogous to the declining salmon populations within Alaska's streams and rivers who indigenous peoples depend on for subsistence living as well as forested communities.

CHENA RIVER & WATERSHED:

The Chena River is part of the Tanana River Valley Watershed and has a vast number of plant species within its riparian zones that are inhabited by an array of wildlife and aquatic species within its river. Fish, like Arctic Grayling, also depend on Alaskan sloughs, as do the fisherman of the Interior. Five sloughs – Chena, Beaver Springs, Piledriver, Twentythree Mile, and Noyes – are rearing and spawning habitat for grayling, which four of these (Chena, Twentythree Mile, Piledriver, and Noyes) are listed as those important in migration of anadromous and resident fishes (Ihlenfeldt and Howard, 2006). These fish include: chinook, chum, round whitefish, northern pike, longnose suckers, slimy sculpin, Alaska blackfish, and arctic lamprey (Ihlenfeldt and Howard, 2006). Agencies and organizations have worked toward improving fish habitats on the Chena Slough, as the Chena Slough Technical Committee have, by replacing culverts at crossings that blocked fish passages flow (70 cfs) at nine road crossing surveyed in 2001 (Ihlenfeldt and Howard, 2006). Dams have been a complex issue, where they have impeded fish passage elsewhere and migratory fish species in the Chena and Tanana Rivers since the late 1980s (US Department of the Army Alaska District Corps of Engineers, 1998)

Other improvements have been on streambanks by using bioengineered erosion control structures, including impounding the Chena during high flows to minimize water flooding of the river (Rozelle, 2003). Practices used on Alaskan streams have been root wads, live stacking, brush layering, and coir logs for erosion (Karle, 2003). These structures have faced damages due to ice, which undermines toe protection, contribute to buoyancy effects, and failure of construction fabrics (Karle, 2003). With these considerations, riprap integration could provide additional strength; however, root wads and willow (for brush layer) cuttings show greater promises of bank protection, especially for boat wakes (Karle, 2003).

HABITAT, STREAMBANK, & FLOODPLAIN:

Streambanks & Habitat Assessments: Streambanks are essential components of riparian areas. Habitats are integrated along banks as well as sediment sources for the stream. Often, river classifications in studies, manuals, or documents use Rosgen Method of the 8 types of rivers, which can be seen in the appendix for more information, based on bankful and longitudinal profiling of the river (Hey, 2006). When streambanks become degraded or impaired, detrimental affects are felt throughout terrestrial and aquatic systems. The key for restoration projects to be successful is in the design of the project. Manuals, reports, articles, and documents indicate that the first step, like many, focuses on identifying issues and problems of the stream (Browne, 2001; Georgia Soil and Water Commission, 2011). A major source of impairment is attributed to stormwater runoff (Browne, 2001). Failures of banks lead to erosion from: increased discharge, faster flow velocity, smoothing channel gradients, loss of bank vegetation, reduction in lower bank materials, lowering of bed or widening of toe erosion, erosion elsewhere displacing channel water flow, and overbank flows (Georgia Soil and Water Commission, 2000). Based on the erosion types, categorization of specific categorical erosion include general bank scour, toe and upper bank erosion, local streambank and streambed scour, and overbank runoff (Georgia, 2000).

The next step is identifying constraints and communication with appropriate agencies, individuals, and organizations (Browne, 2001; Georgia, 2011). In doing so, time management and dates begin to form an evolving plan. For instance, consciousness of depositional zones along banks and structures along floodplains in the design of restoration projects or maintenance could avoid scouring of piers or abutments (Johnson, Hey, Brown, and Rosgen, 2002).

It is not appropriate and fitting to identify streambank conditions (Browne, 2001). At this point, the site should be critically assessed with information as follows: width, channel cross-section, longitudinal view, regular view, indicators of quality, habitat data parameters, basic information (soils, adjacent wetlands, slopes, vegetation present, etc), in-stream features, – i.e. woody debris, riffles, pools – and constraints (Browne, 2001; Flosi, Downie, Hopelain, Bird, Coey, and Collins, 2010).

The appendix provides appropriate watershed assessment forms, habitat inventory sheets and forms, and important stream passage surveys that can be used as templates for assessing and evaluating channel conditions compiled from literature. Important considerations when achieving successful restoration projects are meeting the criteria, whether it is for one or multiple target species (Flosi et al., 2010). Maps, datasheets, necessary tools or supplies, and data collection are critical for obtaining information and evaluating information on reach, stream, or site conditions.

The following successful restoration project step is evaluation of channel conditions and assessment then follows (Browne, 2001; Georgia, 2011). It is within this step that methodology and design for the stream restoration is developed. Bioengineering is common due to, when properly done, resulting toe protection, flow redirection or moderation, bank (middle and upper) stabilization, and surface protection (Browne, 2001). Studies indicate the importance of stress, velocity, and soil texture in the insurance of bank restoration success (Brown, 2001). The last two steps are to do calculations, such as velocity and shear stress, and begin monitoring (Browne, 2001; Flosi et al., 2010).

An older concept since the 1990s are incorporation of reference sites, or reaches, of which site selection, mapping, measuring, surveying, and measurables for monitoring are essential in comparing streambank and habitat conditions, as with before and after (Harrelson, Rawlins, and Potyondy, 1994). Studies have indicated the importance of fluvial geomorphology that mimics nature, incorporates strambank parameters, and ratios when considering resistance to flow and boundary conditions (Hey, 2006). Reference reaches are critical and very useful if the appropriate selection of site is selected to minimize scale issues with spatial scaling from origin site to other locations as well as for monitoring and river equilibrium (Hey, 2006; Rosgen, 1997; Rosgen, 1998).

Fish Habitat Specifics: Overall, these steps provide opportunity to restore habitats used by fish, such as salmon. Illustrated in literature, fish passages are major components to either impeding or killing fish populations like salmon at stream crossings, culverts, and possibly accessibility to other streams (Flosi et al., 2010). Thus, when considering passage design, implementation and monitoring for measurables like fish mortality aid in improving infrastructure or placement of colverts, passages, streambank restoration, and databases for habitats within specified channels. Barriers for stream passages for fish can be temporary, partial, or total that may be affected by flow conditions, and should be considered with restoration to improve overall fish habitats, populations, and streambank health.

An excellent fish passage blockage and conditions are shown in the Appendix, which indicate rapid water velocity, low stream level flow, lack of resting pool, and height to great for fish to jump into culverts impeded success of fish, like salmon, to travel (Flosi et al., 2010). Salmon is an essential part of Alaskan subsistence living and recreational fishing. Ecologically, salmon provide ecosystem services and food to both terrestrial and aquatic habitats. Restoring or enhancing fish habitats through understanding of land use practices and thalweg (longitudinal profile measured along the deepest part of the stream for streambed elevation) allow for greater assessment and monitoring that capture increases in fish densities like Chinook salmon populations (Mossop and Bradford, 2006). Increases in chinook density correlates to residual pool and mean maximium residual pool depth in mining locations, but loss of habitat quality and abundance of andronomous fish to such land alterations by humans like mining (Mossop and Bradford, 2006; Kreshner, Roper, Bouwes Henderson, and Archer, 2004).

There are characteristics that Flosi et al. (2010) for the California Department of Fish and Game highlight that aid in fish friendly crossings at culverts below:

- Width at crossing minimum as wide as active channel
- Culvert: 100-year storm flow pass <100% of culvert's height
- Crossing bottom buried by streambed
- Natural bed material accumulate along bottom of crossing
- Water, within crossing, bends smoothly at the surface without excessive drops
- No turbulence
- Streambanks (upstream and downstream) are stable at crossings

It is important to consider the life stages of fish, and their movements throughout their life cycle. Evaluation can be implemented to assure salmonid species are able to pass throughout their life cycle based on filtering (i.e. allowing certain fish at developmental stages to pass) criteria, which is available in the Appendix. Maintenance and risk of culvert failure should be considered as well as the channel's conditions. Thus, minimizing stream crossings would minimize backwaters and bed materials being deposited upstream among other constraints on fish passage from culverts (Hoffman and Dunham, 2007; Bates et al., 2003).

Other considerations for riparian habitats should be in colonizers, recolonozation succession, organization, and tolerance or resistance and resilience that incorporate biotic communities, which a 28-year study at Wolf Point Creek, Glacier Bay, Alaska indicated (Milner et al., 2008). The importance of this acknowledgement helps promote ecosystem services, functionality, and enhancement of habitats. For instance, a Whiteway, Biron, Zimmermann, Venter, and Grant (2010) meta-analysis study showed that on average of the 6,000 instream habitat improvements was between $20,000 to $36,295. This study indicated that a significant increase in the parameters of 211 projects increased salmon density (73%) and biomass (87%), which habitat size increases also increases salmonid population increase in size (Whiteway et al., 2010).

Many studies have showed benefits in fish biomass, such as various salmon species, populations, quality of the environmental conditions, habitat and LCW, and invertebrate (macro and micro) from habitat improvements and bioengineering or bank restoration and rehabilitation (Baldigo and Warren, 2008; D'Aoust, 1998). For instance, juvenile coho salmon fall size could predict smolt size and overwintering location where higher spawning coho in spawning and rearing high growth rates resulting in bigger smolts in improved winter and forging habitats (Ebersole, Wigington, Baker, Cairns, Church, Hansen, Miller, et al., 2006). The installations or structures with vegetation enable seasonal habitats and critical overwintering refuges, which addressing sliding risks and design approaches can reduce the potential failures (D'Aoust, 1998).

Floodplain & Watershed Specifics: Scale, spatially and temporally, indicate complex systems and their interaction are interdependent that can be seen at watershed levels like sediment supply, bed load transport, water discharge, and anthropogenic activities (Habersack, Piegay, and Rinaldi, 2008). These sediment interactions influence wave, erosion, morphology, and bed texture as well as ecological responses to such changes (Habersack et al., 2008). To remedy this situation, many times dams aimed to control sediments and gravel mining in floodplains and watersheds; however, more needs to be done on fluvialmorphologic and ecohydraulic aspects or effects of reservoir operations with restoration of fish habitats within watersheds and floodplains, such as an ecosystem approach used in dredge-mined floodplains (Habersack et al., 2008; Bellmore, Baxter, Ray, Denny, Tardy, and Galloway, 2012). At the watershed or floodplain scale, habitat protection, connectivity, and restoration practices of habitat enhancement as or salmonid spawning and rearing should be considerations prior to monitoring (Cramer, 2012). Strong linkages between habitat quality and presence within basins and watershed exists with land management practices an andronomous fish as indicate in 62 references watershed, which also has been seen in southcentral Alaska with juvenile coho salmon of biofilm and analog additions (Kershner et al., 2004; Martin, 2007).

A trend of studies in enhanced emergent wetlands contained water controlled structures providing fish emigration and longer rearing hydroperiod where coho salmon 1 year or younger were common and comparable in growth rate and survival with other side-channel rearing studies (Henning, Gresswell, and Fleming, 2006). From the study in emerging wetland, floodplain areas, survival of coho salmon was dependent on path to river prior to water quality decreases, and enhancement to freshwater wetlands through water control structures benefited juvenile salmonids growth, survival, and emigration, short term (Henning et al, 2006). Similarly, Chinook salmon summer microhabitats and yearlings or younger follow the same pattern as coho salmon within pools and runs habitat types within watershed riverways (Holecek, Cromwell, and Kenndedy, 2011).

Overall, off-channel aquatic habitats are important as well as in-shore for food, habitat, and salmon production and redd, i.e. sockeye salmon, which spawning and species survival are at stake with the diminishing of floodplain habitats (Hall and Wissmar, 2004). Floodplains are significantly different and are important to Chinook salmon growth as well as river diverse complexity (Jeffres, Opperman, and Moyle, 2008). Jeffres et al. (2008) shows this in his study of the Cosummes River where flows of water high showed little growth and high mortality, whereas flows that were low had fish with rapid growth, unless in tidal locations that influences habitat below floodplains that displaced fish. Increases or improvements were not just in natural sites or project types in-stream, but also in constructed as with coho salmon in size and density; in- and off-stream showed greater results than pond-type side channels, optimized below 5,000 – 10,000 m^2 (Roni, Morley, Garcia, Detrick, King, and Beamer, 2006; Rosenfield, Raeburn, Carrier, and Johnson, 2008).

Urbanized locations, the major contributor to degradation of floodplain communities and functions, can improve or reestablish such situations through flow patterns, flow systems, and address sources of pollution in order to improve biotic communities in these areas (Booth, 2005). Salmon redd selection are frequently dependent on substrate and waters depth, fitting the criteria of upwelling water areas with gravel or cobble substrate in 10-80cm water depth (Hall and Wissmar, 2004). The failure in the function of the riparian floodplains and reduction in wetland function contribute to the impairment of fish habitat as well. The need for improvement at a watershed level is possible through rehabilitation, restoration, or other practices involving bioengineering that improve river diversity and terrestrial wildlife.

BIOENGINEERING & OTHER PRACTICES:

Bioengineering can be viewed in three ways, which are preferred, acceptable, and discouraged, and are strongly dependent on streambank and channel conditions as well as the causes of erosion. Improvements to streambanks and habitats with bioengineering practices have shown positive results for water quality, salmon populations, and benthic macroinvertebrates (Selvakumar, O'Connor, and Struck, 2010; Smith, Bumstead, and Brannon, 2008; Sudduth and Meyer, 2006; Admiraal, 2007). Major causes of erosion are steeping of stream banks and fluvial activity, which the focus on alleviation should be on the causes of fluvial erosion and weaker layers of sediment to reduce erosion rates (Admiraal, 2007).

Table 1 depicts these categories and describes the various practices:

TABLE 1: RESTORATION PRACTICE PREFERENCES (Georgia, 2000; Danot, 1995)

Restoration Practice	Method Preference	Description	Advantages/Disadvantages
Live staking	P	Living, woody plant cuttings rooted when inserted into the banks called stakes, often willow species	Stabilizes streambank or shoreline; Provides riparian habitat
Live fascines	P	Bounded live branch cuttings that are buried into banks and dtiches along the contours of the slopes, like willow species, with at least	Stabilizes streambank or shoreline; Provides riparian habitat
Branchpacking	P	Alternating layers of live branch cuttings and soil compaction or gravel layers within holes, gully, slump, or	Stabilizes streambank or shoreline; Provides riparian habitat

		depressions often with stakes (5 to 8ft long)	and restore sever bank damage
Vegetated geogrid	P	Use of branchpacking with natural or synthetic geotextiles* materials are wrapped around soil between the layers of live branch cuttings and soils along trenches or banks (vegetated palisades similarly in trenches – plants driven in soil side by side to form a fence of a wish-bone pattern	Stabilizes streambank or shoreline;
Brushmattress	P	Combination of live branch cuttings, live stakes, and live fascines above normal stream flow	Covers and stabilizes streambank or shoreline secured place
Coconut fiber roll	P	Flexible log made of coconut hull fibers, staked at toe of the bank, and mixed with native plants	Stabilizes streambank or shoreline; Sediment entrapment; Plant growth
Dormant post plantings	P	Rootable vegetative material placed along streambanks that are permeable as square or triangular patterns	Streambanks or shoreline stability
Joint plantings (vegetated riprap)	A	Tamping live stakes (deep rooted species) into joints or open spaces in rocks or stonewalls along slopes;	Increase stability of slopes of banks or shoreline
Live cribwall	A	Box-like structure with framework of logs or timbers, rock, concrete, steel, pr plastic and live cuttings that protect eroding streambanks or shorelines;	Vegetative cuttings mature to take over structural functions of the log and timber to promote habitat and bank/shore stability
Vegetated gabion baskets	A	Rectangular containers fabricated from heavily galvanized steel wire/triple twisted hexagonal mesh, wired to each	Stabilizes streambanks or shoreline

		other once in place, and filled with stones before being wired shut; vegetation is then incorporated into the rock at each layer between the rock baskets	
Tree revetments	A	Rows of cut trees anchored to toe of banks	Low cost method that is used for toe protection; can be used with other streambank restoration
Logs, rootwad, and boulder revetments	A	As indicated, a mix of logs, rootwads, and boulders selectively placed in or on streambanks	Streambank stabilization
Rock rip-rap	D	Rocks of various sizes designed for placement on the right bank slopes	Protect banks from wave and current action; Prolong life of embankment
Rock gabions	D	Can be with vegetation; stiffer box, or rolls, of wire and rocks or gravel along streambanks that intertwine living plants;	Purpose of stabilizing banks
Bulkheads and seawalls	D	Sterile, vertical, flat-faced object makes of sheet steel, concrete, or wood that are adjacent to banks	Reflect waves, high potential for erosion problems, structures and foundations tend to be at risk from erosive forces that can be allievated when rocks placed at toe of the wave impacts
* geotextiles are made of biodegradable materials – jute, kokos, wood-wool, reed, flax, synthetic fibers (cellulose) – used to stabilize loose topsoil layers			

With many of these restoration practices, the incorporation of large woody debris (LWD) potential may be one goal for habitat enhancement, which have been seen in macroinvertebrates as well as fish since the 1990s (Hilderbrand, Lemly, Dolloff, and Harpster, 1996). Gravel-beds improvements and incorporation in bioengineering projects as well as LWD have lead to increase in chinook salmon spawning sites (Kreshner et al., 2004). In situations where both sides of the banks had been vegetated, there were greater volume and magnitude of LWD (Bragg and Kershner, 2004). Once a design is selected, practices researched, and uncertainty addressed, the following considerations are universal for vegetation buffer, etc:

- Social and cultural aspects (consider urban-rurao-wilderness continuum) in populated areas;
- Diagrams, drawings, and data forms are essential;
- Erosion and sediment control plan are necessities;
- Gravel-bed rivers: consider resistance to flow and sediment entrainment into modeling, design, and ecology;
- Proper selection of plant species (2 years or older, 3-5ft minimum depth in ground), site location, placement, and material procurements;
- Rhizomatous and sucker species, ie cottonwood and willows, are commonly used in restoration as trees (6-16ft spacing apart), shrubs (3-8ft spacing apart), and creeping (1-3ft apart) with -0.6m to 2.5m above the low water level;
- Riparian vegetation (tree) management for maintenance and improvements of instream macrophytes, macroinvertebrates, and salmon productivity;
- Buffer, 30 m (100ft) wide, for native vegetation suggested on top of bank differing at base width (per one side): 100ft with 2ft per 1% of slope, 50ft with 2ft per 1% slope, and fixed 100ft; note, 50ft and 100ft buffer would require larger buffers; suggested 10 to 30 m (35 to 100 ft) of native riparian buffer for aquatic habitat, depending on scale, conditions, slope, wetlands present, etc.;
- Reducing impervious surfaces and establishes specific pollution management, which influences stormwater runoff potential.

(Darby and Sear, 2008; Habersack et al., 2008; Hoag, Berg, Wyman, and Sampson, 2001; Hoag et al., 2007, McCormick, 2010; Wenger, 1999; Admiraal, 2007)

The above bullet points revolve around condition, reach, stream, and habitat specific that involves both non-technical and technical structures with the intention to be multi-use for both aquatic and terrestrial organisms, wildlife, and for human appreciation.

Highlighted (preferred) bioengineering or restoration practices from Darby and Sear (2008), Donat (1995), and Flosi et al., 2010,

Root wads: requires a 10 to 24 basal area of trees above (wad) trunk length of 10 to 15ft; mats placedat toe of bank, which bank height 1 to 1 ½ times taller than bankfull heights, with rocks and boulders <1ton behind mats; anchoring is possible if long sections are intact with boulders, bedrock, or stable logs; *can provide fish habitat year-round depending on placement*;

Brushmats: willows or branches used shorter than 1.5m initially with their alignment at a vertical incline of 20°; bank should be smoothed so that willows, or native plant, has highest degree of soil contact; stakes driven (minimum of 2ft into bank) on 3ft centers along bank area for mattress and live willow branches laid on bank with butt ends in trenches (with branch length no shorter than 4ft, 1-2" diameters), with 20-35 branches per linear yard, to cover the upper bank area with one or more layers; tying of the layers, crossing branches, are placed horizontally

Geotextiles: the fibers (cellulose) of various weaves, strengths, and pore sizes important to be aware of that is indifferent to the fact that fine sediment over time enables water movement through it; generally hard to puncture and tear, and may be used together with logs bank structures to reduce sediment build up or flow under logs for added strength; *can be use as effective silt trap when constructing instream structures*

Fascines: Every meter is fixed with pegs with at least 5 rods braches, each with 1cm at front end of ditches, grooves, or along waterways;

Brushlayering: lifts soil for slops and embankment reinforcement along contours and terraces between layers of soil;

Any of these *could* be combined with v-weir, or w-weir, concepts and boulders, but always keep in mind fish filters that would prevent or restrict fish movement (*Note, logs will float if not anchored, tied down, or weight added*)

When considering species for riparian sites, ice flow or high velocity conditions considered suggest deep or rhizomatous root systems better suited (Hoag et al., 2007). Willows and cottonwood are excellent candidates, as well as fire and resprout resistant (Hoag et al., 2007). As part of the design, often planner craft the vegetation so that shrubs are below the trees at bank top of which provides shade to the stream and smaller plant species (Hoag et al., 2007). When bioengineering, armoring, or soft banks are inadequately installed at any level of the process, threats and alterations include lack of river evolution acknowledged, straightening, smoothing, discharges, and diversions leading to (Schiff, MacBrown, and Bonin, 2006). At times, restoration is unnecessary, which in these situations rehabilitations (sites initially impaired improves) or enhancement (sites are initially brought up to average) approaches are sufficient (Schiff, MacBrown, and Bonin, 2006). More information on bioengineering practices and techniques, including hard and soft bank, are provided in the Appendix.

Anchoring techniques are helpful in adding strengthen, longevity, and infrastructure to bioengineering methods. For instance, cable to boulder or bedrock is an option with polyester resin adhesive; however, cable is also able to connect to logs and root wads, either secured through or with use of notching materials (Flosi et al., 2010). It is recommended that site conditions and weather be considered in the design and decision of the anchoring methods. Logs and root wads may also be cabled to boulders and bedrocks, for example, with 1/2" to 5/8" cable and cable hook clamps (Flosi et al., 2010). Other combinations could include rebar, expansion bolts, trenching "key-ins", or deadman (buried 3ft deep stumps, boulders, and cable mix) in various combinations with or without cover structures – divide logs, digger logs, and mats (Flosi et al., 2010).

PRACTICALITY OF BIOENGINEERING IN ALASKA - *RESILIENCE & COLLABORATIVE COOPERATION*:

The importance of understanding stream ecology, riparian health, and monitoring are important to the resilience and resistance to community at the ecotone of aquatic and terrestrial interfaces. In situations of great or severe flooding, flow velocities, and environmental changes allow communities who have adapted to the condition prior to be resilient to such events. Many collaborative cooperation among agencies, individuals, educators, and youth are enabled and empowered to be active stakeholders in riparian streambank restoration. To better capture participants, many entities have explored better ways of reducing gaps in information and participations.

Evaluation and reviewing processes can be improved throughout the planning to implementation to monitoring stages. Failure prevention is often a positive outlook of such checklist or matric formats. For instance, guidelines – SMART (Specific, Measurable, Achievable, Relevant, Time-bound)- , project screening matrices, and project information checklist has been adapted by some organizations to fully capture all facets of the project (NOAA, 2011; Cramer, 2012). Analysis can be done with tools, like the River RAT (Restoration Analysis Tool), and software like InSTREAM), that captures stream ecology parameters and relationships (NOAA, 2011; Railsback, Harvey, Jackson, Lamberson, and US Forest Service, 2009; Cramer, 2012).

GAPS & CONCERNS:

The needs for long-term, large spatial scale application and research on stream ecosystem restoration are needed (Milner, Robertson, Monaghan, Veal, and Flory, 2008). This is also true for the lack of long-term monitoring of the effectiveness of in-stream structures, which is still considered to provide better habitat and increases for salmonid abundance (167%, 0.51 mean effective size) and biomass (162%, 0.48 mean effect size) at a smaller scale or short-term results following the bioengineering installations (Whiteway, Pascale, Zimmerman, Venter, and Grant, 2009).

It is also unclear, given the lag of research and publication or insufficient studies, as to the importance of seasonal floodplains to Chinook salmon (Sommer, Harrell, and Norbriga, 2005). Sommer et al. (2005) have established through their study that during winter – spring, the salmon and other fish were later in floodplain (outlet) diverse habitats comparatively to inlet. Thus, floodplains are valuable habitats chinook salmon growth, rearing and migration (Sommer et al., 2005; Sommer, Nobriga, Harrell, Batham, and Kimmerer, 2001). In terms of cold climate conditions, we see that a lag of published data is available on bioengineering structure to better suite the floodplain and habitat restoration seen in Alaska. Thus, more research is need.

CONCLUSIONS:

Large woody debris enhancement has shown to improve fish habitat, fish populations, and water quality through source or maintenance of organics and cover from predators and from streamflow of which has been known since the late 1990s; however, barriers to fish migration can occur or significant reduce of LWD when forested banks are harvested that reduce overwinter survival of all species (Bisson, Bilby, Bryant, Dolloff, Grette, House, Murphy, et al., 1987). It is crucial to include fish life stage and cycle into the methods chosen for habitat enhancement and bank protection. Problem identification to the implementation process should be continually improved and addressed with a number of agencies and stakeholders. Monitoring is the last stage of the installation process, which connects perfectly to research opportunities that should continue for several years for the insurance of great habitat for salmon, adequate spawning and rearing conditions, and improvements to water quality and streambanks.

Chinook and coho salmon utilize off-channel habitats, which utilization during the wintertime was especially noticeable (Pehl and Flynn, 2009).

Salmon carcasses in stream ecosystems of the Pacific Northwest are important for ecosystem functions and aid in restoring degraded rivers, which nutrient retention, although high turnover, in habitats with pools and debris dams (Monaghan and Milner, 2008).

REFERENCES AS ANNOTATED BIBLIOGRAPHY:

The ranking system of the literature is based on a combined date-of-publication and quality of the literature. When a reference citation is noted as "inaccessible", "unable to obtain", or other indication refers to the document, article, or book not being easily accessible from personal and library search. Below is the scale used for ranking references. Each section is divided, and within each section, alphabetized by last name, are the reference citation and description following.

E = excellent
G = good
O = ok
N = not referencable, but background

STREAM BANK OR HABITAT ASSESSMENT:

American Fisheries Society Annual Meeting. (2001). Assessment of restoring anadromous salmonid habitats and rivering processes in the Lower Snake River, Washington. 187-188.

Unable to access article.

Biedenharm, D.S., Elliot, C.M., and Watson, C.C. (1997). *The WES stream investigation and stream bank stabilization handbook.* Retrieved http://chi.erdc.usace.army.mil/Media/2/8/7/Stream bankManual.pdf.

This manual details the basic concepts and processes associated with fluvial geomorphology and channel/river characteristics, which includes erosion protection principles.

This manual has a section that explores design, methods, surveys, and mapping for channel or geomorphic assessments. The manual also details stabilization techniques and what to account for in selecting one such as environmental, economical, and alternative approaches. Hydraulics is included in the design and toe protection in the techniques. The bank stabilization section is also informing, especially unique in its consideration of other factor or regulations. Grading, surface armoring, vegetative methods, and indirect techniques are described with basic concepts, advantages, disadvantages, and construction (in general and detailed). Monitoring and maintenance efforts of bank stabilization was described and emphasized. Although this manual is dated, it incorporates valuable information on assessment of aquatic and terrestrial habitat. (E)

Brannaka, L. and US Fish and Wildlife. (2005). *U.S. Region 3 introduction to ecological restoration: integrating ecological enhancements into remedial activities at contaminated sites - essentials of stream restoration*. Retrieved November 2012 from http://www.epa.gov/reg3hwmd/risk/eco/restoration/workshops/Essentials_of_Stream_Restoration.pdf

This PowerPoint describes degradation, agradation, stream bank instability or severe erosion, and river instability. The slides show photos to the sections. Stable streams are defined. Images go closely to the titles to the restoration and structural methods. Also provided are consultant and technical assistance are listed. Funding phases (five) are also provided. (O – N)

Browne, F.X. (2001). *Stream bank restoration design.* Retrieved November 2012 from http://www3.villanova.edu/VUSP/Outreach/pasym01/pdffiles/B12.pdf.

This very concise and short document is excellent for reviewing basic information on stream bank degradation, design criteria and assessment, and bioengineering methods. The author targets excessive stormwater runoff as the major cause for stream bank degradation. A great point by the author is that stream dynamic equilibrium is achieved through adjustment in hydraulic parameters. Designing restoration method is central to fitting the right technique to the right condition. Five issues much be addressed for this, which include identifying stream problems, identifying constraints, identifying stream bank conditions, evaluating channel conditions, and calculating velocity and shear stress. This information allows for better site assessment. Crucial site assessment should include the stream's cross-section, longitudinal view, regular view, indicators, information (ie. soils, wetlands, slopes, vegetation, etc), in-stream features (ie. woody debris, riffles, pools), and constraints. Bioengineering methods listed are toe protection, flow redirection and moderation, middle and upper back stabilization, and surface protection; generally, these methods have some degree of grading of the shore area. Furthermore, the author provides charts with shear stress-treatment and velocity-soil texture. (E)

Bulletin Francais de la Peche et de la Pisciculture. (1995). The development of habitat models for stream salmonids, and their application to fisheries management. 68(337-338):375-385.

Unable to access this article.

California Department of Fish & Game. (1998). *California salmonid stream habitat restoration manual, 3rd edition.* Retrieved November 2012 from http://www.dfg.ca.gov/fish/resource/habitatmannual.asp.

NOT REFERENCED as older version; Replaced with July 2012, 4th edition, see reference citation below, as it replaces (or updated) the 1998 3rd edition version.

Flosi, G., Downie, S., Hopelain, J., Bird, M., Coey, R., Collins, B., California Department of Fish & Game, and others. (2010). *California salmonid stream habitat restoration manual, 4rd edition*. [Volume 1 & 2]. Retrieved November 2012 from http://www.dfg.ca.gov/fish/resource/habitatmannual.asp.

This is an excellent resource for salmon and steelhead habitat restoration in California. Although specific to California, information can be pulled for Central Alaska. The manual opens to history of Californian salmonids, and then is followed by description of parts to conduct surveys that include materials, tools/supplies, instructions to conduct survey, and actual work sheet forms. It then details tools and supplies needed for watershed assessment, which include various maps and detailed work sheet, and background information on part of stream ecology. The habitat inventory section provides information on tools, supplies, criteria, and stream classification system based on a two person crew. This section provides a terminology part, diagrams, keys, and text to further illustrate the information that is tied into a worksheet. A salmon spawner survey is provided and most relevant to readers interested in conducting the survey, which a technique of electrofishing follows a similar pattern of survey description and background on the technique.

The manual transitions into sections to work the data collected. Data entry into a database is critical in order to do analysis and summarization, which examples of charts and tables are provided for California. The manual indicates storage of data as well as example data format and GIS format to be incorporated in the stream report. The recommendation piece of the manual is helpful in portraying the need for critical habitat being met in order for communities, and its species, to survive within the selected site of interest. This can be done with target species and detailing its life cycle. The manual includes biological and environmental factors of which ties into the following section of each salmonid California Fish and Wildlife Service (CAFWS) highlighted (Chinook, Coho, Steelhead, Coast Cutthroat Trout, and Resident Trout). Habitat evaluation procedure and forms are included in this booklet as well as various stream habitat enhancement project evaluation forms.

Project planning and organization section aim to act as a guide in providing improvements to instream habitats that effect salmonid population numbers, which need to include extraneous factors. Acknowledging funding and capacity of resources also affect the project. This, among other reasons, impacts the method chosen and efforts put into why stream habitat modification is done. Permits that may be required and treatment-related agencies and conditions are listed in Volume I. This section also recommends habitat inventory data and describes its development that incorporated project site layout to achieve optimal improvements in-channel design based on geomorphology and hydraulic analysis, including means to anchor bioengineering techniques. This would include surveying longitudinally, cross-sectional profiles, and selection of sites that are implementable for restoration. The manual lists and describes characteristics that are relevant, such as substrate, stream width, channel sinuosity, and structural material with definitions.

It also includes a fish passage section that is essential in success of salmonid populations within sites or potential sites of bioengineering of Volume 2. Detailed information on stream crossings, upslope assessment, restoration practices, and fish passages design, and implementation. Data sheets and surveys, including forms, are incorporated on fish passages inventory as well as basic information on fish passage challengers, analysis, failures, filters, and sketching. Ranking of stream crossing for treatments and guidance to constructing stream passages are described in its own passage. Project monitoring and implementation of these passages include measureing mortality of species as well as other sections in this booklet (Volume 2 specifically). This would include culverts.

Appendix of policies and regulations on salmon and other salmonids are also made available in this booklet. It includes more appendices on threatened species, maps, images, programs and databases, tools, and other instructions, agreements, environmental documents, and more. Guidelines for fish passages and examples of calculations are part of the appendix. Figures and diagrams have been incorporated within the booklet as means of aiding readers in understanding the content of the literature.

In conclusion, the ~1,200 –page booklet of Volume 1 and 2 provide excellent information and reference for surveying instructions, forms, and incredibly-detailed procedures for bioengineering techniques and methods.. There are project site completion and monitoring forms available and procedures in Volume 1. Watershed and stream bank stability is detailed in many angles and degrees throughout the booklet in exemplary writing that is easily understood. (E)

Georgia Soil and Water Conservation Commission. (2011). *Stream bank and shoreline* *stabilization: techniques to control erosion and protect property.* Retrieved November 2012 from http://www.gaepd.org/Files_PDF/techguide/wpb/Stream bank_and_Shoreline_Guidance_Book_Revised_April_2011.pdf.

This excellent manual provides quick background information on erosion. It then goes into summarization on practices that are broken into preferred, acceptable, and discouraged. The preferred common bioengineering practices include live staking, live fascines, branchpacking, vegetated geogrid, brushmattress, coconut fiber roll, and dormant post plantings. Acceptable practices include joint planting, live cribwall, vegetated gabion baskets, tree revetments, and log, rootwad, and boulder revetments. These are described as integrated bioengineering with structural components. Discouraged practices were listed as rock riprap, rock gabions, bulkheads, and seawalls. Structural practices with limited or lacking vegetation function are the discouraged practices. (E – G)

Georgia Soil and Water Conservation Commission. (2000). *Guidelines for stream bank restoration*. [Revised]. Retrieved November 2012 from http://www.gaepd.org/Files_PDF/techguide/wpb/Guidelines_Stream bank_Restoration_GSWCC_Revised_2000.pdf

This booklet details information on carrying out projects as well as the planning process based on description of stream dynamics and relationship with riparian zone and habitat. It also has section that discusses common stream bank erosion and their causes, which should be assesses and evaluated in order to manage or control techniques or methods. The booklet describes common soil bioengineering erosion control and management strategies. It begins with the concepts that each stream is unique and stabilization techniques should be specific to each stream thusly so as it will impact individuals and wildlife upstream. A table for selected erosion measures and page number make it an easy reference for the reader. Also, asking for advice is also a suggested as well as applicability to laws and regulations of local and state levels.

Communication with agencies or local offices and evaluation of alternatives as well as techniques are mentioned throughout the booklet. Similar steps in identification of the problem, communication with appropriate agencies or individuals, project date, evaluation and designing protection method are all incorporated in the project plan. Cost and accessibility are mentioned in the booklet in text and table format. The objective is the promotion and maintenance of a healthy aquatic population and habitat suitability through the protection of stream bank vegetation zones, or riparian zone. Tables were created for conditions and characteristics erosion and banks as well as diagrams to further illustrate information to the reader.

The sections with each soil bioengineering method provides text description and visual images to assist in readers understanding that complements advantages, installation process, tips, and materials described. A glossary of terms is provided at the end as well as a list of species chosen by Georgia SWCD based on region, which sources for plant list is provided. The booklet further assists the reader in determining hand tools and costs associated with them. Overall, this resource is excellent for considering stream bank restoration. (E)

Harrelson, C.C., Rawlins, C.L., and Potyondy, J.P. (1994). *Stream channel reference sites: an illustrated guide to field technique.* Retrieved December 2012 from http://stream.fs.fed.us/publications/PDFs/RM245E.PDF

This field technique guide depicts aspects of permanent reference sites and their creation. This dated document is very useful in the establishment and usefulness of such sites. For instance, the ability to monitor and compare is one of many uses. In the guide, the minimal needs to characterize channels and to correctly do informative techniques. These procedures the authors describe involve site selection, mapping, measuring, surveying, and what to measure. All this information is incorporated into a permanent file for referencing. This article stresses efficiency, reference site and what has been done as it relates to stream restoration reference sites. Many of the information are updated in newer publications available; however, basic “how-tos” for note-taking, drawing, mapping, etc. is described excellently. (O – N)

Hey, R.D. (2006). Fluvial geomorphological methodology for natural stable channel design. *Journal of the American Water Resources Association.* 42(2):357-374. Retrieved November 2012 from http://www.keystonestreamteam.org/PDFLibrary/Hey_2006.pdf.

The methodology of natural stable channel is applicable for restoration. Stream types at stream site are scaled for the restoration design with nature. A reference reach is used to create particular combinations of streambank factors, ie. bed material, and ratios. This article provides the Rosgen Method, or the river classification procedure, as a design process that incorporates river types. This method of classification is based on bankfull cross sectional and longitudinal profiles of rivers that resulted in 8 types. The article also explores equations and reviews application for geomorphological procedure for stable restoration design and reference reaches. Type and cause of instability of streambanks are briefly discussed as it related to the restoration options chosen. It is also important to look at adjacent streambanks for instability as well.

Overall, this article provides useful equations and information. The comparisons between actual and predicted channel reach had significant errors in predicting curvature of stream types, which was noted and the impacts of the error explained. Resistance to flow and boundary conditions were important factors in the study. The authors stress the importance of selecting the appropriate reference reach for restoration design in order to minimize error in scaling. Conclusively, the study indicated successful restoration design can be achieved using the geomorphological procedure if the appropriate reference reach is selected. (G - O)

Hoag, J.C. and NRCS (Natural Resources Conservation Service). (1997). *Riparian/wetland project information series no.2. planning a project: selection and acquisition of woody and herbaceous plant species and materials for riparian corridor, shoreline, and wetland restoration and enhancement.* Retrieved November 2012 from http://www.plant-materials.nrcs.usda.gov/pubs/idpmcarwproi2.pdf.

This paper focuses on woody and herbaceous plantings along water bodies or wetlands. The document states steps that are important in the success of plant establishment and considerations (i.e. permits). The riparian corridor and shoreline projects should clearly and firmly identify the objectives as well as potential problems that may arise. Objectives and goals incorporate various factors, which determine the revegetation treatment. Planning and management are important as well soils/soil conditions at the site. Factors such as microclimate and precipitation should be considered at the project site when conducting a site inventory in order to select plants for the location. The paper expresses environmental, physical and ecological factors that will allow survivorship and adaptation. Species selection is also dependent on the purpose of the vegetation along banks, which the paper discusses briefly on types of planting stock hardwood and classes of plant materials (native, ecotypes, and cultivars). It briefly details use of planting windows and procure materials; however, time accounted for seed collection for native plants and handling before and after planting events should be included in planning. This document does a concise description with useful information. (O)

Iowa Department of Natural Resources. (2006). *How to control stream bank erosion.* Retrieved November 2012 from http://www.ctre.iastate.edu/erosion/manuals/stream bank_erosion.pdf.

This manual assists in stream bank erosion control for various interested parties. This manual provides basic information on stream bank erosion and alternative approaches to landowners in particular of Iowa. Stream bank erosion control maintenance are detailed as a chart or written explanation. Riparian stabilization for stream banks is explained through advantages and disadvantages, materials, preparation, installation, and photos. The methods described include: seeded banks, live stake, joint planting, riprap, branch packing, and many others. The description for each of the methods is exception. (E)

Johnson, P.A., Hey, R.D., Brown, E.R., and Rosgen, D.L. (2002). Stream restoration in the vicinity of bridges. *Journal of the American Water Resources Association.* [Reprint}. 38(1):55-67. Retrieved November 2012 from http://www.wildlandhydrology.com/assets/SRITVOB.pdf.

This study indicates small-scale laboratory experiments have shown rock structures commonly used in restoration projects along streams are able to transition flowing water from target banks to through bridge openings. These structures are vanes, cross vanes, and w-weirs used along floodplains. It is important to incorporate depositional zones along banks with these approaches to avoid scouring at piers or abutments. (O)

Milner, A.M., Robertson, A.L., Monaghan, K.A., Veal, A.J., and Flory, E.A. (2008). Colonization and development of an Alaskan stream community over 28 years. *Frontiers in Ecology and the Environment.* 6(8):413-419.

This article stresses the lack of long-term application of successional theory with stream ecosystem at large spatial scale. This article focuses on Wolf Point Creek in Glacier Bay, Alaska. The study examines recolonization as it relates to community organization and succession, which dispersal constraints influence, of the post-emergent stream's development since mid-1940s during the period from 1977 to 2005. The authors state that tolerance and biotic processes are a major factor for macroinvertebrate community assembly after colonization. For instance, red digging by spawning salmon facilitate patches for early colonizers. Furthermore, deterministic and stochastic elements influenced succession and community assembly, which the study stresses the importance of reestablishing riparian vegetation during in-stream habitat restoration. An important example highlighted was salmon carcass nutrients retention by coarse woody debris. Water temperature increases allowed for recolonization (E – G)

Mossop, B., and Bradford, M.J. (2006). Using thalweg profiling to assess and monitor juvenile salmon (*Oncorhynchus* spp.) habitat in small streams. *Canadian Journal of Fisheries and Aquatic Sciences*. 63: 1515-1525

Thalweg profiles, which are longitudinal profiles of the streambed elevation measured along the deepest portion of the stream, are used to assess and monitor fish habitat. The information provides habitat quality data. Documents have indicated a relationship between thaleweg and land use. However, fish abundance and thalweg metric has not been established.

The study concentrated on 14 reaches of smaller tributaries of the upper Yukon River where surveys of thalweg profiles and juvenile Chinook salmon took place. The Chinook density correlated with three thalweg metrics, which included residual pool and mean maximum residual pool depth, provides useful information for assessing and monitoring. The last metrics variation index does not support better habitat for fish. In the study, Chinook density did not correlate with available pool habitat. The thalweg profiling would be the effective tool to monitor geomorphological recovery and subsequent recovery of fish habitat after placer mining stops. In conclusion, the Yukon streams results indicate that both length in residual pool and mean maximum residual pool depth in assess and monitor habitat for pool-rearing juvenile salmonids in small streams. (E – G)

NOAA (National Oceanic and Atmospheric Association). (2011). *Science base and tools for evaluating stream engineering, management, and restoration proposals.* Retrieved November 2012 from http://www.arlis.org/docs/vol1/D/776673943.pdf.

This is an excellent manual for evaluation and reviewing process in order to improve projects. The tools described include Project Screening Matrix, Project Information Checklist, and RiverRAT (Restoration Analysis Tool) provide excellent venues to secure participation, reduce information gaps, and improve projects. In addition to tools the manual describes fluvial processes and stream development, including disturbances and responses. A section depicts project development and enhancement through problem identification, goals, implementation, and monitoring. For instance, nine principles are guides detailed that focus on physical processes and habitats important to ecological recovery. The project development section improves projects through seven steps: problem identification, project context, goals and objectives, alternative (approaches) evaluation, project design, implementation, and monitoring or management. The manual is very descriptive and detailed. (E)

NRCS (Natural Resources Conservation Service). (2008). *Stream Restoration Design NEH-654*

(National Engineering Handbook) [PowerPoint slides]. Retrieved November 2012 from http://www.canaanvi.org/canaanvi_web/uploadedFiles/Events_and_Education/Workshops/bernard_nrcs.pdf.

This PowerPoint shows objectives, challenges, and solutions of stream restoration projects and those involved. The slides then go into describing the National Engineering Handbook part 654, which can be used as a tool to design stream restoration projects. There have been many agencies involved in the writing and reviewing of NRCS Handbook. It is also indicated that there is a companion handbook as well – NEH-653:Basic, Principles, Planning – of which NEH-654 is dependent on. Overall, this PowerPoint does a quick overview of the handbook as well as restoration-based conservation examples. (O)

Paulsen, C.M., and Fisher, T.R. (2005). Do habitat actions affect juvenile survival? An information-theoretic approach applied to endangered Snake River Chinook salmon. *Transactions of the American Fisheries Society.* 134:68-85.

The 33 Snake River sites over 11 years of parr-to-smolt survival study indicated that prior habitat enhancement actions associated with higher parr-to-smolt survival of endangered Chinook salmon despite confounding factors. The study incorporates estimated weight and actions taken to improve fish habitat that positively increase parr-to-smolt survival. The study looked at survival rate of juvenile survival rate. (O)

Quigley, J.T., and Harper, D.J. (2004). Streambank protection with rip-rap: an evaluation of the effects on fish and fish habitat. Retrieved December 2012 from http://www.dfo-mpo.gc.ca/Library/285541.pdf.

The document explores the effects of rip-rap on fish and fish habitats. A review and evaluation over 20 years suggests effects of rip-rap are both positive and negative. The watershed scale effects include restricted lateral channel migration, decreased natural sediment deposition, reduced recruitment of debris, and other affects from rip-rap. The effects from riprap are largely negative and culminating in nature. Impacts to landscape-level ecological and hydrological processes should be considered in rip-rap projects. Long-term and short-term management recommendations were listed.

Kochl, D.A., and Neville, J.I. (?). Literature review on the effects of rip-rap on fish and fish habitat with habitat management implications. Attached to Quigley, J.T., and Harper, D.J. documents.

Rip-rap is used to protect streambanks from erosive forces and runoff. Indications of preference for softer banks due to disadvantages of rip-rap. Positive effects of rip-rap on fish and fish habitat arise from improving degraded conditions, which are combined with other mechanisms. Negative effects of rip-rap on fish and fish habitat are categorized in aquatic, terrestrial, and aesthetic impacts that also lead to indirect effects. The review had a section on mitigating negative effects.

The attributes conflicting findings of rip-rap studies indicate that integrated streambank protection should select methods to address site- and reach- based conditions. The rip-rap alternatives should also be considered. (O)

Railsback, S.F., Harvey, B.C., Jackson, S.K., Lamberson, R.H., & US Forest Service. (2009). *InSTREAM: the individual-based stream trout research and environmental assessment model.* Retrieved November 2012 from http://www.arlis.org/docs/vol1/C/488776523.pdf.

This report explores the software InSTREAM (Version 4.2), which also acts as a manual. This program allows for parameters such as age, age class, habitat distance, mortality and survival into a formulation within the software. This is an excellent resource for relationships or equations to represent relationships of the parameters. (Depending on the use of this report, it rates E for software use and O for basic information related to restoration.)

USGS. (1993). *Methods for characterizing stream habitat as part of the National Water-Quality*

Assessment Program. [Report no. 93.408.] Retrieved November 2012 from http://water.usgs.gov/nawqa/protocols/OFR-93-408/habit1.html.

NOT REFERENCED as older version; See reference citation below, as it replaces (or updated) the 1998 version.

Fitzpatrick, F.A., Waite, I.R., D'Arconte, P.J., Meador, M.R, Maupin, M.A., and Gurtz, M.E. (1998). (1998). *Revised methods for characterizing stream habitat as part of the National Water-Quality Assessment Program US Geological Survey Water-Resource Investigations Report 98.4052*. Retrieved November 2012 from http://pubs.usgs.gov/wri/wri984052/pdf/wri98-4052.pdf.

This document begins with glossary of terms or concepts. It is a protocol for habitat methodology of evaluating natural environments. The revision was due to updated "lessons" learned over the 6-year timeframe. Procedures for data collection as well as what to collected is described according to US Geological survey NAWQA (National Water-Quality Assessment) Program. The goal of the program is assessing the status of and trends developing due to factor affecting water quality. Thus, after 4 to 5 intense years of assessment, low-intense assessments are conducts. This document describes the finds and procedures to do so. A section describes the revision to the 1993 original protocol.

A section then follows characterization of stream habitat on describing further application and importance of habitat-sampling design and assessment techniques through physical, chemical, and biological factors of a drainage area. A very descriptive list of basin and segment (reach) habitat assessment is available for the reader to digest. Measurements are conducted after site selection. Forms are available at the end of the paper. (O)

Ward, N.A. (2010). *Monitoring the efficacy of juvenile salmon (Onchorhynchus spp.) off-channel* *habitat restoration projects in south central, Alaska*. *Dissertation*, Masters Thesis. Alaska Pacific University.

Inaccessible

Washington State Aquatic Habitat Guidelines Program. (2002). *Integrated stream bank protection guidelines.* Retrieved November 2012 from http://wdfw.wa.gov/publications/00046/wdfw00046.pdf.

This is a great guide for "how to" that can be used by a number of departments or individuals through use of this tool – Integrated Stream bank Protection Guidelines (ISPG). The guideline opens with a description principles of ISPG, Aquatic habitat Guidelines, and ecosystem function, bank protection, project planning and implementation that briefly are intended to orient the reader to the importance of protection and restoration of habitat (aquatic, marine, and terrestrial). ISPG is integration of assessments of site, reach, risk, and habitat that fits the project objectives; once completed ISPG further investigates design and mitigation of methods of protection in order to select the right technique for the stream bank.

Objectives and design should incorporate addressing stream-erosion problems as well as preventing further erosion of the river along structures of residential, commercial and industrial presence. Mechanisms of failure and suitable alternative stream banks for protection should be incorporated in the assessments. It is also important to recognize that erosion of riparian banks is a natural process essential to habitat function and creation, as the guideline discusses in its habitat and mitigation sections. An easily followed table was created for the protection techniques for various purposes, i.e. flow redirection that stresses the importance of understanding objectives and techniques based on assessment results. Floodplains are important to the strength of soil and association with vegetation to dissipate flow and energy of water movement. Thus, avulsion is of interest where floodplain disruption occurs.

The guide greatly details the mechanisms of failure and site-based causes that enables the decision maker of the technique to gain preparation for such challenges. This also lets the cause of bank erosion to be determined and addressed adequately. The authors create a descriptive, concise chart of the mechanisms and site-based causes of failure and examples as well as a separate table with habitat considerations to possible reach-based/site-based causes. These can be seen as problems, physically, on the sites that can be seen visually in the diagrams the authors used to go with text of each cause or mechanism.

This is an excellent resource with checklists for site characteristics available to readers as well as basic information if needed on channel formation and conditions, which include equilibrium and disequilibrium formats. Easy to follow description, diagrams, charts, and detail on treatment consideration for the causes of erosion (i.e. degradation of banks should be treated with lowering the channel bed, grade-control structures, and reducing hydrology and increasing sediment storage through channel adjustments of size or shape) support the usefulness of this guidance document, or book. (E)

Whiteway, S.L., Biron, P.M., Zimmermann, A., Venter, O., and Grant, J.W.A. (2010). Do in-stream restoration structures enhance salmonid abundance? A meta-analysis. *Canandian Journal of Fisheries and Aquatic Sciences.* 67:831-841.

This study uses a meta-analysis approach to impact of weirs, deflectors, cover structures, boulder placement, and large woody debris on salmonid abundance as well as physical habitat characteristics. Median cost range for projects was $36,295 to $20,000 over 6,000 in-stream habitat improvements, according to Bernhardt et al. (2005) work. Significant increase in particular stream parameters of 211 restoration projects after installation of the structures. Another result of the installation was increase in salmonid density (73%) and biomass (87%). Habitat sizes much increase in order to allow increase population sizes. The decreases were associated with poor study design, unexpected events, and sudden physical changes; increasing fishing pressures could also impact the study results. Increases reported in the study may also be a result of redistribution of salmonid populations. The largest impacts were seen with rainbow trout. It is worth considering that different developmental stages of salmonids use and prefer different habitats. However, the article stresses the need for long-term monitoring of the in-stream structures, which is currently lacking. Generally, in-stream structures last approximately 20 years given their design before failing. The authors indicate that more evidence is needed in determining structure type in streams of varying topography, i.e. slope, and their failure probability. Furthermore, the authors indicate that there is not one solution or structure that is successful in all stream types, and that this can be seen as a temporary tool or solution while larger changes at a watershed level are being done. (G – O)

BIOENGINEERING:

Allen, H.H., and Leech, J.R. (1997). *Bioengineering for streambank erosion control report 1 guidelines.* Retrieved November 2012 from http://www.engr.colostate.edu/~bbledsoe/CIVE413/Bioengineering_for_Streambank_Erosion_Control_report1.pdf.

The document acts as a guideline for bioengineering treatments or techniques, which can be done with hard toe/ flanking protection and deflection of water away from target reach to be protected through deflection structures. The document emphasizes using herbaceous and woody species with grass/grass-like plants where able. Shrubby, woody vegetation is ideal in the middle zone. Larger shrubs and trees are best the uppermost/canopy zone. Bed stability and whole subject area would need to be addressed holistic bank stability. Thus, planning and design models much are specific to reach site of interest.

This document highlights five mechanisms: 1) vegetation assists in erosion control, 2) dissipate wave energy, 3) intercept water, 4) enhanced water infiltration, and 5) deplete soil water by uptake and transpiration. These are done through vegetation's root systems, increase resistance to flow and velocities, buffer against the effects of transported materials, and close-growing vegetation induce sediment deposition. This guide emphasizes biological attributes and interdependence within the bioengineering project. The document mentions equipment, materials, and permit considerations. Monitoring and aftercare also is described with emphasis on documentation, cost, potential for areal photography with discussions on aerial components and wildlife like beavers. The last section of the document focuses on obtaining plants (wild or commercial with advantages and disadvantages), handling herbaceous and woody plants, and when to plant.

The main portion of the document begins with hard structures and examples shown as photos. Bioengineering zones of toe, splash, and bank are described as it related to plant considerations and water levels. Terrace zone is inland from riparian banks, which are less significant for protection from flooding. Bioengineering treatments include: stone or rock revetment, gabions, lunker, log revetments, deflectors, dikes, cribs, rock, and geotextile rolls, root wads, or combinations of the listed. Stone and rock are generally used in the toe. Splash zones may carry below toe zone stone to this level with vegetation. Bank zones are vegetation primarily. This document really focuses on practices of each zone, which adds a nice structure for the document. Much of the document has examples around the world of the techniques. Other document sources include more up-to-date techniques based on time-derived improvements and knowledge acquired over the years. (O – N)

Amaral, S.V., Mathur, D., and Edward, P.T., III. (2008). Advances in fisheries bioengineering. American Fisheries Society: The University of California.

Unable to access or obtain

American Society of Civil Engineers. (ASCE). (1998). *Engineering Approaches to Ecosystem Restoration.* Available at Wetlands, Engineering, and River Restoration Conference 1998.

This dated 3CD provides the emphasis interdisciplinary cooperation when it comes to restoring or establishing wetlands, riparian zones, and streams, which engineers have always been a part of. The papers presented from in the1998 ASCE Wetlands, Engineering and River Restoration Conference are available on the table of contents. The conference was held at Denver, Colorado during March 22-27, 1998. The paper’s themed around river restoration approaches, wetland restoration, watershed management, and the use of constructed wetlands for water and wastewater treatment. Further information on the table of contents of the articles are available in the appendix. (O – N)

(2002, August). Advances in fisheries bioengineering. In Amaral, S.V., Mathur, D., and Taft, E.P., III. (Ed), *Fourth fisheries bioengineering symposium*. Symposium conducted in Baltimore, Maryland, USA.

This book presents 65 papers on bioengineering focused on habitat improvements, restoration, and mitigation with hatcheries. A table of contents has been provided. (G - O)

Bentrup, G., Hoag, J.C., and USDA NRCS. (1998). *The practical streambank bioengineering guide: user's guide for natural streambank stabilization techniques in arid and semi-arid Great Basin and Intermountain West.* Retrieved November 2012 from http://www.urbancreeks.org/The%20Practical%20Streambank%20Bioengineering%20Guide.pdf.

This guide is geared towards arid and semi-arid Great Basin and Intermountain West riparian ecosystems. Environmental stewardship is important to understand in relationship to stream and river connection to other resource. Much of the information in this document is within more recent documentation and publications, in particular streambank bioengineering options, design, and process. Unlike the Intermountainous West, Pacific Northwest does not have a strong economy central to agriculture. This document does take mountainous and arid considerations, which may be helpful to Alaskan climate. (N)

Berube, M., Gagnon, G., Hardy, L., and Bariteau, L. (2000). The stabilization of the Ottawa River Banks: a comparative study between bioengineering methods and a method based on natural gravel embankments installed in winter. *Ecohydraulics Proceedings of the 2nd international symposium on habitat hydraulics*, B718, 717-728

During the 1995-1996 winter the Ottawa River in Quebec experienced the start of a shore protection program. The project was large; over 70 km of shore stabilized along the Carillon dam. The different protection methods reviews and developed offered complex bioengineering techniques (natural gravel bank and vegetation). It was then decided to embank the foot of the slopes with 20 to 40 cm maximum diameter of 15% sand, which was the smallest to meet local erosion conditions. The resulting field tests of 1992 and 1993 demonstrated generally natural retake would cover over 80% of the sites within 5 years. Trees and dense plant community allowed for rapid retake of bank. The same embarkment was done elsewhere – Chisasibi – and is still functioning.

The significance of this study/test is that it is the first large-scale stabilization program of Quebec done in the winter, which ice was used as an access point to the banks. The project also was the first to submit and EIA (environmental impact assessment). (N)

Berube, M. (1986). Stream improvements and fish response: a bio-engineering assessment. *Ecohydraulics 2000 Proceedings of the 2nd international symposium on habitat hydraulics,* 22(3): 381-388.

Unable to locate the actual article.

Bragg, D.C., and Kershner, J.L. (2004). Sensitivity of a riparian large woody debris recruitment model to the number of contributing banks and tree fall pattern. *Western Journal of Applied Forestry,* 19(2):117-122.

Riparian large woody debris (LWD) recruitments models incorporate the traditional random angle fall of trees from two banks that are well-forested, which the assumptions was tested in this study. The quantity and direction of the simulated LWD appeared to not have an explicit interaction. Simulations of total recruitment with bank cover categories, which one or both banks were forested, are dependent on directionality of falling trees. The prediction of the models was the similar with one sided or two sided forested banks in the computer recruitment model using CWD and the random LWD recruitment. Thus, the study confirmed the benefit of checking consistency of simulated and actual local wood delivery to streams for local forest cover and tree pattern failure. One bank being forested provided less in volume and magnitude of the LWD compared to both banks being forested. (G)

Colt, J., White, R.J. [editors]. (1991). Fisheries bioengineering symposium. American Fisheries Society: Bethesda.

Given the date of the book publications and the articles, this reference is useful for more historical reference and change perspective. Articles are broken into subsections characterized by perspectives, habitats, fish passage, and fish hatcheries. An appendix of the articles in the book via table of content is provided. (N)

Darby, S., and Sear, D. (2008). *River restoration: managing the uncertainty in restoring physical habitat.* Retrieved January 2013 from http://www1.inecol.edu.mx/repara/download/III_1_RiverRestorationManagingTheUncertaintyInRestoringPhysicalHabitat_I.pdf

The document is very useful in addressing uncertainty in river restoration. The first chapter is divided into three sections that discuss the significance of river restoration uncertainty, sources of the uncertainty in research, and scope of uncertainty. A valid point made in the section is the complexity of uncertainty and the lack of sufficient interdisciplinary infrastructure to properly deal with the problems faced. Research, theories, and communication of scientific results can be biased, ambiguous and present gaps that add to the sources of uncertainty in scientific processes and river restoration knowledge. The idea of the adolescent practice of river restoration is “working” and is subjective, and in itself lending to uncertainty. The article explores what a lexicon uncertainty refers to in the context of terms, parameters, and potential synonyms.

The next focuses on planning and design of restoration projects, which include many angles and dimensions. An article is dedicated to the social and cultural significance that is best explored on the urban-rural-wilderness continuum. Humans respond in preference to veering views of landscapes within riparian communities and the participation of public and stakeholders are at the center for the restoration process. Value of riparian ecosystems is vast, and the approaches to restoration can cause conflict between professionals, legal groups, stakeholders, and citizens.

Mathematical modeling, thresholds, sources of error, and confidence are another important aspect of planning and design of projects, especially geomorphic models. Floodplain restoration also has uncertainty given the channels dynamic nature. Another article in this chapter focuses solely on the hydraulic and hydrological aspects of uncertainty for ecological purposes, as the title implies. The last article discusses uncertainty as it related ot ecological targets and response of river/ stream restoration.

The last sections of the document were not available on this pdf link. (E)

Doli, B.A., Grabow, G.L., Hall, K.R., Hailey, J., Harman, W.A., Jennings, G.D., and Wise, D.E. (1999?). *Stream restoration: a natural channel design handbook*. Retrieved November 2012 from http://www.bae.ncsu.edu/programs/extension/wqg/sri/stream_rest_guidebook/guidebook.html.

This document provides higher-knowledge description and into fluvial process including natural channel stability and channel profile patterns and dimensions. Stream assessment and survey procedures from both in the office and field, and measuring and profiling processes as well as forms, diagrams, and formulas. The Rosgen stream classification systems and channel assessment procedures at each level are discussed. Stream gage and bankfull verification through step by strep determination of indicators and others are introduced. Channel erosion is addressed and bank profiling, and incised streams with the position adjacent of instable banks. Priorities are important, like incorporate restoration and new stable channel of lower floodplain and narrow floodplain. Advantages and disadvantages are places in a tabular in terms of long-term results, stream stability, flooding, vegetation disruption, and others. The document also incorporates photos and diagrams to help with understanding. Reference reach section, for instance, incorporates survey, field and office procedures and where to references to help in understanding the topic.

Chapter 7 becomes most helpful, laying out succinct and precise step-by-step design procedures. The downfall of the documents section is its focus on math of shear stress. The following chapter is where bioengineering becomes the focus. Structural channel designs of root wad, vanes, and rock/boulders are discussed. The analysis, assessment, measurements, and stream characteristics all play into this decision. Variety and combination of techniques specific to nature vegetation and stream conditions allow for habitat improvement site specific and general site goals based on Roegen's work. Design criteria of root wad, for instance depicts requirements of 10 to 24 in basal area of trees above wad trunk length of 10 to 15 ft, and mats placed/stall at toe of bank. Bank heights are low 1 to 1½ times bankfull heights place boulders at least 1 ton or heavier behind root mat; high bank, if plenty of vegetation and biomass footer log, boulders may not be needed. Permanent seeding, maximum habitat diversity, and grand cover enable herbaceous species to utilize the areas. Also available are container plant material i.e. potted size and shapes that list of spp in appendix for North Carolina.

Erosion and sediment control plan three approaches to address potential sediment and erosion associated with stream restoration, which include: new channel in dry, pump/divert water around a project, and work in active channel. Diversion to divert water away, stream crossing coverts, ramps graded could be stone fence used to trap sediment waterways, disposal of runoff from fields, or coconut fibermat. Vanes include single, j-hook, cross-vane and w-weir created from large tree trunk or boulders. J-hook promotes streambank-redirecting thawleg away from the streambank and toward center of channel. Improve in-stream habitat by creating pools and oxygen and cover. All four technology 20° to 30° angles offbank located downstream of where stream flow encounters the streambank at acute angles. Vanes highest next to the bank are dependent on erosion rocks maybe needed, preferably flat downward, and pointed them upstream. Rock incorporation to the system is needed in all except j-hook. W-weir can be used to large rivers and similar to vanes.

Habitat enhancement through design and structures focused on diversion, pattern, profile, stream reaches proper riffle, pool sequences encouraging neolongation, woody vegetation overhanging rock, large woody debris. Vegetation stabilization and riparian buffer re-establishment can be salvaging on-site vegetation, these transplant in include live staking, bare-root plantings. More detail and information is available on the techniques. (G)

Donat, M. (1995). *Bioengineering techniques for streambank restoration: a review of Central European practices*. Retrieved January 2013 from http://www.env.gov.bc.ca/wld/documents/wrp/wrpr_2.pdf

The use of plants has been used in Europe for riverbank protection and erosion control has been a long practice. Versions of the methods discusses, also known as bioengineering, include ecological, economics, and aesthetic advantages that improve technical protection for riparian streambank rehabilitation, according to the author. Riparian vegetation and stream ecology are briefly highlighted as well as their ecological function (i.e. microclimate, bank security, habitats, provisioning services). Both mechanical and hydrological benefits are seen with bioengineering. Bioengineering, through trial and error, is described as replacing soft practices with hard constructional practices. The approach taken to this concept is the incorporation and improvements of vegetation or their parts into traditional hydraulic or geotechnical engineering. Surface protection methods are used as covering techniques for soil conservation and stability. Stabilization methods use live materials, which some methods may combine dead and live vegetation, for erosion control and improving stability of slopes. Other techniques use support structures without living materials are less favorable, but helpful to augment living material constructions. Supplementary methods are categorizes separate and useful for specific, effective facilitation of climax communities, which can be costly. Maintenance, care, and monitoring is discussed and detailed in the latter part of the document. Topics of plant care, soil conditions, irrigation, and long-term maintenance to dams and bank mowing.

Construction of brush mattress is slope surface covering with dense layer of long and large, branches or rods of sprouting willows (shorter 1.5m). The branches or rods should be vertically inclined to 20^{o}. Geotextiles with biotechnical are usually made of biodegradable materials like jute, kokos, wood-wool, reed, flax, or synthetic fibers (cellulose). This method is used to stabilized loose topsoil layers until roots of plant take over. Fascine (bush wattles) sprouting materials are placed in ditches with at least 5 rods, each a diameter of at least 1cm, along waterways. Thin fascines are incorporated on front edges of the front end of shallow ditches with fixed pegs every meter, which is called groove or cordon structures. Wattle (wicker) fences are wooden poles or pegs driven into the soil at 1m apart. The fences are embedded in the soil and are used for slope cutting or dams. Live slope grating involves grating of wooden, metals, plastic and concrete poles are sixed to slope surface with living plant pegs or poles used for very steep slopes. Vegetated palisades are plants driven into soil side-by-side to form a palisade, and branch layers in gullies are similar in idea to geotextiles or fascines that place live branches in gullies that form a wish-bone pattern with tops. Riprap is mentioned.

Layering structures include side cuttings that are less than a meter berms or terraces built from bottom layer to top. Hedge layer are side-by-side wide terrace rooted plants covered with soil and the last layer is above the surface. Brush layer construction is similar; terraces are dug and on a 10° to 90° incline are branches placed cross-wide so that ¼ meter of branches reach above surface. A hedge-brush mix can be used to secure side cutting slope, local small sides and landfills. A section discusses placement of cutting, which would drive a clump of plants into soil perpendicular to surface. Joint planting would incorporate placement within dry stonewalls or rock-pavings after construction. Crib walls with branch layering look like longitudinal elements and crossing of wood, concrete, steel, or plastic material that alternates to join to form a box-like walls. Gravel and soil within layers of living branches fill space of the walls. Gabions are stiffer boxes or rolls (flexible) of meshed wire filled with coarse gravel that have living plants growing from roots intertwined and mixed in the structure. Log brush and branch packing are used to restore severe bank damage while combining several biotechnical methods. This concept can be applied to log brush barriers, which are "sandwich" of mattresses of live branches and gravel layering on top of each other. (E)

Eubanks, C.E., and Meadows, D., and Cremer, J.S. (2002). *A soil bioengineering guide for streambank and lakeshore stabilization FS-683.* Retrieved November 2012 from http://www.fs.fed.us/publications/soil-bio-guide/.

This guide includes information bioengineering projects that include successfully planning and implementation strategies. There is basic information provided on ecology and stream dynamics, which is in the introduction as well. The audience is specific to those doing the project for ideas. Effectiveness is more challenging to these bioengineering techniques. The first chapter explores interaction between humans and the environment as it related to the watershed as well as treating problems along reaches of streams. The second chapter details more about riparian ecosystem and its connection or relationships among composition, structure, and function within upland forest and streambanks. Chapter three is another section of river and stream ecological and dynamic relationships. Chapter four is the meat of the planning, designing, and implementing process, which include tips, materials, and available tools. The last chapter explains the various bioengineering techniques used in combinations or individually in projects. The guide indicates the need for a functioning riparian ecosystem and provides examples of some functions as well as a description of what is meant to be a failing ecosystem. The photos complement many of the discussed as examples of issues, situation, techniques. Overall, the last two chapters are most useful, especially as a complementary guide for riparian bioengineering projects. (E)

Fausch, K.D., and Northcote, T.G. (1992). Largse woody debris and salmonid habitat in a small coastal British Columbia Stream. *Canadian Journal of Fisheries and Aquatic Sciences,* 49:682-693

A study was conducted on a small British Columbia stream that had previously been cleaned of large woody debris (LWD), and was compared with sections with undisturbed or untouched debris for at least 40 years. Three sections were looked at in particular that had simple habitats in the removed debris locations and four locations where debris remained were complex systems. The results showed standing crop and coho individual weights (1year and older) as well as cutthroat trout were significantly higher in complex than simpler systems, which incorporated undisturbed LWD. There was a positive relationship between salmonids (1year and older) and sectional pool volume. In 1990, the previous removal of debris contributed to a loss of 8kg in salmonid biomass, 5Xs the standing crop. (O)

Gray, D.H., and Sotir, R.B. (1996). Biotechnical and soil bioengineering slope stabilization: a practical guide for erosion control. John Wiley & Sons, Inc.: New York.

This book begins with discussing biotechnical, or soil bioengineering, approaches to erosion control and bank stabilization. It then goes into detail on surficial and mass erosion, slope failures, and informative tables and equations to complement the text. A descriptive table on p37 of Chapter 2 indicates the basis for classifying mass soil movements. A useful section on root morphology and strength classifies and defines terminology off the root systems and grading desgins. Like other more recent publications or books, the information on suitable plants, engineering functions, and bioengineering techniques are included in the book. (O)

Habersack, H., Piegay, H., and Rinaldi, M. [Editors] (2008). Gravel bed rivers VI: from process understanding to river restoration. Elsevier: Oxford.

This book focuses on gravel-bed rivers, the scale of analysis, the analysis process, and basin to channel parameters (sediment, storage, instabilities). The authors also include ecohydrology and ecohydraulics into the operations, processes, and biological and ecological components of gravel beds. River management and restoration is the last piece of the book that includes an example, uncertainty, impact of forest decline and restoration of another example river.

Multiple scales in river section characterize the rivers based on length and time. River behavior also occurs at different scales. Turbulent fluid motion is determined by fluid properties. Texture of boundary materials is important for resistance to flow and sediment entrainment. Macroscale (turbulent motion is confided by boundaries) also examines size of the channel that water passing through channel and channel depths are critical. Generally, scaling of channels depend on sediment fluxes, valley gradient, and channel morphology. From all these conditions, the channel state can be determined. The physical scales are over laid ecological scales expressed by aquatic organisms.

New ways of addressing bed characteristics are through approaches of degree of freedom, computing power, and remote sensing or modeling methods. A point raised was examining streams at different scales of self-organizing and spatially variable in nature with temporal fluctuations. The hydrodynamics of gravel-bed rivers must consider scale as an inherent property of which include velocity spectra and hydrodynamic equations. Three-range spectral model for gravel-bed rivers, which could be refined to four, allow setting scales of simulations and defining fluid motions associated with turbulence-related interactions with flow and biota. It is suggested to begin with models then move to experimental support if needed. Another issue lies with averaging the hydraulic flows that incorporate time and space in transport equation known as double-averaging. This equation would include suspended sediment, passive substances, and fluid momentum. Examples are presented in chapter 3.

Another study in the book aims to provide better knowledge and understanding of flow in the hyperheic interstitial that is influenced by turbulence in the main flow. Pressure and velocity fluctuations decreased with increase gravel depth, especially in the first gravel layers. A study then explored the stream-interstitial pore water in the hyporheic zone, which flow velocity is difficult but oxygen supply and thermal conditions are dependent. Velocity calculated using time-lag, and temperature damping are compared with 1D-numerical models, which the latter appeared appropriate.

Bifurcation behavior of in gravel-bed streams of recent experimental and theoretical work examined occurrence, the8999999990 interactions between bed and bank evolutionary at maximum amplitude of its oscillation, and migration speed of bars form in channel. Migrating bars control an important result of this study showed that stability of bifurcation as well as adaption of channel width and planform and morphodynamic influence. Evolution may depend on the trigger of the flow bifurcation. It is also explained that gravel-bed channels formed in coarse sediment or mix bedrock-coarse sediment hold higher thresholds to fluvial erosion than finer-grained sediments. Variables would include: hydroclimatic and damburst processes, position within drainage basin, erosional threshold, sediment supply, land use, in-channel wood, riparian vegetation, and time since last flood. There are also geomorphic and ecological effects of floods, which impact the channel and the riparian and aquatic community.

Modeling of bank erosion processes and mechanisms, that include fluvial erosion and mass failure, and research can aid in future progress. A chapter on this topic reviews mass mechanism failures that use limited equilibrium models in bank stability assessments. Progress leads to understanding and modeling the positive and negative pore water pressure, confining river pressures, and hydrograph characteristics. Key limitations are in few studies examined interactions between these studies and feedbacks between them. *"The higher flows support higher* *transport rate of coarser material and the lower flows support a lower transport rate of finer materials."* The cycling of discharge in rivers can evolve to minimal changes in flow, mean bed elevation/averaged over bars, and surface grain size, which the variables are incorporated into bed load.

Bed load transport and streambed structure in gravel streams phenomena being research enable allow for greater understanding in the context of watershed processes and characteristics. Some of this understanding is within the interaction between sediment supply, armor layer development, and bed load transport. Likewise the basin scale sediment discharge, over longer time scales, has shown non-stable relationship with waters discharge when routed through prototype catchment. Simulated 90 years of data of bedload rating curve models indicate that long-term basin-scale between the parameters mentioned above during stable climatic periods, and can help predict future changes in climate change. An example of New Zealand landscape portrays complex systems and behavior of watershed-based relations and can add challenges in predictions and control of the dynamic interactions spatially and temporally, especially with anthropogenic activities. Other scale, sediment organization, and variability (spatial and temporal) case study examples are in places of Maryland, Wyoming, etc.

A chapter study focuses on evolution sediment waves, which are created by large input sources, and transport capacity in heterogeneous rivers. Models and evidence from studies indicate strong influence on wave evolution from this sediment transport. Patterns (3D) of erosion and deposition related to sediment waves indicate the unsolved problems for the changing alluvial forms and effect on aquatic and riparian ecosystems. The result would be changes in channel morphology and bed texture. The stress of the book portrays the importance of scale in which segregates bedforms into micro, meso, macro, and mega forms. An excellent hierarchical bedform classification is described on p477.

Ecological responses to disturbance regime, life history traits of organisms (riparian and aquatic), and anthropogenic activity are also seen in segment scale, intermediate reach-scale, and microhabitat include spatial and temporal variables. The 19th chapter is focused on this issue and shows that activities of sediment control dams and gravel mining in rivers and floodplains. Contemporary morphological changes in New Zealand braided rivers of Canterbury case study indicate field and laboratory methods of recent development indicate the tendency for the evolution of into single-braid channel from vegetation encroachment. Challenges and facts from a severe flood in various parts of Switzerland are collectively described in chapter 22.

The effects of alterations of large reservoirs and fragment river systems are substantial, and little is being done to address the fluvialmorphologic and ecohydraulic aspects of fish habitat and substrate regimes of the channels. About this topic, chapter 23 looks at the example in the Pacific Northwest, US, that look at examination and quantification of the effects of reservoir operations, ecological results in predictions, and evaluation restoration possibilities. Chapters to follow address macroinvertebrate movement across gravel-bed substrate under increased discharge, ecological implications and hydraulic geometry, and importance of gravel bars in flora and woody vegetation substrate for recruitment/colonization/development.

The last sectional chapters focus on river management and restoration, challenges that arise, uncertainty, and modifications at landscape scales to reach scale. (E)

Hayes, D.F. [Editor]. (1998). Engineering approaches to ecosystem restoration: wetlands engineering and river restoration conference 1998. CD.

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Hoag, J.C., Berg, F.E., Wyman, S.A., and Sampson, R.W. (2001). Riparian planting zones in the intermountain west. *Riparian/Wetland Project Information Series No. 16*. Retrieved November 2012 from http://plant-materials.nrcs.usda.gov/pubs/idpmcarwproj16.pdf.

The document stresses the importance of proper selection of plant species, site location, and material procurements. Also emphasized was location of existing vegetation to streams and water-table levels. Rhizomatous root systems are planted from water line to top of bank zones and herbaceous plants preferring wetlands are planted in stream cross-section up to upland zones. The document describes riparian plantings zones, which are: toe zone (below water elevation or levels), bank zone (between water level and bankfull discharge elevation), overbank zone (between bankfull discharge and overbank elevation), transitional zone (between overbank and floodplains), and upland zone (above floodplain). Species in each zone is well adapted to the conditions and different degrees of erosion or erosional causes.

The document then discussed hydrolic zones within toe and bank areas. These zones include deep-water pool (3-6ft), shallow water bench (2-18in), shallow water fringe (0-2in), and shoreline fringe (permanent moisture and periodically inundated). Post installation monitoring improves probability for future projects are also discussed. (E – G)

-----. and USDA-NRCS Plant Materials Center. (2007). *How to plant willows and cottonwoods for riparian restoration*. Retrieved November 2012 from http://www.plant-materials.nrcs.usda.gov/pubs/idpmctn7064.pdf.

This technical note indicates a growing interest of rehabilitation of riparian zones with use of willows and cottonwoods. Research is being placed on meeting the needs of riparian rehabilitation. Three principles to understand before planting vegetation state elevation that should be a gradual transition to rise away from and roughness increase from the center of the channel. Planting should be done after a number of steps have been taken. These include: site assessment, inventory of planting site, and detailed survey and evaluation of soils, water, and vegetation (p3). Site assessment would include the causes and problems for erosion, and what sections need the most work. Considerations for cottonwood or willow planting site should address management, if they are local, and if establishment and success of survival is possible. Plantings would greatly be successful if it was similar to vegetated areas. Areas with great stream velocities should consider structural and bioengineering techniques with vegetation. Species selected should also include native riparian species with willows and cottonwood and appropriate for soil conditions.

Willows species come in three types: tree, shrub, and creeping. Authors suggest that suckers and rhizomatous species be used. The commonly used shrub willows are rhizomatous or creeping. Upland willow species, such as the scouler willow, are common on moist area of intermittent watercourses, whereas wetland willows grow in standing water. It is mentioned that species with deep or rhizomatous root systems might be better suited for ice flow and greater velocities of water flow. Plants listed that wildlife or livestock find palatable include willow, cottonwood, chokeberry, skunkbush, sumac, golden current, serviceberry, Syringa, and silver buffaloberry; these may be disadvantageous for riparian zones. Thus, less favorable species such as hawthorn, Woods' rose, Douglas spirea, dogwood, river birch, thinleaf alder, and common snowberry may be better suited in certain conditions. Unfortunately, it is not known as to whether these species are specific to a region, ie. mid-west USA.

Regardless, cottonwood and willow species tend to be tolerant to fire and resprout that account for preference of species based on ecological zones and floodplains. Native species should be 2 years or older, which can be sourced at nurseries, near rehabilitation sites, and like conditions. Harvest timing is ideal when cutting is from live, dormant willow or cottonwoods in late fall, winter, or early spring after leaves fallen and before buds break. In situations, such as salmon runs, harvesting of cuttings (3/4 inches to 3 inches diameter) when plants are in full leaf. It is also mentioned and detailed for diameter of cutting and depth of hole (larger stem, deeper hole; min 3-5ft into ground) as well as its length to water-table.

Once species are selected, planting design and development on the site should be specific to preventing future erosion from water in early spring to late fall. Shrubby species generally are planted on outside of curves, which have flexible stems. Trees are then planted up bank from shrubs or on the bank tops, which the shrubs allow protection for the trees by this design. Spacing of the species, whether they are cuttings, whips, plugs, conetainers, bare-root, potted, clumps, balled-and-burlap, and paper-sleeved, should consider root development, carbohydrate reserves, pest/disease problems, and moist soil conditions. For instance, space considerations are 1-3ft for creeping, 3-8ft for shrubs, and 6-16ft for trees. Advantages and disadvantages of nursery stock are available. The technical note includes details on each type of sapling. Cuttings divide softwood, semi-hardwood, and hardwood (deciduous, narrowleaf evergreen, broadleaf evergreen) categories.

Overall this technical paper is excellent in its detail of planting and steps, including ideal plants for harvesting and suggestions for helping inexperienced planters know what side of the cutting is its top. The paper goes into detail of hoe to proceed with storage and treatment of cuttings, such as 33-40°F cooler and pre-soaking prior to planting (24hrs). Permits, management, and maintenance/monitoring are mentioned as sections in the technical note as well. (E)

------., Simonson, B., Cornforth, B., and St. John, L. (2001). *Waterjet stinger a tool to plant dormant unrooted cuttings of willow, cottonwood, dogwood and other species*. Retrieved November 2012 from ftp://ftp-fc.sc.egov.usda.gov/NDCSMC/Stream/pubs/WaterjetStinger.pdf.

This document explores planting of dormant unrooted cuttings for streambank stabilization and riparian buffer plantings, which are often limited to easily sprouting, dormant hardwood cuttings. Most practices for planting unrooted cuttings are average 5 to 6 feet, which most planting project requires a depth of 3 to 6 ft. The issues arise in digging holes deeper than 3 to 4 ft. As a result, equipment developed into the Waterjet Stingern despite the concept having a place in history. The procedure of scalping the ground for the hydrodrill hole allows for planting of the bundle of cuttings. Greater detail is given to the process, safety, and includes photos within the document.

Waterjet stinger uses high-pressure water to hydrodrill holes in the ground, which is applicable to planting unrooted hardwood cuttings. The parts of the equipment are a nozzle, stainless steel welded to steel pipe, a vertical lift (<18ft), and powered by gasoline allowing the machine to be 80psi or higher. Generally, this is powered in order to provide 120 gallons/minute output through a garden hose. The document uses the example to explain the used and practicality of the tool in hole drilling for planting of willow or cottonwood cuttings. Overall, benefits of this tool include: easy to operate, easy to transport, fast results, greater plantings per time period, moistens environment for roots, and reduces air pockets of the root zone. (O)

Hilderbrand, R.H., Lemly, A.D., Dolloff, C.A., and Harpster, K.L. (1996). Effects of large woody debris placement on stream channels and benthic macroinvertebrates. *Canadian Journal of Fisheries and Aquatic Sciences*, 54:931-939.

Large woody debris (LWD) was used as an experimental stream restoration technique in two streams of Virginia. The LWD designed to compare human judgment in log placements comparatively to randomized design and unmanipulated reaches. Another purpose for this study is to compare the effectiveness of low and high gradient stream. The results of the test indicated an increase of 146% in pool area in the systematic placement and 32% in random placement sections of the low-gradient streams. Thus, human judgment was shown to be effective than placing logs at random in low-gradient streams. On the other hand, high-gradient stream changed minimal after LWD add-ons were place that suggests hydraulic controls like boulders, bedrock, etc. counter act LWD influences in high-gradient streams. Dams are generally the reason for pools created from log additions regardless of method of which the logs were placed or the stream type.

The total benthic macroinvertebrates remained similar comparative to LWD additions or no placement. Net abundance decreased for stoneflies, beetles, caddisflies, and worms. Mayflies increased with proportional increase in pool area for the low-gradient stream. Clearest difference in sinuosity, width, depth, pool volume, and overhead cover for fish in channel morphology was complex than simple sections. The LWD were less evident, which volume and biomass were similarly subtle. Pool volume and overhead cover potentially provide important overwinter habitat for juvenile coho salmon and cutthroat trout. Cleaning woody debris form stream channel affects channel formation that affects salmonid populations. (E – G)

Orsborn, J.F., and Anderson, J.W. (1987). Stream improvements and fish response a bio-engineering assessment. *Water Resource Bulletin*, 22(3): 381-388.

Habitat improvements of natural streams can take many forms and the impacts can be positive or negative. The positive can be accomplished through careful and timely planning, design, installation, and monitoring of projects. The negative are often a result of rushing, lack of consideration for limiting factors, untrained or inexperienced personnel, force-fitting structures, lack of watershed plan, poor communication, and many more. Emphasis on integrated, bioengineering approach is incorporated in the discussions of the problems. General systems approach is a common problem in resource management. Factors that constrain project evaluations biologically, physically, economically, and in other parametric factors. Successful projects and recommendations for successful stream stewardships are also discussed in the article. (O – N)

Rosgen, D.L. (1997). *A geomorphological approach to restoration of incised rivers.* Retrieved January 2013 from http://www.wildlandhydrology.com/assets/a_geomorphological_approach_to_restoration_of_incised_rivers.pdf

The concepts of geomorphology incorporated incised, or v-shaped cut entrenchments, river restoration project in order to reestablish natural stability and river functionality. Applying morphological relations use the reference reach to help classify the stream. Designs can aim to return streams to its original elevation and re-connect floodplains to changing stream types. Where reference reach streams are most important is in incised streams and understanding the similar valley types in order to compare for restoration. The article uses examples of projects to show the incised river restoration methodology and ideas.

The author describes equilibrium, graded channel, probable natural state, and natural stability are synonymous in the paper. The restoration concepts of the paper describe it as restoring natural function, stability and biological conditions. In addition, understanding the causes of river/watershed instability or disequilibrium and possible morphological character of a stable form (stream classification, reference reach) are important. Evolutionary likelihood of rivers to change variables that shape and maintain form are altered, which can be seen in different types seen in the Appendix. (G)

-----. (n/a). *The cross-vane, w-weir, and j-hook vane structures… their description, design, and application for stream stabilization and river restoration.* Retrieved November 2012 from http://www.wildlandhydrology.com/assets/cross-vane.pdf.

This article describes descriptions, design specifications, placement locations, spacing and various applications of structures of cross-vane, w-weir, and j-hook. The development of these structures included 13 applications. The 13 listed were: established grade control, reduced streambank erosion, facilitate sediment transport, irrigation diversion structures, enhanced fish habitat, maintained ration of width/depth, improved recreational boating, maintained river stability, dissipated excess energy, withstood large floods, maintained channel capacity, compatible with natural channel design, and visually accepted to the public. Bankfull shear stress dictates sizes of rocks for the structures.

The structures showed to reduce near-bank shear stress and stream power, which the study focused on the 14 rivers with bankfull widths from 9m to 150m of slope 0.05 to 0.0003. Bedrocks of the study included cobble to gravel to sand bed streams. Monitoring and evaluating data dates back from 1986 over 48km of river following major floods. It is important for consideration of discharge, river flow, and potential river instability among six other variables (slope, width, depth, velocity, boundary roughness, size of sediment transported, and concentrations of sediment). The author detailed drawings, indicated footers, cross-section shape, profile shape, appropriate channel locations, angle, slopes, spacing, and elevation.

The document states that failures of river engineering structures result in design incompatibility with river dynamics. Overall, can enhanced river stability and functions to waterways with the diagrams and descriptions about j-hook, w-weir, and cross-vanes. It is noted that improvements can arise from monitoring, which should include softer structures. Spacing, placement, and design are emphasized in the document description. (G – O)

-----. (1998). *The reference reach a blueprint for natural channel design*. Retrieved January 2013 from http://www.wildlandhydrology.com/assets/the_reference_reach_ii.pdf

A reference reach, which is a stable stream, is used in channel design development based on morphology for stable stream type. Information collected and presented as ratios per stream type are used for extrapolation of reaches, reference or unstable, were for the purpose of restoration, stream enhancement, stabilization, or stream naturalization - from bankfull discharge and dimensions from stations (streamgage) for specific locations that correlate with drainage area to create curves at a regional level for extrapolated to non-gaged reaches. Equations used for restoration design is used for data developed empirically from stream types, which are important for regime equations implemented, are similar to stream characteristics. The advantage of using reference (stable) reaches are the ability to integrate dependent variables of streams dimensions, pattern, and profile with independent variables of streamflow, sediment regime, channel materials and valley slope. (G – O)

-----. (n.a). *The natural channel design method for river restoration*. Retrieved from January 2013 from http://www.wildlandhydrology.com/assets/FINAL_The_Natural_Chann_River_Restoration_pape_ASCE_2006.pdf

A four-decade research and restoration implementation process assist in developing the principles and procedural order of natural channel designs. A number of factors involved in channel design would include procedures that are analog, empirical, and analytical. The restoration process allows for integration of multiple disciplines and appropriate field implementation. The article indicates competence in sediment and capacity computations as important aspects of the assessment and design phases. There are eight series, which are: 1) define restoration objectives related to biological, physical, and/or chemical process; 2) develop regional and localized information on geomorphology and hydraulics; 3) conducting watershed assessment to establish river characteristics; 4) consider passive recommendations dependent on land use (move onto monitoring phase if passive efforts meet multiple objectives); 5) analytical testing of sediment and hydraulic transport and install natural channel design; 6) select and design vegetative measures and materials to meet state objectives; 7) implement proposed design and stabilization measures of layout, water quality, and construction; and 8) design plan for effectiveness, implementation, and validation in meeting set objectives. The last stage would be the design and implement of a maintenance plan. The approach is not a "simple cookbook", according to the author, who stresses the complexity of assessment and designing process. (G)

Schiechtl, H.M., and Stern, R. (1997). *Water bioengineering techniques for watercourse, bank, and shoreline protection.* Blackwell Science Ltd: Cambridge

The book begins with a chapter on planning and implementation that should fit and consider adjacent landscapes and the role of bioengineering plays out on water resource protection, maintenance, and costs. As with much of the newer literature, this book includes biological and ecological consideration. Water bioengineering techniques are discussed including the function and effects that include enhancement of aquatic and riparian habitat, greater microclimatic regulation, and water purification. Live construction materials section include trees, shrubs, grasses and legumes that can be used as biotechnical constitution. In addition, specific functions of bioengineering techniques are portrayed in a chart that describes soil, ground stabilization, combined construction, and supplementary techniques. Greater detail of the techniques follows in the next chapters on advantages, disadvantages, costs, timing, implementations, and materials. There are newer publications, manuals, books, or other documents with similar information that would have incorporated any improvements since 1994 and 1997.

Information on wetlands, Earth dam and floodbank construction using bioengineering techniques were in the latter chapters of the book. Care and maintenance was also incorporated into a chapter prior to the glossary. (O – N)

Schiff, R., MacBroom, J.G., and Bonin, J.A. (2006). *White paper: river restoration and fluvial geomorphology.* Retrieved November 2012 from http://des.nh.gov/organization/commissioner/pip/publications/wd/documents/r-wd-06-27.pdf.

The document discusses natural river forms and processes using spatial (catchment to reach) and temporal (flow of water and volume) scales and fluvial geomorphology (variables, discharge, channel classification, and channel evolution). The dynamic equilibrium, between water and sediment in channels, has threats to the river system, which include channel alterations, land cover changes, and climatic trends. A brief description of channel alterations includes straightening, smoothing, armoring/canalization, gravel mining, dams, and diversions and discharges. The integration of physical, chemical, and biological processes is being working into application, which link to functions and parameters of the river. River restoration discussed includes approaches to stabilization and design methods. Many approaches to restoration include passive or active as well as analytical, empirical, analog, or a combination of the three. The document depicts the differences between restoration (return to healthy state), rehabilitation (sites initially impaired), and enhancement (sites initially average).

These approaches can be applied into the design (natural to unnatural) of the project that incorporates the overall goals. The restoration processes include identification of site/ problem, establish goals and objectives, selection of design after alternatives are explored, implementation, continuous monitoring and assessing using adaptive management. These actions done must incorporate evolution of a river: sinuous (premodified) (Class 1), channelization (Class 2), degradation (Class 3), widening with more degradation (Class 4), aggradation with widening (Class 5), and quasi-equilibrium (Class 6). A chapter is dedicated to river restoration in New Hampshire specifically. Overall, this is a very informative document. (G)

Selvakumar, A., O'Connor, T.P., and Struck, S.D. (2010). Role of stream restoration on improving benthic macroinvertebrates and in-stream water quality in an urban watershed: case study. *Journal of Environmental Engineering,* 136(1): 127-139.

Long-term monitoring as an inclusive stream restoration project requirement is often overlooked. This study indicates the resulting lack of information about the success or failure of certain restoration techniques as an issue. This study was conducted by the National Risk Management Research Laboratory (part of the EPA Office of Research and Development) to evaluate the effectiveness of stream bank and channel restoration with intentions of improving in-stream water quality habitats. The Accotink Creek, Fairfax City, VA was the location used for sampling and monitoring prior to and after the restoration. Native plant material and bioengineering structures were used to stabilize the stream channel and bank, which reduces erosion and sediment load. The sampling and monitoring for two years indicated some improvement in biological quality for macroinvertebrate indices. Those indices below impairment levels were poor quality conditions. Stream restoration alone had little effect in improving conditions of in-stream water quality and biological habitat, but it has lessened further degradation of stream banks in critical areas, like those at risk. Storm-water flows as best management practices in watershed may reduce or delay discharge to stream, and improve habitat and water quality conditions. (E)

Smith, D.L., Bumstead, T.W., and Brannon, E.L. (2008). An engineered natural channel for coho salmon rearing. *American Fisheries Society Symposium*, no. 61:71-85

The article focused on side channels, which are important for habitats of resident species of the stream like coho salmon (*Oncorhynchus kisutch*). The study designed, constructed, and monitored a channel for rearing coho salmon. Authors had presented an alternative technique that could be incorporated into hatchery operations. Migration, growth, habitat use, and ultimate return rate were written as the collected data. Within the stream were riffles to ponds and large woody debris. Discharge, channel width, and invertebrate drift were prescribed and controlled by the authors. Fry from the 50,000 coho eggs incubated were enumerated and had emigrated so that resident fish were of their own will. Habitat use was collected from visual counts, snorkeling, and underwater video footage. Density showed a 7x higher in this constructed channel than in natural habitats. Thus, the result indicated that constructed streams could viably support fish and at higher densities comparative to natural habitat given the behavior of incubated fish was comparative to wild fish. (G)

Sudduth, E.B., and Meyer, J.L. (2006). Effects of bioengineered streambank stabilization on bank habitat and macroinvertebrates in urban streams. *Environmental Management,*38(2): 218-1226.

The article indicates that the stream restoration practices that are bioengineering based rarely conduct assessments of the ecological effect. The sampled bank macroinvertebrates and surveyed bank habitats indicated at four bioengineered sites in Atlanta, GA. Sampling and surveying was done at an unrestored site and a reference site in urban Peachtree-Nancy Creek as well. Three of the bioengineered sites incorporated similar methodology, which the other site used joint planting technique. Aside from that different bioengineered site and the unrestored site, the reference site as well as the three similar bioengineered sites (geotextiles fabrics and live cuttings) was higher in roots and wood for bank habitat. Pollution-tolerant taxa, i.e. chirmonids and oligochaetes, were present in high abundance at all the sampled sites. Other parameters – total biomass, insect biomass, non-chironomid insect biomass – were highest in two bioengineered sites. Higher biomass and abundance on organic habitat comparatively to inorganic habitat were common in all sites. A strong positively correlated relationship between the percent organic bank habitat with taxon richness, total biomass, and shredder biomass. The overall result of the effects on bank habitat and macroinvertebrate communities in urban streams, but impacts of urbanization cannot be completely mitigated. (E - G)

U.S. Army Corps of Engineers. (1998). *Illustrations of environmental engineering features for planning.* Retrieved December 2012 from http://www.iwr.usace.army.mil/docs/iwrreports/98r08.pdf.

The document states the purpose of the document is to discuss examples of many engineering features or management measures with their components with the audience of many managers, engineers, planners (water-related), and designers applicable to restoration projects. Thus, the document is intended to provide information for planning process. The content of this document is good; however, newer documentation have incorporated updates or refined procedure since the publication in 1998. The information is provided in concise, descriptions or "lines." The document also provided a visual tabular chart of summarized engineering features. This alone makes the document a good resource. The document incorporates pictures of current deflectors, sandbag, bank cribs (with cover logs), and bank shaping and vegetation. Bank shaping involves placing topsoil, soil materials, and plant growth to fill raw, eroded strambanks while vegetation includes planting of selected plants.

Bioengineering and techniques incorporate living vegetation to address instability (erosive and sedimentation related) problems. Appropriate conditions and applicability lead to successful projects. Key take-aways (EPA from 1999 based) are: a) accessibility to site, b) design to strengthen plants stability function, c) cost-effective, d) most successful installations during dormant season (late fall, winter, or early sping), e) long-term incremental increase in strength over time, f) small-scale projects, g) native or well-adapted species selection, and h) younger sapling do better in sprouting than older wood. Brushlayering systems are able to lift soil for slope or embankment reinforcement. Furthermore, techniques or coconut fiber/ coir rolls/mats and grass rolls, dormant posts/cuttings, blankets/turf (for temporary erosion control), gabions, and other are also described in their roles of stability and erosion control. Materials specifically like the Fabriform is also included within this section as well as various conditional limitations that would make some of these unsuitable. For instance, joint planting or vegetative riprap should be incorporated in where rocks or openings of riprap have existed as opposed to putting in log vanes; it makes more sense for the vegetation to be installed. (O)

US Department of Transportation, and Federal Highway Administration. (2009). *Bridge scour and stream instability countermeasures experience, selection, and design guidance third edition volume 1*. Retrieved January 2013 from http://www.fhwa.dot.gov/engineering/hydraulics/pubs/09111/09111.pdf.

THIS DOCUMENT HAS BEEN UPDATED IN 2009 FROM THE 1997 VERSION LISTED

The document opens with glossary of terms and definitions. The purpose of the document is to identify and provide guidelines for bridge scour and stream instability countermeasures implemented by many state department of transportation (DOTs) in the USA. The information in the document relates to the problems of scour and stream instability has on highway bridges as well as monitoring, planning and trial-and-error. This is volume one of two. These volumes are part of the Hydraulic Engineering Circulars, which the first parts include *Evaluating Scour at Bridges* and *Stream Stability at Highway Structures.* The scour monitoring program is part of the plan of action includes early identification of potential scour problems and precision on what was done if bridge is at risk of scouring.

The National Bridge Inspection Standards was established by a Technical Advisory, which provided the following guidance topics: 1) scour evaluation for new bridge designing, 2) evaluating bridge scour vulnerability, 3) use of scour countermeasures, and 4) improving state-of-practice for estimating scour at bridges. Frequency and type of inspection at bridge, including scheduled timely design and construction of scour countermeasures. Flood inspection is essential in identifying the scour conditions, what to do when detected, and repair measures.

A countermeasure matrix is described with countermeasures and their attributes that are developed. These countermeasures are broken into hydraulic, structural, biotechnical, and monitoring. The armoring countermeasures resist erosive hydraulic forces, which are characterized revetments and bed armoring or local scour armoring. Structural countermeasures involve modifying bridge structure to prevent scouring damage, such as foundation strengthening and pier geometry modifications. Biotechnical countermeasures are using vegetation over past decades to control streambank erosion or bank stabilizer. These include vegetated geosynthetic products, fascines/woody mats, vegetated riprap, root wads, and live staking. Lastly, monitoring is inclusive to activities used to facilitate early identification of potential scour or continuously checking in on the progress of scour. Two types instrumentation used to monitor bridge scour are fixed instruments and portable instruments.

The suitable river environment characteristics influenced by channel width, bankheight, configurations, vegetative cover, sediment transport condition, bend radius, ice, debris, and floodplain characteristics. The construction and maintenance requirements are dependent on the methods chosen. The countermeasures evaluated are dependent on five factors used to compute selection index of each countermeasures that include bed material size and transport, severity of debris/ice loading, constructability constraints, inspection and maintenance requirements, and life-cycle costs.

The document mentions countermeasures for meander migration, which would include protect an existing bank line, establishing new flow line/alignment, and control/ constrict channel flow. Countermeasures for channel braiding and anabranching also are discussed. Aggradation control for countermeasures is also included. Countermeasures for local scours, which happen at bridge piers and abutments, and methods to prevent damage are strengthening foundations or increasing stability. Riprap and reduction of debris build up are some practices that allow for strengthening piers and bridges.

A concept of life-cycle in the document looks at initial design, construction, maintenance, and monitoring. This should include the intended service-life for the countermeasure installation. Bank and bed characteristics, including factors affect stream or hydraulic conditions, should be acknowledged in design approaches. However, aspects of potential environmental impacts, maintenance, construction-related activities, legal aspects, and stream ecology must be considered in stream selection. Soils, aerial photography, permitting and field reconnaissance are also important factors a designer should shed light onto. In addition, relationships are described such as radial stress, shear stress, flow depth, and flow direction through equation.

A very valuable chapter devotes to riprap design, failure, and alternatives. Riprap consists of layer of rock with the purpose of erosion control. Disasters include mass failures when large section of riprap face gravitational forces and fall off (slumping and translational slides), which leads to scouring. Another is substrate particle erosion between the riprap and base material, which filters may help. Erosion later down the channel may also happen as well as migration or scouring leading to loss of toe support. Various other shapes of riprap may help. This chapter goes in great detail of riprap design, revetment, use for bridge piers or/and abutments specifically, and protection for countermeasures. Filters, such as geotextile/granular filters, allow for courser particles to be held in place through semi-permeable material that infiltrate and exfiltrate. Pier riprap failures could be contributed to ice, erosion, and flow or movement of hydromorphological/geomorphological. Stress is given to inspection of riprap and indicators of failures and deficiencies.

The chapter to follow explores biotechnical engineering, which includes vegetation (grasses and woody plants, ie trees, shrubs). The document indicates that vegetation should not be the only countermeasure to severe bank erosion or high-risk banks. The root system and exposed parts of the plants provide stability of soil and reduced velocity of flow/rainfall runoff. Soft revetments, or biotechnical engineering, are also known as bioengineering, soil/ground/ecological bioengineering. This document indicates lack of sufficient knowledge about bioengineering at the time of the document, but acknowledges success of effective erosion control in Europe and United States. Riprap or hard revetment mixed with vegetation is appropriate for geotechnical problems given benefits to additional strength, but may also have negative impacts on banks. Thus, the authors encourage correct design and installed. In order for appropriate methods the designer should look to watershed's stability. A list of commonly used vegetative methods and environmental considerations/benefits are provided for the reader. The later part of the guide includes information on toe zone, bank zone, and overbank zone treatments with bioengineering (lowest zone with shorter vegetation that leads to tall flood-tolerant, deep-rooted trees). Included in this later part are sections with diagrams of specific bioengineering techniques. See Appendix A for more specific information. (G)

US Department of Transportation, and Federal Highway Administration. (2009). *Bridge scour and stream instability countermeasures experience, selection, and design guidance third edition volume 2*. Retrieved January 2013 from http://www.fhwa.dot.gov/engineering/hydraulics/pubs/09112/manual.pdf.

THIS DOCUMENT HAS BEEN UPDATED IN 2009 FROM THE 1997 VERSION LISTED

This guideline builds off volume one. The six main chapters of this volume go in greater detail on countermeasures for streambanks, bridges, abutment and filter design. The stabilizing application is focused on bendway wiers/stream barbs, spurs, and check dams/drop structures. Bendway weirs/stream barbs are useful for bankline protection and flow alignment in meandering channel bends. Check dams/drop structures are useful in alleviating or preventing degradation of channels. Spurs are useful for bankline stabilization and flow alignment. More description is given in a quick design guideline in the beginning of the chapter, which greater detail follows in the first section of the document. This is helpful for the reader for finding application of the interested stream countermeasure. The general format for the guideline is to introduce the practice, and discuss the design concepts/considerations associated with that particular method as well as guidelines. Diagrams, formulas, and specifics, such as materials and examples, are detailed as it relates to that countermeasure approach. The authors then provide a case study to assist in the understanding and putting the information into real world context.

The next chapter discusses armoring or hard revetment – riprap, soil cement, concrete or grout mattresses and their intermixed versions. The purpose of this section is to give descriptive details on design guideline. See Appendix for diagram & descriptive sketches. (G)

BIOENGINEERING:

Allen, H.H., and Leech, J.R. (1997). *Bioengineering for streambank erosion control report 1 guidelines.* Retrieved November 2012 from http://www.engr.colostate.edu/~bbledsoe/CIVE413/Bioengineering_for_Streambank_Erosion_Control_report1.pdf.

The document acts as a guideline for bioengineering treatments or techniques, which can be done with hard toe/ flanking protection and deflection of water away from target reach to be protected through deflection structures. The document emphasizes using herbaceous and woody species with grass/grass-like plants where able. Shrubby, woody vegetation is ideal in the middle zone. Larger shrubs and trees are best the uppermost/canopy zone. Bed stability and whole subject area would need to be addressed holistic bank stability. Thus, planning and design models much are specific to reach site of interest.

This document highlights five mechanisms: 1) vegetation assists in erosion control, 2) dissipate wave energy, 3) intercept water, 4) enhanced water infiltration, and 5) deplete soil water by uptake and transpiration. These are done through vegetation's root systems, increase resistance to flow and velocities, buffer against the effects of transported materials, and close-growing vegetation induce sediment deposition. This guide emphasizes biological attributes and interdependence within the bioengineering project. The document mentions equipment, materials, and permit considerations. Monitoring and aftercare also is described with emphasis on documentation, cost, potential for areal photography with discussions on aerial components and wildlife like beavers. The last section of the document focuses on obtaining plants (wild or commercial with advantages and disadvantages), handling herbaceous and woody plants, and when to plant.

The main portion of the document begins with hard structures and examples shown as photos. Bioengineering zones of toe, splash, and bank are described as it related to plant considerations and water levels. Terrace zone is inland from riparian banks, which are less significant for protection from flooding. Bioengineering treatments include: stone or rock revetment, gabions, lunker, log revetments, deflectors, dikes, cribs, rock, and geotextile rolls, root wads, or combinations of the listed. Stone and rock are generally used in the toe. Splash zones may carry below toe zone stone to this level with vegetation. Bank zones are vegetation primarily. This document really focuses on practices of each zone, which adds a nice structure for the document. Much of the document has examples around the world of the techniques. Other document sources include more up-to-date techniques based on time-derived improvements and knowledge acquired over the years. (O – N)

Amaral, S.V., Mathur, D., and Edward, P.T., III. (2008). Advances in fisheries bioengineering. American Fisheries Society: The University of California.

Unable to access or obtain

American Society of Civil Engineers. (ASCE). (1998). *Engineering Approaches to Ecosystem Restoration.* Available at Wetlands, Engineering, and River Restoration Conference 1998.

This dated 3CD provides the emphasis interdisciplinary cooperation when it comes to restoring or establishing wetlands, riparian zones, and streams, which engineers have always been a part of. The papers presented from in the1998 ASCE Wetlands, Engineering and River Restoration Conference are available on the table of contents. The conference was held at Denver, Colorado during March 22-27, 1998. The paper's themed around river restoration approaches, wetland restoration, watershed management, and the use of constructed wetlands for water and wastewater treatment. Further information on the table of contents of the articles are available in the appendix. (O – N)

(2002, August). Advances in fisheries bioengineering. In Amaral, S.V., Mathur, D., and Taft, E.P., III. (Ed), *Fourth fisheries bioengineering symposium*. Symposium conducted in Baltimore, Maryland, USA.

This book presents 65 papers on bioengineering focused on habitat improvements, restoration, and mitigation with hatcheries. A table of contents has been provided. (G - O)

Bentrup, G., Hoag, J.C., and USDA NRCS. (1998). *The practical streambank bioengineering guide: user's guide for natural streambank stabilization techniques in arid and semi-arid Great Basin and Intermountain West.* Retrieved November 2012 from http://www.urbancreeks.org/The%20Practical%20Streambank%20Bioengineering%20Guide.pdf.

This guide is geared towards arid and semi-arid Great Basin and Intermountain West riparian ecosystems. Environmental stewardship is important to understand in relationship to stream and river connection to other resource. Much of the information in this document is within more recent documentation and publications, in particular streambank bioengineering options, design, and process. Unlike the Intermountainous West, Pacific Northwest does not have a strong economy central to agriculture. This document does take mountainous and arid considerations, which may be helpful to Alaskan climate. (N)

Berube, M., Gagnon, G., Hardy, L., and Bariteau, L. (2000). The stabilization of the Ottawa River Banks: a comparative study between bioengineering methods and a method based on natural gravel embankments installed in winter. *Ecohydraulics Proceedings of the 2nd international symposium on habitat hydraulics*, B718, 717-728

During the 1995-1996 winter the Ottawa River in Quebec experienced the start of a shore protection program. The project was large; over 70 km of shore stabilized along the Carillon dam. The different protection methods reviews and developed offered complex bioengineering techniques (natural gravel bank and vegetation). It was then decided to embank the foot of the slopes with 20 to 40 cm maximum diameter of 15% sand, which was the smallest to meet local erosion conditions. The resulting field tests of 1992 and 1993 demonstrated generally natural retake would cover over 80% of the sites within 5 years. Trees and dense plant community allowed for rapid retake of bank. The same embarkment was done elsewhere – Chisasibi – and is still functioning.

The significance of this study/test is that it is the first large-scale stabilization program of Quebec done in the winter, which ice was used as an access point to the banks. The project also was the first to submit and EIA (environ[mental impact assessment). (N)

Berube, M. (1986). Stream improvements and fish response: a bio-engineering assessment. *Ecohydraulics 2000 Proceedings of the 2nd international symposium on habitat hydraulics,* 22(3): 381-388.

Unable to locate the actual article.

Bragg, D.C., and Kershner, J.L. (2004). Sensitivity of a riparian large woody debris recruitment model to the number of contributing banks and tree fall pattern. *Western Journal of Applied Forestry,* 19(2):117-122.

Riparian large woody debris (LWD) recruitments models incorporate the traditional random angle fall of trees from two banks that are well-forested, which the assumptions was tested in this study. The quantity and direction of the simulated LWD appeared to not have an explicit interaction. Simulations of total recruitment with bank cover categories, which one or both banks were forested, are dependent on directionality of falling trees. The prediction of the models was the similar with one sided or two sided forested banks in the computer recruitment model using CWD and the random LWD recruitment. Thus, the study confirmed the benefit of checking consistency of simulated and actual local wood delivery to streams for local forest cover and tree pattern failure. One bank being forested provided less in volume and magnitude of the LWD compared to both banks being forested. (G)

Colt, J., White, R.J. [editors]. (1991). Fisheries bioengineering symposium. American Fisheries Society: Bethesda.

Given the date of the book publications and the articles, this reference is useful for more historical reference and change perspective. Articles are broken into subsections characterized by perspectives, habitats, fish passage, and fish hatcheries. An appendix of the articles in the book via table of content is provided. (N)

Darby, S., and Sear, D. (2008). *River restoration: managing the uncertainty in restoring physical habitat.* Retrieved January 2013 from http://www1.inecol.edu.mx/repara/download/III_1_RiverRestorationManagingTheUncertaintyInRestoringPhysicalHabitat_I.pdf

The document is very useful in addressing uncertainty in river restoration. The first chapter is divided into three sections that discuss the significance of river restoration uncertainty, sources of the uncertainty in research, and scope of uncertainty. A valid point made in the section is the complexity of uncertainty and the lack of sufficient interdisciplinary infrastructure to properly deal with the problems faced. Research, theories, and communication of scientific results can be biased, ambiguous and present gaps that add to the sources of uncertainty in scientific processes and river restoration knowledge. The idea of the adolescent practice of river restoration is "working" and is subjective, and in itself lending to uncertainty. The article explores what a lexicon uncertainty refers to in the context of terms, parameters, and potential synonyms.

The next focuses on planning and design of restoration projects, which include many angles and dimensions. An article is dedicated to the social and cultural significance that is best explored on the urban-rural-wilderness continuum. Humans respond in preference to veering views of landscapes within riparian communities and the participation of public and stakeholders are at the center for the restoration process. Value of riparian ecosystems is vast, and the approaches to restoration can cause conflict between professionals, legal groups, stakeholders, and citizens.

Mathematical modeling, thresholds, sources of error, and confidence are another important aspect of planning and design of projects, especially geomorphic models. Floodplain restoration also has uncertainty given the channels dynamic nature. Another article in this chapter focuses solely on the hydraulic and hydrological aspects of uncertainty for ecological purposes, as the title implies. The last article discusses uncertainty as it related ot ecological targets and response of river/ stream restoration.

The last sections of the document were not available on this pdf link. (E)

Doli, B.A., Grabow, G.L., Hall, K.R., Hailey, J., Harman, W.A., Jennings, G.D., and Wise, D.E. (1999?). *Stream restoration: a natural channel design handbook*. Retrieved November 2012 from http://www.bae.ncsu.edu/programs/extension/wqg/sri/stream_rest_guidebook/guidebook.html.

This document provides higher-knowledge description and into fluvial process including natural channel stability and channel profile patterns and dimensions. Stream assessment and survey procedures from both in the office and field, and measuring and profiling processes as well as forms, diagrams, and formulas. The Rosgen stream classification systems and channel assessment procedures at each level are discussed. Stream gage and bankfull verification through step by strep determination of indicators and others are introduced. Channel erosion is addressed and bank profiling, and incised streams with the position adjacent of instable banks. Priorities are important, like incorporate restoration and new stable channel of lower floodplain and narrow floodplain. Advantages and disadvantages are places in a tabular in terms of long-term results, stream stability, flooding, vegetation disruption, and others. The document also incorporates photos and diagrams to help with understanding. Reference reach section, for instance, incorporates survey, field and office procedures and where to references to help in understanding the topic.

Chapter 7 becomes most helpful, laying out succinct and precise step-by-step design procedures. The downfall of the documents section is its focus on math of shear stress. The following chapter is where bioengineering becomes the focus. Structural channel designs of root wad, vanes, and rock/boulders are discussed. The analysis, assessment, measurements, and stream characteristics all play into this decision. Variety and combination of techniques specific to nature vegetation and stream conditions allow for habitat improvement site specific and general site goals based on Roegen's work. Design criteria of root wad, for instance depicts requirements of 10 to 24 in basal area of trees above wad trunk length of 10 to 15 ft, and mats placed/stall at toe of bank. Bank heights are low 1 to 1½ times bankfull heights place boulders at least 1 ton or heavier behind root mat; high bank, if plenty of vegetation and biomass footer log, boulders may not be needed. Permanent seeding, maximum habitat diversity, and grand cover enable herbaceous species to utilize the areas. Also available are container plant material i.e. potted size and shapes that list of spp in appendix for North Carolina.

Erosion and sediment control plan three approaches to address potential sediment and erosion associated with stream restoration, which include: new channel in dry, pump/divert water around a project, and work in active channel. Diversion to divert water away, stream crossing coverts, ramps graded could be stone fence used to trap sediment waterways, disposal of runoff from fields, or coconut fibermat. Vanes include single, j-hook, cross-vane and w-weir created from large tree trunk or boulders. J-hook promotes streambank-redirecting thawleg away from the streambank and toward center of channel. Improve in-stream habitat by creating pools and oxygen and cover. All four technology 20^{o} to 30^{o} angles offbank located downstream of where stream flow encounters the streambank at acute angles. Vanes highest next to the bank are dependent on erosion rocks maybe needed, preferably flat downward, and pointed them upstream. Rock incorporation to the system is needed in all except j-hook. W-weir can be used to large rivers and similar to vanes.

Habitat enhancement through design and structures focused on diversion, pattern, profile, stream reaches proper riffle, pool sequences encouraging neolongation, woody vegetation overhanging rock, large woody debris. Vegetation stabilization and riparian buffer re-establishment can be salvaging on-site vegetation, these transplant in include live staking, bare-root plantings. More detail and information is available on the techniques. (G)

Donat, M. (1995). *Bioengineering techniques for streambank restoration: a review of Central European*

practices. Retrieved January 2013 from
http://www.env.gov.bc.ca/wld/documents/wrp/wrpr_2.pdf

The use of plants has been used in Europe for riverbank protection and erosion control has been a long practice. Versions of the methods discusses, also known as bioengineering, include ecological, economics, and aesthetic advantages that improve technical protection for riparian streambank rehabilitation, according to the author. Riparian vegetation and stream ecology are briefly highlighted as well as their ecological function (i.e. microclimate, bank security, habitats, provisioning services). Both mechanical and hydrological benefits are seen with bioengineering. Bioengineering, through trial and error, is described as replacing soft practices with hard constructional practices. The approach taken to this concept is the incorporation and improvements of vegetation or their parts into traditional hydraulic or geotechnical engineering. Surface protection methods are used as covering techniques for soil conservation and stability. Stabilization methods use live materials, which some methods may combine dead and live vegetation, for erosion control and improving stability of slopes. Other techniques use support structures without living materials are less favorable, but helpful to augment living material constructions. Supplementary methods are categorizes separate and useful for specific, effective facilitation of climax communities, which can be costly. Maintenance, care, and monitoring is discussed and detailed in the latter part of the document. Topics of plant care, soil conditions, irrigation, and long-term maintenance to dams and bank mowing.

Construction of brush mattress is slope surface covering with dense layer of long and large, branches or rods of sprouting willows (shorter 1.5m). The branches or rods should be vertically inclined to 20°. Geotextiles with biotechnical are usually made of biodegradable materials like jute, kokos, wood-wool, reed, flax, or synthetic fibers (cellulose). This method is used to stabilized loose topsoil layers until roots of plant take over. Fascine (bush wattles) sprouting materials are placed in ditches with at least 5 rods, each a diameter of at least 1cm, along waterways. Thin fascines are incorporated on front edges of the front end of shallow ditches with fixed pegs every meter, which is called groove or cordon structures. Wattle (wicker) fences are wooden poles or pegs driven into the soil at 1m apart. The fences are embedded in the soil and are used for slope cutting or dams. Live slope grating involves grating of wooden, metals, plastic and concrete poles are sixed to slope surface with living plant pegs or poles used for very steep slopes. Vegetated palisades are plants driven into soil side-by-side to form a palisade, and branch layers in gullies are similar in idea to geotextiles or fascines that place live branches in gullies that form a wish-bone pattern with tops. Riprap is mentioned.

Layering structures include side cuttings that are less than a meter berms or terraces built from bottom layer to top. Hedge layer are side-by-side wide terrace rooted plants covered with soil and the last layer is above the surface. Brush layer construction is similar; terraces are dug and on a 10° to 90° incline are branches placed cross-wide so that ¼ meter of branches reach above surface. A hedge-brush mix can be used to secure side cutting slope, local small sides and landfills. A section discusses placement of cutting, which would drive a clump of plants into soil perpendicular to surface. Joint planting would incorporate placement within dry stonewalls or rock-pavings after construction. Crib walls with branch layering look like longitudinal elements and crossing of wood, concrete, steel, or plastic material that alternates to join to form a box-like walls. Gravel and soil within layers of living branches fill space of the walls. Gabions are stiffer boxes or rolls (flexible) of meshed wire filled with coarse gravel that have living plants growing from roots intertwined and mixed in the structure. Log brush and branch packing are used to restore severe bank damage while combining several biotechnical methods. This concept can be applied to log brush barriers, which are "sandwich" of mattresses of live branches and gravel layering on top of each other. (E)

Eubanks, C.E., and Meadows, D., and Cremer, J.S. (2002). *A soil bioengineering guide for streambank and lakeshore stabilization FS-683.* Retrieved November 2012 from http://www.fs.fed.us/publications/soil-bio-guide/.

This guide includes information bioengineering projects that include successfully planning and implementation strategies. There is basic information provided on ecology and stream dynamics, which is in the introduction as well. The audience is specific to those doing the project for ideas. Effectiveness is more challenging to these bioengineering techniques. The first chapter explores interaction between humans and the environment as it related to the watershed as well as treating problems along reaches of streams. The second chapter details more about riparian ecosystem and its connection or relationships among composition, structure, and function within upland forest and streambanks. Chapter three is another section of river and stream ecological and dynamic relationships. Chapter four is the meat of the planning, designing, and implementing process, which include tips, materials, and available tools. The last chapter explains the various bioengineering techniques used in combinations or individually in projects. The guide indicates the need for a functioning riparian ecosystem and provides examples of some functions as well as a description of what is meant to be a failing ecosystem. The photos complement many of the discussed as examples of issues, situation, techniques. Overall, the last two chapters are most useful, especially as a complementary guide for riparian bioengineering projects. (E)

Fausch, K.D., and Northcote, T.G. (1992). Largse woody debris and salmonid habitat in a small coastal British Columbia Stream. *Canadian Journal of Fisheries and Aquatic Sciences,* 49:682-693

A study was conducted on a small British Columbia stream that had previously been cleaned of large woody debris (LWD), and was compared with sections with undisturbed or untouched debris for at least 40 years. Three sections were looked at in particular that had simple habitats in the removed debris locations and four locations where debris remained were complex systems. The results showed standing crop and coho individual weights (1year and older) as well as cutthroat trout were significantly higher in complex than simpler systems, which incorporated undisturbed LWD. There was a positive relationship between salmonids (1year and older) and sectional pool volume. In 1990, the previous removal of debris contributed to a loss of 8kg in salmonid biomass, 5Xs the standing crop. (O)

Gray, D.H., and Sotir, R.B. (1996). Biotechnical and soil bioengineering slope stabilization: a practical guide for erosion control. John Wiley & Sons, Inc.: New York.

This book begins with discussing biotechnical, or soil bioengineering, approaches to erosion control and bank stabilization. It then goes into detail on surficial and mass erosion, slope failures, and informative tables and equations to complement the text. A descriptive table on p37 of Chapter 2 indicates the basis for classifying mass soil movements. A useful section on root morphology and strength classifies and defines terminology off the root systems and grading desgins. Like other more recent publications or books, the information on suitable plants, engineering functions, and bioengineering techniques are included in the book. (O)

Habersack, H., Piegay, H., and Rinaldi, M. [Editors] (2008). Gravel bed rivers VI: from process understanding to river restoration. Elsevier: Oxford.

This book focuses on gravel-bed rivers, the scale of analysis, the analysis process, and basin to channel parameters (sediment, storage, instabilities). The authors also include ecohydrology and ecohydraulics into the operations, processes, and biological and ecological components of gravel beds. River management and restoration is the last piece of the book that includes an example, uncertainty, impact of forest decline and restoration of another example river.

Multiple scales in river section characterize the rivers based on length and time. River behavior also occurs at different scales. Turbulent fluid motion is determined by fluid properties. Texture of boundary materials is important for resistance to flow and sediment entrainment. Macroscale (turbulent motion is confided by boundaries) also examines size of the channel that water passing through channel and channel depths are critical. Generally, scaling of channels depend on sediment fluxes, valley gradient, and channel morphology. From all these conditions, the channel state can be determined. The physical scales are over laid ecological scales expressed by aquatic organisms.

New ways of addressing bed characteristics are through approaches of degree of freedom, computing power, and remote sensing or modeling methods. A point raised was examining streams at different scales of self-organizing and spatially variable in nature with temporal fluctuations. The hydrodynamics of gravel-bed rivers must consider scale as an inherent property of which include velocity spectra and hydrodynamic equations. Three-range spectral model for gravel-bed rivers, which could be refined to four, allow setting scales of simulations and defining fluid motions associated with turbulence-related interactions with flow and biota.

It is suggested to begin with models then move to experimental support if needed. Another issue lies with averaging the hydraulic flows that incorporate time and space in transport equation known as double-averaging. This equation would include suspended sediment, passive substances, and fluid momentum. Examples are presented in chapter 3.

Another study in the book aims to provide better knowledge and understanding of flow in the hyperheic interstitial that is influenced by turbulence in the main flow. Pressure and velocity fluctuations decreased with increase gravel depth, especially in the first gravel layers. A study then explored the stream-interstitial pore water in the hyporheic zone, which flow velocity is difficult but oxygen supply and thermal conditions are dependent. Velocity calculated using time-lag, and temperature damping are compared with 1D-numerical models, which the latter appeared appropriate.

Bifurcation behavior of in gravel-bed streams of recent experimental and theoretical work examined occurrence, the interactions between bed and bank evolutionary at maximum amplitude of its oscillation, and migration speed of bars form in channel. Migrating bars control an important result of this study showed that stability of bifurcation as well as adaption of channel width and planform and morphodynamic influence. Evolution may depend on the trigger of the flow bifurcation. It is also explained that gravel-bed channels formed in coarse sediment or mix bedrock-coarse sediment hold higher thresholds to fluvial erosion than finer-grained sediments. Variables would include: hydroclimatic and damburst processes, position within drainage basin, erosional threshold, sediment supply, land use, in-channel wood, riparian vegetation, and time since last flood. There are also geomorphic and ecological effects of floods, which impact the channel and the riparian and aquatic community.

Modeling of bank erosion processes and mechanisms, that include fluvial erosion and mass failure, and research can aid in future progress. A chapter on this topic reviews mass mechanism failures that use limited equilibrium models in bank stability assessments. Progress leads to understanding and modeling the positive and negative pore water pressure, confining river pressures, and hydrograph characteristics. Key limitations are in few studies examined interactions between these studies and feedbacks between them. *"The higher flows support higher transport rate of coarser material and the lower flows support a lower transport rate of finer materials."* The cycling of discharge in rivers can evolve to minimal changes in flow, mean bed elevation/averaged over bars, and surface grain size, which the variables are incorporated into bed load.

Bed load transport and streambed structure in gravel streams phenomena being research enable allow for greater understanding in the context of watershed processes and characteristics. Some of this understanding is within the interaction between sediment supply, armor layer development, and bed load transport. Likewise the basin scale sediment discharge, over longer time scales, has shown non-stable relationship with waters discharge when routed through prototype catchment. Simulated 90 years of data of bedload rating curve models indicate that long-term basin-scale between the parameters mentioned above during stable climatic periods, and can help predict future changes in climate change. An example of New Zealand landscape portrays complex systems and behavior of watershed-based relations and can add challenges in predictions and control of the dynamic interactions spatially and temporally, especially with anthropogenic activities. Other scale, sediment organization, and variability (spatial and temporal) case study examples are in places of Maryland, Wyoming, etc.

A chapter study focuses on evolution sediment waves, which are created by large input sources, and transport capacity in heterogeneous rivers. Models and evidence from studies indicate strong influence on wave evolution from this sediment transport. Patterns (3D) of erosion and deposition related to sediment waves indicate the unsolved problems for the changing alluvial forms and effect on aquatic and riparian ecosystems. The result would be changes in channel morphology and bed texture. The stress of the book portrays the importance of scale in which segregates bedforms into micro, meso, macro, and mega forms. An excellent hierarchical bedform classification is described on p477.

Ecological responses to disturbance regime, life history traits of organisms (riparian and aquatic), and anthropogenic activity are also seen in segment scale, intermediate reach-scale, and microhabitat include spatial and temporal variables. The 19th chapter is focused on this issue and shows that activities of sediment control dams and gravel mining in rivers and floodplains. Contemporary morphological changes in New Zealand braided rivers of Canterbury case study indicate field and laboratory methods of recent development indicate the tendency for the evolution of into single-braid channel from vegetation encroachment.

Challenges and facts from a severe flood in various parts of Switzerland are collectively described in chapter 22.

The effects of alterations of large reservoirs and fragment river systems are substantial, and little is being done to address the fluvialmorphologic and ecohydraulic aspects of fish habitat and substrate regimes of the channels. About this topic, chapter 23 looks at the example in the Pacific Northwest, US, that look at examination and quantification of the effects of reservoir operations, ecological results in predictions, and evaluation restoration possibilities. Chapters to follow address macroinvertebrate movement across gravel-bed substrate under increased discharge, ecological implications and hydraulic geometry, and importance of gravel bars in flora and woody vegetation substrate for recruitment/colonization/development.

The last sectional chapters focus on river management and restoration, challenges that arise, uncertainty, and modifications at landscape scales to reach scale. (E)

Hayes, D.F. [Editor]. (1998). Engineering approaches to ecosystem restoration: wetlands engineering and river restoration conference 1998. CD.

Unable to access DVD

Hoag, J.C., Berg, F.E., Wyman, S.A., and Sampson, R.W. (2001). Riparian planting zones in the intermountain west. *Riparian/Wetland Project Information Series No. 16*. Retrieved November 2012 from http://plant-materials.nrcs.usda.gov/pubs/idpmcarwproj16.pdf.

The document stresses the importance of proper selection of plant species, site location, and material procurements. Also emphasized was location of existing vegetation to streams and water-table levels. Rhizomatous root systems are planted from water line to top of bank zones and herbaceous plants preferring wetlands are planted in stream cross-section up to upland zones. The document describes riparian plantings zones, which are: toe zone (below water elevation or levels), bank zone (between water level and bankfull discharge elevation), overbank zone (between bankfull discharge and overbank elevation), transitional zone (between overbank and floodplains), and upland zone (above floodplain). Species in each zone is well adapted to the conditions and different degrees of erosion or erosional causes.

The document then discussed hydrolic zones within toe and bank areas. These zones include deep-water pool (3-6ft), shallow water bench (2-18in), shallow water fringe (0-2in), and shoreline fringe (permanent moisture and periodically inundated). Post installation monitoring improves probability for future projects are also discussed. (E – G)

-----. and USDA-NRCS Plant Materials Center. (2007). *How to plant willows and cottonwoods for riparian restoration*. Retrieved November 2012 from http://www.plant-materials.nrcs.usda.gov/pubs/idpmctn7064.pdf.

This technical note indicates a growing interest of rehabilitation of riparian zones with use of willows and cottonwoods. Research is being placed on meeting the needs of riparian rehabilitation. Three principles to understand before planting vegetation state elevation that should be a gradual transition to rise away from and roughness increase from the center of the channel. Planting should be done after a number of steps have been taken. These include: site assessment, inventory of planting site, and detailed survey and evaluation of soils, water, and vegetation (p3). Site assessment would include the causes and problems for erosion, and what sections need the most work. Considerations for cottonwood or willow planting site should address management, if they are local, and if establishment and success of survival is possible. Plantings would greatly be successful if it was similar to vegetated areas. Areas with great stream velocities should consider structural and bioengineering techniques with vegetation. Species selected should also include native riparian species with willows and cottonwood and appropriate for soil conditions.

Willows species come in three types: tree, shrub, and creeping. Authors suggest that suckers and rhizomatous species be used. The commonly used shrub willows are rhizomatous or creeping. Upland willow species, such as the scouler willow, are common on moist area of intermittent watercourses, whereas wetland willows grow in standing water. It is mentioned that species with deep or rhizomatous root systems might be better suited for ice flow and greater velocities of water flow. Plants listed that wildlife or livestock find palatable include willow, cottonwood, chokeberry, skunkbush, sumac, golden current, serviceberry, Syringa, and silver buffaloberry; these may be disadvantageous for riparian zones. Thus, less favorable species such as hawthorn, Woods' rose, Douglas spirea, dogwood, river birch, thinleaf alder, and common snowberry may be better suited in certain conditions. Unfortunately, it is not known as to whether these species are specific to a region, ie. mid-west USA.

Regardless, cottonwood and willow species tend to be tolerant to fire and resprout that account for preference of species based on ecological zones and floodplains. Native species should be 2 years or older, which can be sourced at nurseries, near rehabilitation sites, and like conditions. Harvest timing is ideal when cutting is from live, dormant willow or cottonwoods in late fall, winter, or early spring after leaves fallen and before buds break. In situations, such as salmon runs, harvesting of cuttings (3/4 inches to 3 inches diameter) when plants are in full leaf. It is also mentioned and detailed for diameter of cutting and depth of hole (larger stem, deeper hole; min 3-5ft into ground) as well as its length to water-table.

Once species are selected, planting design and development on the site should be specific to preventing future erosion from water in early spring to late fall. Shrubby species generally are planted on outside of curves, which have flexible stems. Trees are then planted up bank from shrubs or on the bank tops, which the shrubs allow protection for the trees by this design. Spacing of the species, whether they are cuttings, whips, plugs, conetainers, bare-root, potted, clumps, balled-and-burlap, and paper-sleeved, should consider root development, carbohydrate reserves, pest/disease problems, and moist soil conditions. For instance, space considerations are 1-3ft for creeping, 3-8ft for shrubs, and 6-16ft for trees. Advantages and disadvantages of nursery stock are available. The technical note includes details on each type of sapling. Cuttings divide softwood, semi-hardwood, and hardwood (deciduous, narrowleaf evergreen, broadleaf evergreen) categories.

Overall this technical paper is excellent in its detail of planting and steps, including ideal plants for harvesting and suggestions for helping inexperienced planters know what side of the cutting is its top. The paper goes into detail of hoe to proceed with storage and treatment of cuttings, such as 33-40°F cooler and pre-soaking prior to planting (24hrs). Permits, management, and maintenance/monitoring are mentioned as sections in the technical note as well. (E)

------., Simonson, B., Cornforth, B., and St. John, L. (2001). *Waterjet stinger a tool to plant dormant unrooted cuttings of willow, cottonwood, dogwood and other species*. Retrieved November 2012 from ftp://ftp-fc.sc.egov.usda.gov/NDCSMC/Stream/pubs/WaterjetStinger.pdf.

This document explores planting of dormant unrooted cuttings for streambank stabilization and riparian buffer plantings, which are often limited to easily sprouting, dormant hardwood cuttings. Most practices for planting unrooted cuttings are average 5 to 6 feet, which most planting project requires a depth of 3 to 6 ft. The issues arise in digging holes deeper than 3 to 4 ft. As a result, equipment developed into the Waterjet Stingern despite the concept having a place in history. The procedure of scalping the ground for the hydrodrill hole allows for planting of the bundle of cuttings. Greater detail is given to the process, safety, and includes photos within the document.

Waterjet stinger uses high-pressure water to hydrodrill holes in the ground, which is applicable to planting unrooted hardwood cuttings. The parts of the equipment are a nozzle, stainless steel welded to steel pipe, a vertical lift (<18ft), and powered by gasoline allowing the machine to be 80psi or higher. Generally, this is powered in order to provide 120 gallons/minute output through a garden hose. The document uses the example to explain the used and practicality of the tool in hole drilling for planting of willow or cottonwood cuttings. Overall, benefits of this tool include: easy to operate, easy to transport, fast results, greater plantings per time period, moistens environment for roots, and reduces air pockets of the root zone. (O)

Hilderbrand, R.H., Lemly, A.D., Dolloff, C.A., and Harpster, K.L. (1996). Effects of large woody debris placement on stream channels and benthic macroinvertebrates. *Canadian Journal of Fisheries and Aquatic Sciences*, 54:931-939.

Large woody debris (LWD) was used as an experimental stream restoration technique in two streams of Virginia. The LWD designed to compare human judgment in log placements comparatively to randomized design and unmanipulated reaches. Another purpose for this study is to compare the effectiveness of low and high gradient stream. The results of the test indicated an increase of 146% in pool area in the systematic placement and 32% in random placement sections of the low-gradient streams. Thus, human judgment was shown to be effective than placing logs at random in low-gradient streams. On the other hand, high-gradient stream changed minimal after LWD add-ons were place that suggests hydraulic controls like boulders, bedrock, etc. counter act LWD influences in high-gradient streams. Dams are generally the reason for pools created from log additions regardless of method of which the logs were placed or the stream type.

The total benthic macroinvertebrates remained similar comparative to LWD additions or no placement. Net abundance decreased for stoneflies, beetles, caddisflies, and worms. Mayflies increased with proportional increase in pool area for the low-gradient stream. Clearest difference in sinuosity, width, depth, pool volume, and overhead cover for fish in channel morphology was complex than simple sections. The LWD were less evident, which volume and biomass were similarly subtle. Pool volume and overhead cover potentially provide important overwinter habitat for juvenile coho salmon and cutthroat trout. Cleaning woody debris form stream channel affects channel formation that affects salmonid populations. (E – G)

Orsborn, J.F., and Anderson, J.W. (1987). Stream improvements and fish response a bio-engineering assessment. *Water Resource Bulletin*, 22(3): 381-388.

Habitat improvements of natural streams can take many forms and the impacts can be positive or negative. The positive can be accomplished through careful and timely planning, design, installation, and monitoring of projects. The negative are often a result of rushing, lack of consideration for limiting factors, untrained or inexperienced personnel, force-fitting structures, lack of watershed plan, poor communication, and many more. Emphasis on integrated, bioengineering approach is incorporated in the discussions of the problems. General systems approach is a common problem in resource management. Factors that constrain project evaluations biologically, physically, economically, and in other parametric factors. Successful projects and recommendations for successful stream stewardships are also discussed in the article. (O – N)

Rosgen, D.L. (1997). *A geomorphological approach to restoration of incised rivers.* Retrieved January 2013 from http://www.wildlandhydrology.com/assets/a_geomorphological_approach_to_restoration_of_incised_rivers.pdf

The concepts of geomorphology incorporated incised, or v-shaped cut entrenchments, river restoration project in order to reestablish natural stability and river functionality. Applying morphological relations use the reference reach to help classify the stream. Designs can aim to return streams to its original elevation and re-connect floodplains to changing stream types. Where reference reach streams are most important is in incised streams and understanding the similar valley types in order to compare for restoration. The article uses examples of projects to show the incised river restoration methodology and ideas.

The author describes equilibrium, graded channel, probable natural state, and natural stability are synonymous in the paper. The restoration concepts of the paper describe it as restoring natural function, stability and biological conditions. In addition, understanding the causes of river/watershed instability or disequilibrium and possible morphological character of a stable form (stream classification, reference reach) are important. Evolutionary likelihood of rivers to change variables that shape and maintain form are altered, which can be seen in different types seen in the Appendix. (G)

-----. (n/a). *The cross-vane, w-weir, and j-hook vane structures… their description, design, and application for stream stabilization and river restoration.* Retrieved November 2012 from http://www.wildlandhydrology.com/assets/cross-vane.pdf.

This article describes descriptions, design specifications, placement locations, spacing and various applications of structures of cross-vane, w-weir, and j-hook. The development of these structures included 13 applications. The 13 listed were: established grade control, reduced streambank erosion, facilitate sediment transport, irrigation diversion structures, enhanced fish habitat, maintained ration of width/depth, improved recreational boating, maintained river stability, dissipated excess energy, withstood large floods, maintained channel capacity, compatible with natural channel design, and visually accepted to the public. Bankfull shear stress dictates sizes of rocks for the structures.

The structures showed to reduce near-bank shear stress and stream power, which the study focused on the 14 rivers with bankfull widths from 9m to 150m of slope 0.05 to 0.0003. Bedrocks of the study included cobble to gravel to sand bed streams. Monitoring and evaluating data dates back from 1986 over 48km of river following major floods. It is important for consideration of discharge, river flow, and potential river instability among six other variables (slope, width, depth, velocity, boundary roughness, size of sediment transported, and concentrations of sediment). The author detailed drawings, indicated footers, cross-section shape, profile shape, appropriate channel locations, angle, slopes, spacing, and elevation.

The document states that failures of river engineering structures result in design incompatibility with river dynamics. Overall, can enhanced river stability and functions to waterways with the diagrams and descriptions about j-hook, w-weir, and cross-vanes. It is noted that improvements can arise from monitoring, which should include softer structures. Spacing, placement, and design are emphasized in the document description. (G – O)

-----. (1998). *The reference reach a blueprint for natural channel design*. Retrieved January 2013 from http://www.wildlandhydrology.com/assets/the_reference_reach_ii.pdf

A reference reach, which is a stable stream, is used in channel design development based on morphology for stable stream type. Information collected and presented as ratios per stream type are used for extrapolation of reaches, reference or unstable, were for the purpose of restoration, stream enhancement, stabilization, or stream naturalization - from bankfull discharge and dimensions from stations (streamgage) for specific locations that correlate with drainage area to create curves at a regional level for extrapolated to non-gaged reaches. Equations used for restoration design is used for data developed empirically from stream types, which are important for regime equations implemented, are similar to stream characteristics. The advantage of using reference (stable) reaches are the ability to integrate dependent variables of streams dimensions, pattern, and profile with independent variables of streamflow, sediment regime, channel materials and valley slope. (G – O)

-----. (n.a). *The natural channel design method for river restoration*. Retrieved from January 2013 from http://www.wildlandhydrology.com/assets/FINAL_The_Natural_Chann_River_Restoration_pape_ASCE_2006.pdf

A four-decade research and restoration implementation process assist in developing the principles and procedural order of natural channel designs. A number of factors involved in channel design would include procedures that are analog, empirical, and analytical. The restoration process allows for integration of multiple disciplines and appropriate field implementation. The article indicates competence in sediment and capacity computations as important aspects of the assessment and design phases. There are eight series, which are: 1) define restoration objectives related to biological, physical, and/or chemical process; 2) develop regional and localized information on geomorphology and hydraulics; 3) conducting watershed assessment to establish river characteristics; 4) consider passive recommendations dependent on land use (move onto monitoring phase if passive efforts meet multiple objectives); 5) analytical testing of sediment and hydraulic transport and install natural channel design; 6) select and design vegetative measures and materials to meet state objectives; 7) implement proposed design and stabilization measures of layout, water quality, and construction; and 8) design plan for effectiveness, implementation, and validation in meeting set objectives. The last stage would be the design and implement of a maintenance plan. The approach is not a "simple cookbook", according to the author, who stresses the complexity of assessment and designing process. (G)

Schiechtl, H.M., and Stern, R. (1997). *Water bioengineering techniques for watercourse, bank, and shoreline protection*. Blackwell Science Ltd: Cambridge

The book begins with a chapter on planning and implementation that should fit and consider adjacent landscapes and the role of bioengineering plays out on water resource protection, maintenance, and costs. As with much of the newer literature, this book includes biological and ecological consideration. Water bioengineering techniques are discussed including the function and effects that include enhancement of aquatic and riparian habitat, greater microclimatic regulation, and water purification. Live construction materials section include trees, shrubs, grasses and legumes that can be used as biotechnical constitution. In addition, specific functions of bioengineering techniques are portrayed in a chart that describes soil, ground stabilization, combined construction, and supplementary techniques. Greater detail of the techniques follows in the next chapters on advantages, disadvantages, costs, timing, implementations, and materials. There are newer publications, manuals, books, or other documents with similar information that would have incorporated any improvements since 1994 and 1997.

Information on wetlands, Earth dam and floodbank construction using bioengineering techniques were in the latter chapters of the book. Care and maintenance was also incorporated into a chapter prior to the glossary. (O – N)

Schiff, R., MacBroom, J.G., and Bonin, J.A. (2006). *White paper: river restoration and fluvial geomorphology.* Retrieved November 2012 from http://des.nh.gov/organization/commissioner/pip/publications/wd/documents/r-wd-06-27.pdf.

The document discusses natural river forms and processes using spatial (catchment to reach) and temporal (flow of water and volume) scales and fluvial geomorphology (variables, discharge, channel classification, and channel evolution). The dynamic equilibrium, between water and sediment in channels, has threats to the river system, which include channel alterations, land cover changes, and climatic trends. A brief description of channel alterations includes straightening, smoothing, armoring/canalization, gravel mining, dams, and diversions and discharges. The integration of physical, chemical, and biological processes is being working into application, which link to functions and parameters of the river. River restoration discussed includes approaches to stabilization and design methods. Many approaches to restoration include passive or active as well as analytical, empirical, analog, or a combination of the three. The document depicts the differences between restoration (return to healthy state), rehabilitation (sites initially impaired), and enhancement (sites initially average).

These approaches can be applied into the design (natural to unnatural) of the project that incorporates the overall goals. The restoration processes include identification of site/ problem, establish goals and objectives, selection of design after alternatives are explored, implementation, continuous monitoring and assessing using adaptive management. These actions done must incorporate evolution of a river: sinuous (premodified) (Class 1), channelization (Class 2), degradation (Class 3), widening with more degradation (Class 4), aggradation with widening (Class 5), and quasi-equilibrium (Class 6). A chapter is dedicated to river restoration in New Hampshire specifically. Overall, this is a very informative document. (G)

Selvakumar, A., O'Connor, T.P., and Struck, S.D. (2010). Role of stream restoration on improving benthic macroinvertebrates and in-stream water quality in an urban watershed: case study. *Journal of Environmental Engineering,* 136(1): 127-139.

Long-term monitoring as an inclusive stream restoration project requirement is often overlooked. This study indicates the resulting lack of information about the success or failure of certain restoration techniques as an issue. This study was conducted by the National Risk Management Research Laboratory (part of the EPA Office of Research and Development) to evaluate the effectiveness of stream bank and channel restoration with intentions of improving in-stream water quality habitats. The Accotink Creek, Fairfax City, VA was the location used for sampling and monitoring prior to and after the restoration. Native plant material and bioengineering structures were used to stabilize the stream channel and bank, which reduces erosion and sediment load. The sampling and monitoring for two years indicated some improvement in biological quality for macroinvertebrate indices. Those indices below impairment levels were poor quality conditions. Stream restoration alone had little effect in improving conditions of in-stream water quality and biological habitat, but it has lessened further degradation of stream banks in critical areas, like those at risk. Storm-water flows as best management practices in watershed may reduce or delay discharge to stream, and improve habitat and water quality conditions. (E)

Smith, D.L., Bumstead, T.W., and Brannon, E.L. (2008). An engineered natural channel for coho salmon rearing. *American Fisheries Society Symposium*, no. 61:71-85

The article focused on side channels, which are important for habitats of resident species of the stream like coho salmon (*Oncorhynchus kisutch*). The study designed, constructed, and monitored a channel for rearing coho salmon. Authors had presented an alternative technique that could be incorporated into hatchery operations. Migration, growth, habitat use, and ultimate return rate were written as the collected data. Within the stream were riffles to ponds and large woody debris. Discharge, channel width, and invertebrate drift were prescribed and controlled by the authors. Fry from the 50,000 coho eggs incubated were enumerated and had emigrated so that resident fish were of their own will. Habitat use was collected from visual counts, snorkeling, and underwater video footage. Density showed a 7x higher in this constructed channel than in natural habitats. Thus, the result indicated that constructed streams could viably support fish and at higher densities comparative to natural habitat given the behavior of incubated fish was comparative to wild fish. (G)

Sudduth, E.B., and Meyer, J.L. (2006). Effects of bioengineered streambank stabilization on bank habitat and macroinvertebrates in urban streams. *Environmental Management,*38(2): 218-1226.

The article indicates that the stream restoration practices that are bioengineering based rarely conduct assessments of the ecological effect. The sampled bank macroinvertebrates and surveyed bank habitats indicated at four bioengineered sites in Atlanta, GA. Sampling and surveying was done at an unrestored site and a reference site in urban Peachtree-Nancy Creek as well. Three of the bioengineered sites incorporated similar methodology, which the other site used joint planting technique. Aside from that different bioengineered site and the unrestored site, the reference site as well as the three similar bioengineered sites (geotextiles fabrics and live cuttings) was higher in roots and wood for bank habitat. Pollution-tolerant taxa, i.e. chirmonids and oligochaetes, were present in high abundance at all the sampled sites. Other parameters – total biomass, insect biomass, non-chironomid insect biomass – were highest in two bioengineered sites. Higher biomass and abundance on organic habitat comparatively to inorganic habitat were common in all sites. A strong positively correlated relationship between the percent organic bank habitat with taxon richness, total biomass, and shredder biomass. The overall result of the effects on bank habitat and macroinvertebrate communities in urban streams, but impacts of urbanization cannot be completely mitigated. (E - G)

U.S. Army Corps of Engineers. (1998). *Illustrations of environmental engineering features for planning.* Retrieved December 2012 from http://www.iwr.usace.army.mil/docs/iwrreports/98r08.pdf.

The document states the purpose of the document is to discuss examples of many engineering features or management measures with their components with the audience of many managers, engineers, planners (water-related), and designers applicable to restoration projects. Thus, the document is intended to provide information for planning process. The content of this document is good; however, newer documentation have incorporated updates or refined procedure since the publication in 1998. The information is provided in concise, descriptions or "lines." The document also provided a visual tabular chart of summarized engineering features. This alone makes the document a good resource. The document incorporates pictures of current deflectors, sandbag, bank cribs (with cover logs), and bank shaping and vegetation. Bank shaping involves placing topsoil, soil materials, and plant growth to fill raw, eroded strambanks while vegetation includes planting of selected plants.

Bioengineering and techniques incorporate living vegetation to address instability (erosive and sedimentation related) problems. Appropriate conditions and applicability lead to successful projects. Key take-aways (EPA from 1999 based) are: a) accessibility to site, b) design to strengthen plants stability function, c) cost-effective, d) most successful installations during dormant season (late fall, winter, or early sping), e) long-term incremental increase in strength over time, f) small-scale projects, g) native or well-adapted species selection, and h) younger sapling do better in sprouting than older wood. Brushlayering systems are able to lift soil for slope or embankment reinforcement. Furthermore, techniques or coconut fiber/ coir rolls/mats and grass rolls, dormant posts/cuttings, blankets/turf (for temporary erosion control), gabions, and other are also described in their roles of stability and erosion control. Materials specifically like the Fabriform is also included within this section as well as various conditional limitations that would make some of these unsuitable. For instance, joint planting or vegetative riprap should be incorporated in where rocks or openings of riprap have existed as opposed to putting in log vanes; it makes more sense for the vegetation to be installed. (O)

US Department of Transportation, and Federal Highway Administration. (2009). *Bridge scour and stream instability countermeasures experience, selection, and design guidance third edition volume 1*. Retrieved January 2013 from http://www.fhwa.dot.gov/engineering/hydraulics/pubs/09111/09111.pdf.

THIS DOCUMENT HAS BEEN UPDATED IN 2009 FROM THE 1997 VERSION LISTED

The document opens with glossary of terms and definitions. The purpose of the document is to identify and provide guidelines for bridge scour and stream instability countermeasures implemented by many state department of transportation (DOTs) in the USA. The information in the document relates to the problems of scour and stream instability has on highway bridges as well as monitoring, planning and trial-and-error. This is volume one of two. These volumes are part of the Hydraulic Engineering Circulars, which the first parts include *Evaluating Scour at Bridges* and *Stream Stability at Highway Structures.* The scour monitoring program is part of the plan of action includes early identification of potential scour problems and precision on what was done if bridge is at risk of scouring.

The National Bridge Inspection Standards was established by a Technical Advisory, which provided the following guidance topics: 1) scour evaluation for new bridge designing, 2) evaluating bridge scour vulnerability, 3) use of scour countermeasures, and 4) improving state-of-practice for estimating scour at bridges. Frequency and type of inspection at bridge, including scheduled timely design and construction of scour countermeasures. Flood inspection is essential in identifying the scour conditions, what to do when detected, and repair measures.

A countermeasure matrix is described with countermeasures and their attributes that are developed. These countermeasures are broken into hydraulic, structural, biotechnical, and monitoring. The armoring countermeasures resist erosive hydraulic forces, which are characterized revetments and bed armoring or local scour armoring. Structural countermeasures involve modifying bridge structure to prevent scouring damage, such as foundation strengthening and pier geometry modifications. Biotechnical countermeasures are using vegetation over past decades to control streambank erosion or bank stabilizer. These include vegetated geosynthetic products, fascines/woody mats, vegetated riprap, root wads, and live staking. Lastly, monitoring is inclusive to activities used to facilitate early identification of potential scour or continuously checking in on the progress of scour. Two types instrumentation used to monitor bridge scour are fixed instruments and portable instruments.

The suitable river environment characteristics influenced by channel width, bankheight, configurations, vegetative cover, sediment transport condition, bend radius, ice, debris, and floodplain characteristics. The construction and maintenance requirements are dependent on the methods chosen. The countermeasures evaluated are dependent on five factors used to compute selection index of each countermeasures that include bed material size and transport, severity of debris/ice loading, constructability constraints, inspection and maintenance requirements, and life-cycle costs.

The document mentions countermeasures for meander migration, which would include protect an existing bank line, establishing new flow line/alignment, and control/ constrict channel flow. Countermeasures for channel braiding and anabranching also are discussed. Aggradation control for countermeasures is also included. Countermeasures for local scours, which happen at bridge piers and abutments, and methods to prevent damage are strengthening foundations or increasing stability. Riprap and reduction of debris build up are some practices that allow for strengthening piers and bridges.

A concept of life-cycle in the document looks at initial design, construction, maintenance, and monitoring. This should include the intended service-life for the countermeasure installation. Bank and bed characteristics, including factors affect stream or hydraulic conditions, should be acknowledged in design approaches. However, aspects of potential environmental impacts, maintenance, construction-related activities, legal aspects, and stream ecology must be considered in stream selection. Soils, aerial photography, permitting and field reconnaissance are also important factors a designer should shed light onto. In addition, relationships are described such as radial stress, shear stress, flow depth, and flow direction through equation.

A very valuable chapter devotes to riprap design, failure, and alternatives. Riprap consists of layer of rock with the purpose of erosion control. Disasters include mass failures when large section of riprap face gravitational forces and fall off (slumping and translational slides), which leads to scouring. Another is substrate particle erosion between the riprap and base material, which filters may help. Erosion later down the channel may also happen as well as migration or scouring leading to loss of toe support. Various other shapes of riprap may help. This chapter goes in great detail of riprap design, revetment, use for bridge piers or/and abutments specifically, and protection for countermeasures. Filters, such as geotextile/granular filters, allow for courser particles to be held in place through semi-permeable material that infiltrate and exfiltrate. Pier riprap failures could be contributed to ice, erosion, and flow or movement of hydromorphological/geomorphological. Stress is given to inspection of riprap and indicators of failures and deficiencies.

The chapter to follow explores biotechnical engineering, which includes vegetation (grasses and woody plants, ie trees, shrubs). The document indicates that vegetation should not be the only countermeasure to severe bank erosion or high-risk banks. The root system and exposed parts of the plants provide stability of soil and reduced velocity of flow/rainfall runoff. Soft revetments, or biotechnical engineering, are also known as bioengineering, soil/ground/ecological bioengineering. This document indicates lack of sufficient knowledge about bioengineering at the time of the document, but acknowledges success of effective erosion control in Europe and United States. Riprap or hard revetment mixed with vegetation is appropriate for geotechnical problems given benefits to additional strength, but may also have negative impacts on banks. Thus, the authors encourage correct design and installed. In order for appropriate methods the designer should look to watershed's stability. A list of commonly used vegetative methods and environmental considerations/benefits are provided for the reader. The later part of the guide includes information on toe zone, bank zone, and overbank zone treatments with bioengineering (lowest zone with shorter vegetation that leads to tall flood-tolerant, deep-rooted trees). Included in this later part are sections with diagrams of specific bioengineering techniques. See Appendix A for more specific information. (G)

US Department of Transportation, and Federal Highway Administration. (2009). *Bridge scour and stream instability countermeasures experience, selection, and design guidance third edition volume 2*. Retrieved January 2013 from http://www.fhwa.dot.gov/engineering/hydraulics/pubs/09112/manual.pdf.

THIS DOCUMENT HAS BEEN UPDATED IN 2009 FROM THE 1997 VERSION LISTED

This guideline builds off volume one. The six main chapters of this volume go in greater detail on countermeasures for streambanks, bridges, abutment and filter design. The stabilizing application is focused on bendway wiers/stream barbs, spurs, and check dams/drop structures. Bendway weirs/stream barbs are useful for bankline protection and flow alignment in meandering channel bends. Check dams/drop structures are useful in alleviating or preventing degradation of channels. Spurs are useful for bankline stabilization and flow alignment. More description is given in a quick design guideline in the beginning of the chapter, which greater detail follows in the first section of the document. This is helpful for the reader for finding application of the interested stream countermeasure. The general format for the guideline is to introduce the practice, and discuss the design concepts/considerations associated with that particular method as well as guidelines. Diagrams, formulas, and specifics, such as materials and examples, are detailed as it relates to that countermeasure approach. The authors then provide a case study to assist in the understanding and putting the information into real world context.

The next chapter discusses armoring or hard revetment – riprap, soil cement, concrete or grout mattresses and their intermixed versions. The purpose of this section is to give descriptive details on design guideline. See Appendix for diagram & descriptive sketches. (G)

FISH HABITAT:

Baldigo, B.P., and Warren, D.R. (2008). Detecting the response of fish assemblages to stream restoration: effects of different sampling designs. *North American Journal of Fisheries Management*, 28: 919-934. Retrieved February 2013 from http://ny.water.usgs.gov/projects/catskillgeopmorph/M06-171.pdf.

Abstract: "*Increased trout production within limited stream reaches is a popular goal for restoration projects, yet investigators seldom monitor, assess, or publish the associated effects on fish assemblages. Fish community data from a total of 40 surveys at restored and reference reaches in three streams of the Catskill Mountains, New York, were analyzed a posteriori to determine how the ability to detect significant changes in biomass of brown trout Salmon trutta, all salmonids, or the entire fish community differs with effect size, number of streams assessed, process used to quantify the index response, and number of replicates collected before and after restoration. Analyses of statistical power (probability of detecting a meaningful difference or effect) and integrated power (average power over all possible a-values) were combined with before–after, control–impact analyses to assess the effectiveness of alternate sampling and analysis designs. In general, the more robust analyses indicated that biomass of brown trout and salmonid populations increased significantly in restored reaches but that the net increases (relative to the reference reach) were significant only at two of four restored reaches. Restoration alone could not account for the net increases in total biomass of fish communities. Power analyses generally showed that integrated power was greater than 0.95 when (1) biomass increases were larger than 5.0 g/m2, (2) the total number of replicates ranged from 4 to 8, and (3) coefficients of variation (CVs) for responses were less than 40%. Integrated power was often greater than 0.95 for responses as low as 1.0 g/m2 if the response CVs were less than 30%. Considering that brown trout, salmonid, and community biomass increased by 2.99 g/m2 on average (SD 1⁄4 1.17 g/m2) in the four restored reaches,* *use of two to three replicates both before and after restoration would have an integrated power of about 0.95 and would help detect significant changes in fish biomass under similar situations.*" (E – G)

Bates, K., Barnard, B., Heiner, B., Klavas, J.P., and Powers, P.D. (2003). *Design of road culverts for fish passage.* Retrieved January 2013 from http://wdfw.wa.gov/publications/00049/wdfw00049.pdf.

This is an updated version since the working document published in 1999. The document is stated to be part of a series called Aquatic Habitat Guidelines, which was created by a consortium of individuals, agencies, and field services; such entities include owners, planners, designer, regulators, and public agencies. The information included is collectively from background science, literature, policy issues, site and vicinity environmental-assessment processes, project-design processes, standards and details, case studies, and riparian and aquatic communities, as indicated by the document. Habitat issues at road crossings lead to habitat loss, like rearing and spawning habitat, from culvert installation. Foods such as invertebrates are affected in survival, growth, and reproduction. Mitigation of the habitat loss is possible, but complete replacement and channel length are not. Gravel supplementation and supply should be used for mimicking natural gravel deposits.

Culverts also impact upstream and downstream (erode banks by velocity) hydrohaulic and contribute to habitat losses when channels are widened for fish passage. A suggestion to minimize this would be to minimize stream crossings. A stress on precautionary principle is used for asphalt coating and mitigation for water quality. In addition, undersized culverts can lead to bed instability, as backwaters and bed materials deposited the channel upstream. Ecological connectivity is the capacity of movement of organisms, materials or energy, which processes include movement and distribution of debris and sediment could be hindered through the culvert. This building up of debris, and trash racks or many pipes, blocks fish-passage barriers.

Channel maintenance from poor sitting road crossings and culverts is the greatest impact on aquatic habitats. The document indicates river floodplains are at the cross of highways and small streams, which excursions and avulsions across alluvial fans, and culverts fill with bed materials. For this reason, channel dredging becomes necessary and the removal of bed material is a leading cause of bank instability. Construction also my release sediment or pollution, temporary fish barriers, vegetative and bankline removal, and impeding water flow. The risk of culvert failure also exists.

Five major conditions that are barriers for migration, which are greatest occurrence at high stream flow include: excess drop at outlet, high velocity in barrel, inadequate depth in barrel, turbulence, and debris and sediment accumulation at inlet or internally to culvert. Washington state experience indicates replacement of culvert at about 25% of fish passages. Replacement is also seen with culverts with bridges and abandoned roadways. Three options – no slope, hydraulic, and stream simulation - for culvert designs exist. The section goes in some description on culvert sitting, land use planning, and bridges. Greater descriptions on no-slop design, hydraulic design, and stream-simulation design options. Channel profile and controls is considered and expanded on as it related to solutions or options in retrofitting existing culverts and evolution of the channel regrade. The final section of the document discusses tide- and flood-gate styles, orientation, latches and operators, fishways, hydrology as well as other ecological considerations. (E)

Bisson, Bilby, Bryant, Dolloff, Grette, House, Murphy, and others. (1987). *Large woody debris in forested streams in the Pacific Northwest: past, present and future.* Pages 143-190 in E.O. Salo and T.W. Cundy, editors. S*treamside Management Forestry and Fishery Interactions.* Univ. of Wash., Institute for Forest Resources, Contribution 57, Seattle, WA.

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Abstract: “*This paper reviews the form, function, and management of woody debris in streams, and reaches three major conclusions: (1) Large woody debris enhances the quality of fish habitat in all sizes of stream. (2) Removal of most trees in the riparian zone during logging, combined with thorough stream cleaning and short-rotation timber harvest, has altered the sources, delivery mechanisms, and redistribution of debris in drainage systems, leading to changes in fish population abundance and species composition. (3) There is an urgent need for controlled field experiments and long-term studies that focus on the protection of existing large woody debris in stream channels and the recruitment of new debris from the surrounding forest.*

Woody debris has long been considered a potential source of logjams that could block river navigation, water-based log transport, and the upstream passage of salmon and trout on their way to spawning grounds, but is now understood to play an important role in the creation and maintenance of fish habitat throughout entire rivers. Although wood itself eventually enters the food web of the stream ecosystem as it gradually decays, the major importance of debris lies in its structural characteristics and the way these features influence channel hydraulics. Physical processes associated with debris in streams include the formation of pools and other important rearing areas, control of sediment and organic matter storage, and modification of water quality. Biological properties of debris-created structures can include blockages to fish migration, provision of cover from predators and from high streamflow, and maintenance of organic matter processing sites within the benthic community. The locations and principal roles of woody debris change throughout the river system. In steep headwater streams where logs span the channel, debris creates a stepped longitudinal profile that governs the storage and release of sediment and detritus, a function that facilitates the biological processing of organic inputs from the surrounding forest, When the stream channel becomes too wide for spanning by large logs, debris is deposited along the channel margins, where it often forms the most productive fish habitat in main-stem rivers. In all but the smallest streams there is some degree of clumping, although the size and spacing of debris clumps generally increase in a downstream direction, Debris-related fish habitat can be found anywhere in small forested streams. In large rivers it is primarily associated with debris accumulations along the margins and secondary channel systems of the floodplain, although it also occurs behind and under very large pieces (intact boles and root wads) along main-stem gravel bars.

Changes in tree species composition, abundance, and input rates to streams resulting from forest management practices have differed according to location in the watershed, and many physical and biological processes have been altered by these changes in the river system's debris load. Several questions have not been fully explored, particularly with regard to the long-term consequences of streamside management for debris recruitment. Yet the majority of studies of streams in second-growth forests have demonstrated that the input of large, potentially stable debris from second-growth stands in which nearly all large merchantable trees had been harvested was significantly reduced relative to debris inputs from old-growth stands. Other studies have shown that loss of large debris has led to a shift in stream habitat composition that favored underyearling steelhead (Salmo gairdneri) and cutthroat trout (S. clarki) at the expense of the older troutage classes as well as both underyearling and yearling coho salmon (Oncorhynchus kisutch). Loss of debris has also reduced overwinter survival of all species. In order to *develop procedures that will protect existing instream debris, as well as provide a continued supply of the proper quantity and quality of large woody debris for the future, it will be necessary to test scientifically a variety of management options over a wide range of stream sizes. Many management procedures have been proposed, including techniques for removing slash from stream channels after logging, determining the configuration of buffer strips, selective harvesting within the streamside management zone, and deliberately adding debris to streams for habitat enhancement. Evaluation of these proposals will require a great deal of time and effort, as well as the cooperation of many resource management organizations. However, long-term research is essential in view of the complexity of debris management issues*." (G)

Bjornn, T.C., Kirking, S.C., and Meehan, W.R. (1991). Relation of cover alterations to the summer standing crop of young salmonids in small southeast Alaska streams. *Transactions of the American Fisheries Society*, 120(5): 562-570.

Abstract: "*Summer abundance of young coho salmon Oncorhynchus kisutch, steelhead O. mykiss, and Dolly Varden Salvelinus malma was assessed in small streams on Prince of Wales Island, Alaska, in an attempt to measure the response of these fish to various types of cover alterations. The standing crop of subyearlings decreased during summer, but none of the decrease could be attributed to the changes in cover we made. Subyearling coho salmon (about 75% of the fish present) did not respond either to the removal of natural riparian vegetation or to the addition of simulated riparian canopy, large boulders, woody debris, or simulated undercut banks. Localized movements within the streams were sufficient to provide relatively rapid recolonization of the experimental habitat units. The forms of cover we evaluated were relatively unimportant in regulating abundance of young coho salmon in small streams.*" (N)

Braun, D.C., and Reynolds, J.D. (2001). Relationships between habitat characteristics and breeding population densities in sockeye salmon (Oncorhynchus nerka). *Canadian Journal of Fisheries and Aquatic Sciences*, 68(5):758-767.

"*We examine the importance of stream habitat characteristics in governing variation in spawning densities of sockeye salmon (Oncorhynchus nerka) across 32 streams in the Fraser River Basin,* *British Columbia, Canada. We used mixed-effects models to examine four competing hypotheses for the influence of abiotic stream characteristics acting on either adult salmon or embryo mortality. All models that received support using Akaike's information criterion included stream characteristics that are associated with cover. These included the percent area of pools, percentage of the banks that were undercut, and large woody debris (in that order). These results suggest the importance of stream characteristics, which reduce risk of predation on adults, in determining spawning sockeye salmon densities. Thus, identification of a small number of physical characteristics of streams provides insight into ecological processes that determine population densities. This information can be used to quantify habitat quality, which can guide habitat prioritization for conservation*." (O – N)

Brown, T.G. (1985). *The role of abandoned stream channels as overwintering habitat for juvenile salmonids*. (Master's Thesis). Accessible from World Cat. (780025605).

Abstract: "*The role of ephemeral swamps and intermittent tributaries (off-stream habitat) located on the flood-plain of a west coast Vancouver Island stream (Carnation Creek), as over-wintering habitat, was examined for two winters. All trout (Salmo gairdneri and S_. clarki clarki) and juvenile coho salmon (Oncorhynchus kisutch) off-stream habitat were identified and characterized. Within this habitat: seasonal movement of salmonids was noted, coho growth rates were measured, salmonid populations were enumerated and contribution of off-stream habitat to the total coho smolt production was estimated. Coho and trout did not occupy all winter flooded land. Trout occupied intermittent tributaries, while coho occupied both intermittent tributaries and ephemeral swamps. Salmonid use of flooded meadows was negligible. The contribution of off-stream habitat to the watershed's total smolt production was at least 23% and more than 15% came from sites devoid of water in summer. Seasonal movement of juvenile coho followed a distinct pattern and appeared dependent upon climatic conditions such as magnitude and timing of the first fall (Oct-Nov) freshet. Climatic conditions in spring (March-May) appeared to influence both growth and survival of coho within one small ephemeral swamp.*"

Cada, G.F. (1994). *Review of information pertaining to the effect of water velocity on the survial of juvenile salmon and streelhead in Columbia River basin*. Northwest Power Planning Council, Portland.

Unable to access copy or abstract.

Cramer, M.L. (2012). *The stream habitat restoration guidelines final.* Retrieved January 2013 from http://wdfw.wa.gov/publications/01374/wdfw01374.pdf.

The guideline opens with introducing the Aquatic Habitat Guidelines Program as well as guidelines developed, an overview of the guidelines, and introduction watershed/floodplain processes of riparian and aquatic habitats. Stream habitat was broken down into watershed, reach, and site assessment and their role, implementation, and methodology. This section discusses conducting assessments. Assessment methodologies are divided into physical, chemical, and biological that all incorporate collection of data on parameters and surveys or forms. There is a section on the developing a restoration strategy and project development process, which is summarized by a diagram and another diagram on habitat loss or degradation at various scales. The guideline indicates objective that follows S.M.A.R.T. (Specific, Measurable, Achievable, Relevant, Time-bound) criteria and describe watershed constraints and factors/contexts to consider, i.e. stakeholders, scale, ecological, recovery timeframe, etc. Prioritization to achieve goals is another strategic consideration that would encompass habitat protection, connectivity, restoration process, and any creation or enhancement of habitats. For instance, for salmonid spawning habitats suitability must be determined through substrate size, water velocity, water depth, gravel permeability, surface and sub-surface flow conditions, dissolved oxygen, water temperature, and cover (landscape/riparian). Rearing would be the next habitat component to consider for the restoration area and in the recovery plan. Monitoring is another critical component of testing restoration.

The designing and implementing stream habitat restoration techniques is the heart of the document for site or reach scaled projects intended to improve or increase habitat or the process that create and maintain aquatic habitats. The process of developing and designing the techniques are laid out in three phases of the restoration strategy and project creations, which are: strategy and planning (identifies actions and overall contribution to restoration goals), design and permitting (alternative technique evaluation and outcome of implementation plan to carry out objectives), and implementation and monitoring. Failure can be attributed to skipping out on steps, not defining goals or criteria clearly, and no integration of the various components. It is important to include four technical analyses fundamental to restoration design: hydrology, hydraulics, geomorphology, and sediment transport. Integration of interdisciplinary disciplines should consider fish biology and aquatic ecology (aquatic entomology), botany and plant ecology, wildlife and conservation biology, landscape ecology and watershed science, engineering, geotechnical, construction, survey and drafting, and project management. There are programs like RiverRAT or SHRG that was mentioned as well. Criteria such as channel form, deformability, floodplain function, aquatic habitat, and timeframe are within the design.

The guideline also incorporates an example of the design report that is added as an appendix to this bibliography. The techniques the guideline includes sections on include: dedicating land and water to preservation and restoration of stream habitat; channel modification; levee modification and removal; side channel/off-channel habitat restoration; riparian restoration and management; fish passage restoration; nutrient supplementation; beaver re-introduction; salmonid spawning gravel cleaning and placement; instream structures; large wood and logjams; bank protection construction, modification, and removal; instream sediment detention basins; and floodplain fencing. The guideline clearly indicates what is and what is not included within each technique. The included information is describing effects (physical and biological), application, risk and uncertainty, methodology and design, permitting, monitoring and construction considerations (cost, maintenance). See appendix for the actual techniques of the guidelines. (E)

D'Aoust, S.G. (1998). *Large woody debris fish habitat structure performance and ballasting requirements*. (Master's Thesis). Accessible from The University of British Columbia cIRcle.

Abstract: "*Many stream restoration efforts include placement of constructed large woody debris (LWD) habitat structures. These structures are installed in stable channels to rehabilitate summer habitat and critical overwintering refuges in streams, thus attenuating stresses on the aquatic ecosystem until logged riparian areas naturally supply mature windfalls (Slaney & Martin, 1997). This study addresses one of the main problems faced by restoration practitioners: The lack of physically based design guidelines* *for LWD habitat structures. This study presents the theoretical basis behind design methodologies for three types of LWD structures: (1) Single-LWD, (2) Single-LWD with intact root wad, and (3) Multiple-LWD structures. A field verification program was undertaken to test the applicability the theoretical basis and to refine the design guidelines. Over 80 LWD structures were assessed after construction and again after the fall 1997 to spring 1998 floods. Results indicate that the design approach for single-LWD and single-LWD with root wad structures, based on a factor of safety against sliding failure, successfully predicted the stability of the structures during the past fall to spring floods. The stability of the multiple-LWD structures proved to be more complex to predict since a greater number of design and construction-related factors influence stability. Nonetheless, a design approach based on a safety factor against buoyant failure is recommended. Recommendations with respect to the design and construction of LWD structures are also presented as part of this study.* " (E)

Ebersole, J.L., Wigington, P.J., Jr., Baker, J.P., Cairns, M.A., Church, M.R., Hansen, B.P., Miller, B.A., and others. (2006). Juvenile coho salmon growth and survival across stream network seasonal habitats. *Transactions of American Fisheries Society,* 135: 1681-1697. Accessible from http://andrewsforest.oregonstate.edu/pubs/pdf/pub3859.pdf.

Abstract: "*Understanding watershed-scale variation in juvenile salmonid survival and growth can provide insights into factors influencing demographics and can help target restoration and mitigation efforts for imperiled fish populations. We assessed growth, movement, and apparent overwinter survival of individually tagged juvenile coho salmon Oncorhynchus kisutch in a coastal Oregon watershed from June 2002 to June 2003 and related growth and survival parameters to stream characteristics. Fall body size of juvenile coho salmon was a good predictor of smolt size and survival, but smolt size was also influenced by overwintering location. This was due to strong spatial patterns in winter growth rates associated with residency and movement into a small intermittent tributary. Though nearly dry in midsummer, this stream supported high densities of spawning coho salmon in the fall, and juveniles rearing there exhibited relatively high growth rates and emigrated as larger smolts. Improved winter growth and survival of juvenile coho salmon utilizing tributary habitats underscore the importance of maintaining connectivity between seasonal habitats and providing a diversity of sheltering and foraging opportunities, particularly where main-stem habitats have been simplified by human land uses.*" (E – G)

Gregory, R.W., and Fields, P.E. (1962). *Discrimination of low water velocities by juvenile silver (Oncorhynchus kisutch) and chinook salmon (Oncorhynchus tshawytscha)*. (Thesis). Accessibility from World Cat from http://www.worldcat.org/title/discrimination-of-low-water-velocities-by-juvenile-silver-oncorhynchus-kisutch-and-chinook-salmon-oncorhynchus-tshawytscha/oclc/061493848. (61493848).

Unable to access book or abstract

Gregory, S.V., Swanson, F.J.S., McKee, W.A., and Cummins, K.W. (1991). *An ecosystem perspective of riparian zones*. Retrieved February 2013 from http://www.jstor.org.antioch.idm.oclc.org/stable/pdfplus/1311607.pdf?acceptTC=true.

Riparian zones are described at the interconnection between terrestrial and aquatic ecosystems, as an ecotone. The article proposed to create a conceptual model of riparian zones, which synthesizes geomorphic processes, physical processes, community successional processes, and nutritional sources created for aqueous ecosystems. This articles details riparian zone functionally between land and water that incorporates the above to spatial and temporal patterns into the model. Much of the information has been incorporated in newer documents and articles. (N)

Henning, J.A., Gresswell, R.E., and Fleming, I.A. (2006). Juvenile salmonid use of freshwater emergent wetlands in the floodplain and its implications for conservation management. *North American Journal of Fisheries Management*,26:367-376.

Abstract: "*A recent trend of enhancing freshwater emergent wetlands for waterfowl and other wildlife has raised concern about the effects of such measures on juvenile salmonids. We undertook this study to quantify the degree and extent of juvenile Pacific salmon Oncorhynchus spp. utilization of enhanced and unenhanced emergent wetlands within the floodplain of the lower Chehalis River, Washington, and to determine the fate of the salmon using them. Enhanced emergent wetlands contained water control structures that provided an outlet for fish emigration and a longer hydroperiod for rearing* *than unenhanced wetlands. Age-0 and age-1 coho salmon O. kisutch were the most common salmonid at all sites, enhanced wetlands having significantly higher age-1 abundance than unenhanced wetlands that were a similar distance from the main-stem river. Yearling coho salmon benefited from rearing in two enhanced wetland habitats, where their specific growth rate and minimum estimates of survival (1.43%/d by weight and 30%; 1.37%/d and 57%) were comparable to those in other side-channel rearing studies. Dissolved oxygen concentrations decreased in emergent wetlands throughout the season and approached the limits lethal to juvenile salmon by May or June each year. Emigration patterns suggested that age-0 and age-1 coho salmon emigrated as habitat conditions declined. This observation was further supported by the results of an experimental release of coho salmon. Survival of fish utilizing emergent wetlands was dependent on movement to the river before water quality decreased or stranding occurred from wetland desiccation. Thus, our results suggest that enhancing freshwater wetlands via water control structures can benefit juvenile salmonids, at least in the short term, by providing conditions for greater growth, survival, and emigration*." (E)

Hoffman, R, and Dunham, J. (2007). *Fish-movement ecology in high-gradient headwater streams: its relevance to fish passage restoration through stream culvert barriers.* (Report 1140). Retrieved January 2013 from http://pubs.usgs.gov/of/2007/1140/pdf/ofr20071140.pdf.

The report discusses restoration of fish passages through culvert barriers. A brief overview or review on important characteristics of movements of animals and examples of Washington State fish groups such as salmon, trout, and char, and the salmonid species were chosen due to their migration patterns (widespread and travel farthest north of the waterways in the state). The report also includes consequences of anthropogenic barriers, i.e. culverts, from interrupting salmonid movement. Many evidential information is concisely condensed, which the authors prioritize in terms of needs for effective restoration for salmonid passage restoration through culverts.

It is noted that salmonid species have evolved their behavior to various streams habitats. Their movement extends over many spatial scales across generations of populations that are important to their life history patterns and ability to be resistant to environmental conditions. It is imperative that the fish be able to access these streams they have adapted well to. Many constraints such as channel slope, elevation, stream size, presence of barriers to upstream migration, and cycles of disturbances (environmental and habitat) and limits of food resources. Barriers and salmonid species have coexisted, however human-placed barriers are restrictive or eliminate the upstream movement of fish, which may cause isolation. The barriers impact fish dispersal mechanisms, extirpate mobile life history, fragmentation, and vulnerability, preventing recolonization, and genetics.

Four culvert-caused modification or restrictions affecting fish passages are discussed in the report, which are divided into categories of complete, partial, low-flow related, and variable passage. Studies discuss the effects, but few go into investigation of amelioration to the situation other than baffles and increased roughness to culvert sides. Restoration of fish passages presents opportunities to reconnect the passages used by salmonid fish. Cost, resources, and tradeoffs and values are incorporated in the restoration projects. Assumption of biological systems function and estimates of key parameters like habitat quality are priority. It is pointed out the lack of work on actual responses of native species and consequences of fish barriers, such as migration life histories, persistence population, and genetic impacts. (E)

Holecek, D.E., Cromwell, K.J., and Kennedy, B.P. (2011). Juvenille Chinook Salmon summer microhabitat availability, use, and selection in a central in a central Idaho Wilderness Stream. *Transactions of the American Fisheries Society,* 138(3): 633-644.

Abstract: "*We measured summer microhabitat use, availability, and selection by age-0 Chinook salmon Oncorhynchus tshawytscha in the Big Creek drainage, Idaho. Age-0 fish selected for low-velocity (0-25 cm/s), moderate-depth (40-80 cm) habitats that were located within 80 cm of cover. Pools (52%) and runs (38.5%) were the most commonly used habitat types, while pebbles (33.7%) and sand (23%) were the most often used substrates. Cover type use was predominated by woody debris (54.8%) and rock outcrops (23.7%). Run (38.5%) and riffle (32.9%) were the most available habitats in Big Creek, while pebble (38.4%) and cobble (28.2%) were the most available substrates. Mean water velocity (47 cm/s) availability and distance to cover (108 cm) availability were greater than those selected by age-0 Chinook salmon, while mean total water depth (30 cm) availability was lower than that selected by the fish. Linear regression was used to show that an increase in juvenile Chinook salmon total length was significantly (P*

< 0.05) related to increased total water depth ($r^2 = 0.68$), focal water depth ($r^2 = 0.73$), and focal water velocity ($r^2 = 0.49$) use. The relationship of habitat use and fish total lengths indicate that even within a short temporal period, juvenile Chinook salmon will select for different habitats as they grow. Upper and lower Big Creek microhabitat availability characteristics differed significantly ($P < 0.05$). Upper Big Creek had more fish per unit of preferred rearing habitat than lower Big Creek, which suggests that either summer microhabitat availability or redd density partially explain the density differences observed in Big Creek. Microhabitat use and availability data were useful for identifying habitat selection of age-0 Chinook salmon in Big Creek. The data from this study can be used for future identification, quantification, and restoration of suitable Chinook salmon rearing habitat in other Pacific Northwest streams." (E)

Kershner, J.L., Roper, B.B., Bouwes, N., Henderson, R., and Archer, E. (2004). An analysis of stream conditions in reference and managed watershed on some federal lands within the Columbia River Basin. *North American Journal of Fisheries Management,* 24: 1363-1375.

Abstract: "*The loss of both habitat quality and quantity for anadromous fish in the Columbia River basin has been identified as a major factor in the decline of many species and has been linked to a variety of land management activities. In this study, we compared stream reaches in watersheds representing both managed and reference conditions to determine whether we could detect differences in physical habitat variables. We divided stream habitat measures into three components: stream banks, instream habitat (pools and pool depth), and stream substrate. We randomly sampled perennial streams within 261 sixth hydrologic unit code (HUC) stream reaches on federal lands in Idaho, Montana, Oregon, and Washington. The sample population represented stream reaches in 62 reference watersheds and 199 managed watersheds. An unbalanced, incomplete-block-design analysis of covariance (ANCOVA) was performed on each of the habitat var- iables using geology type as the block effect and bank-full width, stream gradient, and average precipitation as the covariates. Watersheds containing reference stream reaches had a slightly higher percentage of federal lands, were smaller, tended to occur at higher mean elevations, and received more annual precipitation than did the managed watersheds. We observed differences in most measures of stream habitat between reference and managed watersheds, generally in the direction we expected. Stream banks were more stable and more undercut in reference stream reaches. Pools in reference stream reaches were deeper than pools in managed stream reaches and* *had less fine sediment in pool tails. Analysis of covariance was an effective way to compare data across a large, relatively heterogeneous landscape where sample site stratification may be impractical or sample sizes are limited. We believe that the comparison of reference conditions to conditions across managed landscapes provides a credible way to report on the condition of these systems in lieu of trend information at individual sites.*" (E)

Liermann, M., and Roni, P. (2008). More sites or more year? optimal study design for monitoring fish response to watershed restoration. *North American Journal of Fisheries Management*, 28:935-943.

Abstract: "*Every year in the Pacific Northwest, hundreds of stream restoration projects are implemented at great expense in the hope that they will increase salmonid abundance. Our understanding of how salmonids interact with their freshwater habitat has steadily improved, but we are still a long way from being able to reliably predict population-level effects of individual projects. To determine whether these projects are in fact increasing salmonid abundance, we will need to implement restoration at the watershed scale, monitor the populations after the freshwater portion of their life history is completed, and replicate the experiment across multiple watersheds to produce results that can be generalized. Although there has been some progress in this direction, it has largely consisted of independent efforts at a relatively small scale. In this paper, we use smolt counts of coho salmon Oncorhynchus kisutch from streams in western Washington and Oregon, along with approximate restoration and monitoring costs, to estimate the most cost-effective way of allocating monitoring effort between years and watersheds to allow detection of an average response to watershed-scale restoration. We show that it is generally preferable to spread the available effort across more watershed pairs, unless the one-time cost of adding a watershed pair is very high (e.g., when the cost of restoration is included). These results are sensitive to plausible changes in temporal and spatial variability and may change with different assumptions about response type, but they are derived using a logical, transparent process that incorporates available information.*" (E – G)

Liquori, M., and Jackson, C.R. (2001). Channel response from shrub dominated riparian communities and associated effects on salmonid habitats. *Journal of the American Water Resource Association*, 37(6): 1639-1651.

Abstract: “*We surveyed first-to third-order streams (channel widths from 1.4 to 10 m) in the southeastern slopes of the Cascade Range of Washington and found two distinct endpoints of riparian vegetation. Where the forest overstory is dominated by park-like Ponderosa pine (Pinus ponderosa), channels are commonly bordered with a dense scrub-shrub vegetation community. Where fire suppression and/or lack of active riparian zone management have resulted in dense encroachment of fir forests that create closed forest canopies over the channel, scrub-shrub vegetation communities are virtually absent near the channel. Other factors being equal, distinct differences in channel morphology exist in streams flowing thru each riparian community. The scrub-shrub channels have more box-like cross-sections, lower width-to-depth ratios, more pools, more undercut banks, more common sand-dominated substrates, and similar amounts of woody debris (despite lower tree density). Temperature comparisons of forest and scrub-shrub sections of two streams indicate that summer water temperatures are slightly lower in the scrub-shrub streams. We surmise that these morphology and temperature effects are driven by differences in root density and canopy conditions that alter dynamic channel processes between each riparian community. We suspect that the scrub-shrub community was more common in the landscape prior to the 20th century and may have been the dominant native riparian community for these stream types. We therefore suggest that managing these streams for dense riparian conifer does not mimic natural conditions, nor does it provide superior in-stream habitat.*” (O)

Martin, A.E. (2007). *Aquatic community responses to stream restoration: effects of wood and salmon analog additions.* (Masters Thesis). Available from World Cat.

Land use activity greatly impacts ecosystems of the Pacific Northwest, such as indirect and direct effects on the capacity of a habitat to “produce” fish, according to the author. The thesis explores the responses aqueous communities have to exposed woody debris bundles and salmon analog additions in next-year creations of off-channel fish habitat. The location was of southcentral Alaska. Sampling of biofilm, invertebrates, and juvenile coho salmon were done in the control, wood, analog, and analog-wood treatments. Analog treatment had significant biofilm. Coho diets indicated differences between treatments, and their densities and standing stock were significantly higher in wood treatments. In the control, density-dependence signs were present. The study suggests that salmon analog and wood debris bundle additions may be viable for restoration short-term as they provided higher food and shelter for aquatic communities and habitats. (E)

Merz, J.E. (2004). *Spawning habitat enhancement in a regulated river for Pacific salmon (Oncorhynchus spp)*. (Doctoral Dissertation). Accessible from Spawning Habitat Integrated Rehabilitation Approach: http://shira.lawr.ucdavis.edu/publications/Theses/Merz_Thesis.pdf.

Abstract: "*Large, temperate rivers (LTR) throughout the northern hemisphere have undergone dramatic and long-term anthropogenic changes. Such impacts have altered the hydrologic, sediment, temperature and flow regime of these systems and have had negative impacts on their native flora and fauna. Numerous projects have been undertaken to counteract these impacts in the past three decades. Unfortunately, a strong tendency has emerged to focus river conservation, restoration and monitoring on charismatic or economically important fauna without thorough consideration of watershed attributes and processes of the watershed that control biodiversity and production. Furthermore, uncertainty as to how well restoration projects actually work demonstrates the critical need for research to evaluate how habitat manipulations directly influence aquatic resources. Confounding our understanding of how to restore riverine function is the fact that most LTR have been under some state of impairment long before any attempt was made to study them, making evaluation even more difficult.*

In this study, I examined the effects of chinook salmon (Oncorhynchus tschawytscha) and steelhead (O. mykiss) spawning habitat enhancement on specific parameters associated with the spawning environment in the Mokelumne River, a regulated stream in California's Central Valley. Specifically, I assessed: 1) effectiveness of a project to enhance spawning habitat for chinook salmon; 2.) benefits of gravel enhancement to the development and survival of native Chinook salmon and steelhead embryos; 3.) effects of gravel enhancement on the benthic macroinvertebrate community associated with these spawning habitat enhancement sites and; 4.) prospects of estimating an appropriate bed sediment budget for these projects.

Results from specific assessments are as follows:

Physical measurements taken before and after gravel placements show that spawning gravel enhancement sites significantly increased channel water velocities, intergravel permeability and dissolved oxygen, reduced channel depths and equilibrated intergravel and ambient river temperatures. These *positive benefits remained throughout a 30-month monitoring period. Adult chinook salmon began spawning at previously unused sites within 2 months after gravel placement and continued to use sites for the length of the study period. Topographical channel surveys provided a useful tool for monitoring bed material transport and layering redd locations on contour maps.*

Spawning bed enhancement increased survival of chinook salmon embryos in a regulated California stream with a gravel deficit. Eyed chinook salmon eggs planted in enhancement gravels had higher survival to swim-up stage than did eggs planted in unenhanced spawning gravels, although no significant difference in growth was observed. Intergravel temperatures and substrate size within spawning sites were highly correlated with distance downstream from the lowest non-passable dam. Strong correlations were also observed between intergravel turbidity and total suspended and total volatile solids. Four multiple regression models built with a combination of physical parameter measurements performed well in predicting survival and length of chinook salmon and steelhead embryos under various conditions. Survival models accounted for 87% of the variation around the mean for chinook salmon and over 82% for steelhead. Growth models accounted for 95% of the variation around the mean for chinook salmon and 89% for steelhead. These findings suggest that spawning bed enhancement can improve survival of salmonid embryos in degraded habitat. Additionally, measuring a suite of physical parameters before and after spawning bed manipulation can accurately predict benefits to target management species. Gravel enhancement can be an effective means for improving salmon spawning habitat in rivers with low gravel recruitment because of upstream dams.

In spawning enhancement projects, benthic organisms colonized new gravels quickly, equaling densities and biomass of unenhanced spawning sites within 4 weeks. Macroinvertebrate species richness equaled that of unenhanced sites within 4 weeks and diversity within 2 weeks. Standing crop, as indicated by densities and dry biomass, was significantly higher in enhancement sites after 12 weeks and remained so over the following 10 weeks. Although mobile collector/browsers initially dominated new gravels, sedentary collectors were the most common feeding category after 4 weeks, similar to unenhanced sites. These data suggest that cleaned gravels from adjacent floodplain materials, used to enhance salmonid spawning sites, are quickly incorporated into the stream ecosystem, benefiting benthic macroinvertebrate densities and dry biomass.

Finally, short-term bed elevation and feature adjustments were monitored over 36 months at three Chinook salmon (Oncorhynchus tschawytscha) spawning bed enhancement sites in the regulated lower Mokelumne River, California. Our data show that spawning bed sites containing 794 – 1323 m3 of *enhancement gravel lost from 3-20% of remaining gravel volume annually during controlled flows of 8 – 70 m3 sec-1 and 2.6 – 4.6% of placed material during short-duration (19 days) flow releases of 57 m3 sec-1. The oldest site lost ~50% of placed material over the four-year monitoring period. Of the mechanisms monitored, gravel deflation was the greatest contributor to volumetric reductions, followed by surface scour. Salmon spawning, scour around placed features and over-steepened slopes also contributed to volumetric reductions. As sites matured, reductions were less pronounced. Sites entrained as much large woody debris as was lost over the study and large woody debris settled on constructed gravel berms for periods of <12 months to >4 years. While complexity is an extremely important aspect of ecological function, production of highly diverse and complex habitat features appears to come at a cost. Placement of features such as gravel berms, boulders and large woody debris, to attract spawning Chinook salmon, increased gravel cut within enhancement sites. Furthermore, increased spawning activity can reduce the longevity of enhancement sites*." (E)

McCormick, D.P. (2010). *Direct and indirect effects of riparian canopy on the biology of stream-dwelling salmonids in South-west Ireland.*(Doctoral Thesis). Accessible from World Cat. (795332331).

Abstract: "*Previous studies have shown variable negative effects of riparian shade on juvenile salmonids, but little is known about the complex interactions between riparian shade, instream macrophytes and salmonid ecology. The aim of this research was to investigate, both through field surveys and experimentally, the relative roles of riparian canopy and aquatic macrophytes on the ecology of juvenile Atlantic salmon Salmo salar L. and brown trout Salmo trutta L. in south-west Ireland. A paired multi-stream study demonstrated a positive effect of open canopy on population densities of salmon, but positive effects on size and feeding were found to be more related to macrophyte density than the extent of shading. Experimental manipulation of instream macrophytes showed that they can enhance local salmon density and play a dual role in providing both cover and an important source of preferred prey taxa to juvenile fish. By sampling fish at small patch scales, a considerable preference by salmon for macrophyte patches was observed. Additionally, a clear positive effect on the size and feeding of fish of occupying such patches was demonstrated. The final part of the research tested the potential of riparian canopy removal as a management tool for enhancing salmon production. Selective riparian canopy removal resulted in a significant increase in instream macrophyte density with significant positive effects on the density of young-of-year salmon at a local scale. These findings suggest that in systems where the prevailing* *conditions favour the growth of instream macrophytes, considered management of riparian vegetation could significantly increase instream habitat complexity and provide a significant source of macroinvertebrate prey for fish without the need for costly, disruptive instream habitat restoration measures.*" (E)

Miller, D. (2001). *Executive summary: channel design.* Retrieved February 2013 from http://wdfw.wa.gov/publications/00057/wdfw00057.pdf.

This document is outlined in Washington's *Statewide Strategy to Recover Salmon: Extinction is Not an Option*. The document states that the Washington Department of Fish and Wildlife, Ecology, and Transportation charged Aquatic habitat Guidelines as an integrated approach to restoration and habitat protection via manual series. The purpose of this document in particular if for scientific and technical basis for developing the guidelines, as comprehensive (not exhaustive). Natural waterway processes and adjustments arise from channel migration, channel evolution, hydrologic changes, sediment, and debris alteration. The climatic parameters, like precipitation and temperature, and physical factors, like topography, soils, geography, vegetation, and land use (deforestation and urbanization), assist in channel design based on geomorphic processes.

Stream channel design is relatively new and utilized by many disciplines including biologists, ecologists, geomorphologists, and engineering. Design criteria are a first step in design and incorporation of multiple stakeholder entities. Hydraulic and sediment transport analysis aids in design. Three common approaches to channel design include empirical approach, reference reach, and analytical approach. Reference reach approach and empirical approach have restrictions, such as: 1) assumption that a design reach is under regime (stable), and 2) applicability of specific relationships in certain conditions. Analytical approach is most desirable given channel conditions are assessed through the analysis, not assumed; yet, it is not used as often because of the intensity of data collection, designer level experience, and time. The four major category the stream modification, including success and failures, are: 1) channel bed and longitude profile; 2) channel planform, 3) channel cross-section, and 4) creation or adjustment of high flow channels. (G – O)

Monaghan, K.A., and Milner, A.M. (2008). Salmon carcass retention in recently formed stream habitat. *Fundamental and Applied Limnology*, 170(4):281-289.

Abstract: "*Habitat manipulation for migratory fish is typically aimed at fulfilling particular life-cycle stages and rarely acknowledges the wider role of these fish in lotic ecosystems. Recent research, indicating the importance of salmon carcasses in stream ecosystems of the Pacific Northwest has highlighted their potential contribution in restoring degraded rivers. Previous research has emphasised the importance of in-stream habitat features such as pools and debris dams for carcass retention in mature river systems but carcass retention in other river habitats has not been well studied. This study documents the spawning runs of pink salmon (Oncorhynchus gorbuscha) and the retention of their carcasses in the early successional habitat of a recently formed stream. Eight years after initial colonisation, the estimated number of pink salmon spawners exceeded 10,000. Overall carcass retention was low and strongly related to discharge, with most carcasses transported out of the freshwater system to the estuary within a few days. The majority of carcasses that were retained accumulated in the slower moving waters in the stream margins, whilst the spatially scarce habitats of boulders, shallow areas and coarse woody debris were associated with comparatively high carcass densities. Mark and recapture of carcasses indicated that, with the exception of coarse wood debris, the retention of carcasses was an ephemeral and highly dynamic process with the structurally simple retentive features of this stream associated with a high turnover of carcasses.*" (E)

Mull, K.E., and Wilzbach, M.A. (2007). Selection of spawning sites of coho salmon in a northern California stream. *North American Journal of Fisheries Management*, 27: 1343-1354.

Abstract: "*We assessed the relative importance of various factors contributing to spawning site use by a population of threatened coho salmon Oncorhynchus kisutch in Freshwater Creek, California, and created a predictive model of spawning habitat selection based on logistic regression analysis. We excluded sampling sites that previous studies had established as unsuitable on the basis of depth and substrate criteria and asked why fish chose particular locations and not others in seemingly suitable habitat. We evaluated surface water velocity, depth, substrate size composition, gravel inflow rates, vertical hydraulic gradient, geomorphic channel units, hyporheic water physicochemistry, cover, and* *proximity to other redds not in sampling sites during the 2004–2005 spawning season. In univariate comparisons with unused sites, coho salmon selected sites with a smaller median particle diameter, a larger percentage of gravel–pebble substrate, and higher gravel inflow rates. Based on multivariate logistic regression, the probability of a site's being used for spawning was best modeled as a positive function of the gravel–pebble fraction of the substrate, location at a pool or run tail, and the presence of existing redds in close proximity to the site. This model explained 38% of the variation in the data and was a better predictor of spawning habitat use than a more traditional model based on depth, velocity, and substrate. Our results highlight the potential importance of social behavior in contributing to habitat selection by spawning salmonids."* (O)

Pehl, D., and Flynn, M.B. (editor). (2009). *Juvenile salmonid utilization of selected habitat restoration projects in Southern Interior British Columbia.* [Canadian Manuscript Report of Fisheries and Aquatic Sciences 2868]. Retrieved January 2013 from http://www.dfo-mpo.gc.ca/Library/337086.pdf

Abstract: "*Many off-channel and mainstem riparian fish habitat restoration projects have been completed in the British Columbia Interior to restore endangered Interior Fraser coho salmon. However, there has been little assessment of the productivity and success of these projects. This study assessed the utilization by juvenile salmonids of various habitat restoration projects and techniques during the critical rearing periods of summer (early August to early September 2001), fall (late September to late October 2001) and winter (January and February 2002), with a focus on off- channel habitat utilization. Assessments were undertaken at 42 mainstem and 7 off-channel sites in the Shuswap, North Thompson and Thompson-Nicola sub-basins of the Thompson River drainage.*

The structural integrity of some restoration components met performance expectations while others required maintenance, indicating a need to change some techniques. Rock-based (rip-rap) bank stabilization projects generally met stream bank stabilization objectives but did not provide the habitat quality and diversity required to support multiple salmonid species. Projects incorporating woody material with rock addressed both bank stabilization and fish habitat considerations. The success of riparian corridor re-vegetation has not met expectations at many sites, particularly in the Thompson-Nicola sub-region. Observations of successes and failures and recommendations pertaining to alternative techniques to re-establish riparian vegetation have been made.

Despite data and analysis limitations, some trends in juvenile salmonid utilization were evident. Catch per unit effort data suggested greater salmonid utilization of restored habitats than control sites. Salmonid abundance, particularly rearing coho, was in most cases greater in off-channel and tributary restoration sites than mainstem sites. This was most noticeable during winter when almost all coho and chinook were utilizing off-channel habitats. An essential recommendation was therefore to maintain the productivity of those habitats.

To better understand and maximize the success of restoration projects, it was also recommended that assessment studies be continued over the long-term." (G)

Rinella, D.J., Booz, M., Bogan, D.L., Boggs, K., Sturdy, M., and Rinella, M.J. (2009). Large woody debris and salmonid habitat in the Anchor River Basin, Alaska, following an extensive spruce beetle (*Dendroctonus rufipennis)* outbreak.

Abstract: "*A widespread and intense spruce beetle outbreak during the 1990s has killed most of the mature white spruce (Picea glauca) trees across many watersheds in south-central Alaska. To investigate the potential habitat impacts in a salmon stream, we characterized the current abundance and species composition of large woody debris (LWD), examined the linkages between LWD and salmonid habitat, and estimated changes in LWD abundance and associated pool habitat over time. LWD abundance was relatively low (97 pieces/km overall) and varied widely according to riparian vegetation typology, ranging from 15 pieces/km at sites with non- forested riparian zones to 170 pieces/km at sites adjacent to cottonwood forest. LWD provided significant fish cover in pools, especially in cottonwood forest stream reaches. LWD-formed pools were relatively rare (15% of total), but LWD abundance explained much of the variation in pool frequency (r2 = 0.86 in spruce forest reaches) and in the proportion of pool habitats (r2 = 0.85 in cottonwood forest reaches). We project the spruce beetle outbreak to result in a substantial net increase in LWD abundance over a 50-year span, peaking with 243% and 179% increases in LWD abundance for spruce forest and cottonwood forest stream reaches, respectively, in the year 2025. Concurrent with the peak in LWD abundance, our estimates show pool frequency in spruce forest reaches to reach 207% of current levels and the proportion of pools in cottonwood forest reaches to reach 167% of current levels, changes that correspond with substantially increased potential habitat for juvenile salmonids.*" (O)

Roni, P., Bennett, T., Morley, S., Pess, G.R., and Hanson, K. (2006). Rehabilitation of bedrock stream
channels: the effects of boulder wier placement on aquatic habitat and biota. Retrieved February 2013 from http://www.nwfsc.noaa.gov/research/divisions/fed/wpg/documents/blm_boulder_weir_final_report_roni_et_al.pdf.

Abstract: "*The placement of boulder weirs is a popular method to improve fish habitat though little is known about their effectiveness at increasing fish and biota abundance. We examined the effectiveness of boulder weir placement by comparing physical habitat, chemical, and biotic metrics in 13 paired treatment (boulder weir placement) and control reaches in 7 southwest Oregon watersheds in the summer of 2002 and 2003. Pool area, the number of boulders, total large woody debris (LWD), and LWD forming pools were all significantly higher in treatment than control reaches. No differences in water chemistry (total N, total P, dissolved organic carbon) or macroinvertebrate metrics (richness, total abundance, benthic index of biotic integrity, etc.) were detected. Abundance of juvenile coho salmon (Oncorhynchus kisutch) and trout (O. mykiss and O. clarki) were higher in treatment than control reaches ($p < 0.05$), while dace (Rhinichthys spp.; $p < 0.09$) numbers were higher in control reaches and no significant difference was detected for young-of-year trout ($p > 0.20$). Both coho salmon and trout response (log10(treatment density/reference density) to boulder weir placement was positively correlated with difference in pool area (log10(treatment/reference; $p < 0.10$), while dace and young-of-year trout response to boulder weir placement were negatively correlated with difference in LWD ($p < 0.05$). The placement of boulder weirs appears to be an effective technique for increasing local abundance of species that prefer pools (juvenile coho and trout > 100mm). Based on our results and previous studies on bedrock and incised channels, we suggest that the placement of boulder structures is a useful first step in attempting to restore these types of stream channels.*" (O)

Rundquist, L.A., and Baldrige, J.E. (1990). Fish habitat considerations. *Cold regions hydrology and hydraulics.* American Society of Civil Engineers, New York, p 579-613.

Abstract: "*Fish habitats have several inter-dependent physical and biological components that include: channel structure, streamflow, water quality, and food-web relationships. The four major habitat components can be evaluated collectively, since changes in one component affects the other components; each habitat component must have attributes within an allowable range for the habitat to be usable by a given species and life stage. Habitat diversity is important in maintaining healthy fish populations. Overwintering habitats are important in cold regions because they may be a limiting factor to the fish population. Other important, and potentially limiting factors are habitats for spawning and rearing. The optimum means of maintaining fish populations is by preserving or maintaining existing fish habitat, since the art of restoring damaged habitat has not been developed sufficiently to ensure success of the habitat features. Project definition, habitat feature selection, and habitat feature design are three steps of stream restoration design. Three flow categories need to be considered when designing stream and riparian habitat restoration: (1) floodplain design discharges; (2) main channel design discharges; and (3) fish habitat design discharges. The optimum alignment for a stream is often its natural alignment. The design objective for the main channel is to provide sufficient channel conveyance for the bankfull flood while also providing habitat diversity. Habitat diversity can be enhanced by providing:(1) variability in channel depth and velocity; (2) pool and riffle cross sections; and (3) variability in substrate and cover. Habitat features should be monitored after floods and at a range of flow levels to evaluate their effectiveness and integrity. Examples of fish habitat features include rock islands, boulder clusters, submerged rock weirs, spruce tree revetments, rock wing deflectors, and overhanging bank cover.*" (E – G).

Sales, A.K., and Snyder, E.B. (2010). Diel fish habitat selection in a tributary stream. *American Midland Naturalists*, 163:33-43.

Abstract: "*This study investigated the location and diel habitat preferences (at 100 m reach scale) of fish in a small tributary stream in late spring, early summer. During the day, coho (Oncorhynchus kisutch) preferred areas with more cover (deeper, greater extent of undercut banks) vs. night when LWD was preferred (Pearson correlation and step-wise MLR). Chinook (O. tshawytscha) exhibited an opposite pattern, preferring LWD during the day vs. higher velocity at night. This suggests these two potadromous species may be partitioning resources. Pooling coho, chinook and rainbow trout (O. mykiss) indicated reaches with more LWD were selected at night (r^2=0.86, p=0.005) vs. deeper* *reaches during the day ($r^2=0.62$, $p=0.04$). Although not measured specifically, we believe LWD supports more macroinvertebrate production vs. the predominantly sandy substrate. Thus, a potential mechanism behind the observed patterns in reach selection may be the tradeoff between food resource abundance vs. predation risk. The majority of captured fish were juveniles supporting the premise first order tributaries can serve as important nursery habitats, especially if they exhibit stable flow and thermal regimes*." (O)

Sergeant, C.J., and Beauchamp, D.A. (2006). Effects of physical habitat and ontogeny on lentic habitat preferences of juvenile Chinook salmon. *Transactions of the American Fisheries Socirty*, 135(5): 1191-1204.

Abstract: "*We experimentally tested the habitat preferences of juvenile Chinook salmon Oncorhynchus tshawytscha to evaluate whether habitat availability was limited for a lake-rearing population in Lake Washington (Seattle, Washington). A segment of this population resides in shallow (<1 m deep), nearshore areas of the lake during January–May and migrates to saltwater at age 0. During the shallow, nearshore phase, fish are exposed to varying degrees of bottom slope, substrate, and cover (e.g., overhead docks and woody debris) formed by the natural and modified shorelines of this highly urbanized system. The effects of these three habitat variables on patch use or electivity were tested in combination with ontogeny and the presence or absence of piscivores. Fry and presmolts avoided steeper bottom slopes, but presmolt responses were strongest. Responses to substrate and cover options were weak, although fry exhibited some coherent preference for finer substrates. The habitat preferences displayed by both life stages corroborated the observations from nearshore field surveys in Lake Washington. No direct effects on habitat preference from diel period or piscivore presence were evident. These results, combined with field observations, suggest that juvenile Chinook salmon may risk exposure to predation in order to utilize preferred habitat and to forage at a high rate. Therefore, nearshore habitat restoration projects aimed at increasing preferred juvenile Chinook salmon habitat should consider this risk-prone behavior. Future experiments in larger experimental arenas could clarify the importance of heterogeneous nearshore habitat and further examine predation effects on the productivity of lake-rearing juvenile Chinook salmon.*" (O – N)

Slaney, P.A., and Zaldokas, D. (1997). *Fish habitat rehabilitation procedures*. [Watershed Restoration Technical Circular No. 9]. Retrieved February 2013 from http://www.env.gov.bc.ca/wld/documents/wrp/wrtc_9.pdf.

Decline of wild stockfish are due to overharvesting of water stocks, problems associated with hatcheries, hydroelectric developments, and habitat loss. Industrial forest harvest practices are linked to habitat loss that change drainage patterns, increase erosion, and aid in hillside failures. This situation also reduces the decaying wood into the stream. Past legislation and practices of fisheries and water management further promoted or resulted in removal of wood, i.e. log jams, and making the situation worse. Another contribution includes channelization, oligotrophication , and damming activities (beavers). (N)

Taccogna, G.S., and Hillaby, J.E. (2011). *Investigation of juvenile chinook salmon (Oncohynchus tshawytscha) use of off-channel and mainstem habitats in two upper Fraser River watersheds*. (Canadian Manuscript Report of Fisheries and Aquatic Sciences 2848). Retrieved February 2013 from http://www.dfo-mpo.gc.ca/Library/344252.pdf.

This document focuses on the Habitat Restoration and Salmon Enhancement Program (HRSEP), which began in 1996 to 2001, and aimed to revitalize salmonid species among the Pacific Region through 100-funded project. The Fraser River watershed was once of the funded projects. The important lesson from the program's progress in the Upper Fraser was a lack of habitat information for juvenile Chinook salmon. However, since the 1950s knowledge has been acquired on annual spawning, life history, basic population parameters, juvenile migration, overwintering, and studies of dam and fish habitat. Likewise, Dome and Baker Creeks further allowed establishment of this salmonid data.

Dome Creek and Baker Creek Watershed is described and the methodology for relative abundance of Chinook fry, electrofishing, and reconnaissance exercises/trip. Field sample sites are described next and followed by the collected data (fish size, conditions, population density, beach seining surveys, etc), timing, electrofishing surveys) and results. Four dispersal life history patterns were pointed out by Healy – downstream after emergence, redistribution to rearing sites, overwintering habitats, and ocean migration – that rearing and overwintering sites turned out to be significant for off-shore habitats in upper Fraser River populations. More detail in abstract below:

Abstract: "… *Results indicated that rearing chinook salmon heavily utilised all the off-channel habitats surveyed, and some were present in off- channel areas at least until November. In Dome Creek, chinook fry rearing densities in the off-channel sample sites peaked in July at 1.33 fry/m2 and decreased to 0.45 fry/m2 in October. Mainstem chinook fry rearing densities observed in Dome Creek were 0.01 and 0.26 fry/m2 in July and September, respectively. In Baker Creek, off-channel densities also peaked in July at 0.75 fry/m2 and decreased to 0.27 fry/m2 in November. Mainstem chinook fry rearing densities peaked in September at 0.41 fry/m2 and decreased to 0.11 fry/m2 in November. Chinook fry achieved more than 70% of their pre-smolt growth during their first spring and summer rearing months and condition coefficients generally exceeded a value of 1.0. There was evidence of habitat partitioning between salmonid and non-salmonid species, especially in the late spring-early summer high water period when chinook salmon dominated fish populations in off-channel habitats and non- salmonids dominated in the mainstem. Chinook densities were decreasing in off-channel habitats and increasing in mainstem habitats by September. Information on seasonal growth rates for different habitats was confounded by the likelihood of emigration into downstream areas.*" (O)

FLOOD PLAIN AND WATERSHED:

Bellmore, J.R., Baxter, C.V., Ray, A.M., Denny, L., Tardy, K., and Galloway, E. (2012). Assessing the potential for salmon recovery via floodplain restoration: a multi-trophic level comparison of dredge-,in to reference segments. *Environmental Management*, 49(3):734-750.

Abstract: "*Pre-restoration studies typically focus on physical habitat, rather than the food-base that supports aquatic species. However, both food and habitat are necessary to support the species that habitat restoration is frequently aimed at recovering. Here we evaluate if and how the productivity of the food-base that supports fish production is impaired in a dredge-mined floodplain within the Yankee Fork Salmon River (YFSR), Idaho (USA); a site where past restoration has occurred and where more has been proposed to help recover anadromous salmonids. Utilizing an ecosystem approach, we found that the dredged segment had comparable terrestrial leaf and invertebrate inputs, aquatic primary producer biomass, and production of aquatic invertebrates relative to five reference floodplains. Thus, the food-base* *in the dredged segment did not necessarily appear impaired. On the other hand, we observed that off-channel aquatic habitats were frequently important to productivity in reference floodplains, and the connection of these habitats in the dredged segment via previous restoration increased invertebrate productivity by 58%. However, using a simple bioenergetic model, we estimated that the invertebrate food-base was at least 4× larger than present demand for food by fish in dredged and reference segments. In the context of salmon recovery efforts, this observation questions whether additional food-base productivity provided by further habitat restoration would be warranted in the YFSR. Together, our findings highlight the importance of studies that assess the aquatic food-base, and emphasize the need for more robust ecosystem models that evaluate factors potentially limiting fish populations that are the target of restoration.“* (O)

Bolton, S.A., Shellberg, J., Washington State Transportation Center (TRAC), Center for Streamside Studies, Washington State Department of Transportation, and Washington State Transportation Commission. (2001). *Ecological issues in floodplains and riparian corridors.* (Research Project T1803 Task 29. Retrieved February 2013 from http://www.wsdot.wa.gov/research/reports/fullreports/524.1.pdf

Abstract: *"This white paper examines and synthesizes the literature pertaining to the current state of knowledge on the physical and biological effects of alluvial river channelization, channel confinement, and various channel and floodplain modifications. It also examines and summarizes literature on the mitigation, rehabilitation and restoration of rivers affected by these human modifications. Data gaps in our current understanding of physical and biological process, the effects of human modifications, and appropriate rehabilitation or restoration techniques are also reviewed.*

The paper overviews ecological and habitat issues associated with streams and riparian zones in Washington State and the Pacific Northwest. The results of the literature review are documented in a synthesis of the ecological and habitat effects of channelization, channel confinement and construction. The physical and morphologic effects of channelization are first reviewed to highlight how habitat templates have been or potentially could be modified. Then, the responses of different groups of organisms (invertebrates, fish, plants, birds, mammals) that are dependent on functional riparian corridors are reviewed. Data gaps in our current knowledge in connecting cause and effects relationships in complex ecological systems are reviewed. The functional importance of hyporheic and perirheic zones *in alluvial streams is also reviewed.*

The paper includes a section on habitat protection and mitigation techniques. Alternative management strategies such as passive (vs. active) restoration, streamside vegetation retention or promotion, and modified in-channel vegetation removal are reviewed. Recommendations by various authors on minimizing impacts during design and construction are also summarized. Preservation of channel morphology, incorporation of vegetation into embankments, and alternative bank protection techniques are also explored.

In recent years there has been a societal push to rehabilitate and/or restore streams and rivers degraded by channel modifications. The paper ends with a review of large-scale rehabilitation and restoration projects and techniques in the literature."(E – G).

Booth, D.B. (2005). Challenges and prospects for restoring urban streams: a perspective from the Pacific Northwest of North America. *Journal of North American Benthological Society*, 24(3): 724-737.

Abstract: "*Undoing harm caused by catchment urbanization on stream channels and their resident biota is challenging because of the range of stressors in this environment. One primary way in which urbanization degrades biological conditions is by changing flow patterns; thus, reestablishing natural flow regimes in urban streams demands particular attention if restoration is to have a chance for success. Enhancement efforts in urban streams typically are limited to rehabilitating channel morphology and riparian habitat, but such physical improvements alone do not address all factors affecting biotic health. Some habitat-forming processes such as the delivery of woody debris or sediment may be amenable to partial restoration, even in highly disturbed streams, and they constitute obvious high-priority actions. There is no evidence to suggest, however, that improving nonhydrologic factors can fully mitigate hydrologic consequences of urban development. In the absence of effective hydrologic mitigation, appropriate short-term rehabilitation objectives for urban channels should be to 1) eliminate point sources of pollution, 2) reconstruct physical channel elements to resemble equivalent undisturbed channels, and 3) provide habitat for self-sustaining biotic communities, even if those communities depart significantly from predisturbance conditions. Long-term improvement of stream conditions is not feasible under typical urban constraints, so large sums of money should not be spent on unrealistic or unreachable* *targets for stream rehabilitation. However, such a strategy should not be an excuse to preclude potential future gains by taking irreversible present-day development or rehabilitative actions.*" (E – G)

Butera, B., and Billman, D. (1998). Urban stream restoration in Anchorage, Alaska. *Wetlands Engineering and River Restoration Conference 1998,* Engineering Approaches to Ecosystem Resilience.

Abstract: "*Rapid growth of Anchorage, Alaska severely impacted the many creeks that flow through the city. These creeks have resident populations of Dolly Varden and rainbow trout as well as anadromous populations of all five species of Pacific salmon. Impacts ranged from increased peak flows resulting from a more impervious watershed to decreased low flows caused by filling riparian wetlands and decreased habitat diversity for fish created by straightening of the creeks and removal of vegetation. To correct these problems, in the 1980s the city started a program to attempt to restore the habitat values of the creeks while improving flood conveyance of the channels. This paper discusses the results of HDR's restoration work done to date and experience gained from these projects.*" (O)

Darby, S. (2008). *River restoration managing the uncertainty in restoring physical habitat.* John Wiley & Sons Ltd., Hoboken.

Unavailable

Frissell, C.A., and Nawa, R.K. (1992). Incidence and causes of physical failure of artificial habitat structures in streams of Western Oregon and Washington. *North American Journal of Fisheries Management,* 12(1): 182-197.

Abstract: "*In recent years an increasing share of fishery management resources has been committed to alteration offish habitat with artificial stream structures. We evaluated rates and causes of physical impairment or failure for 161 fish habitat structures in 15 streams in southwest Oregon and southwest Washington, following a flood of a magnitude that recurs every 2–10 years. The incidence of functional impairment and outright failure varied widely among streams; the median failure rate was*

18.5% and the median damage rate (impairment plus failure) was 60%. Modes of failure were diverse and bore no simple relationship to structure design. Damage was frequent in low-gradient stream segments and widespread in streams with signs of recent watershed disturbance, high sediment loads, and unstable channels. Comparison of estimated 5–10-year damage rates from 46 projects throughout western Oregon and southwest Washington showed high but variable rates (median, 14%; range, 0–100%) in regions where peak discharge at 10-year recurrence intervals has exceeded 1.0 $m^3 \cdot s^{-1} \cdot km^{-2}$*. Results suggest that commonly prescribed structural modifications often are inappropriate and counterproductive in streams with high or elevated sediment loads, high peak flows, or highly erodible bank materials. Restoration of fourth-order and larger alluvial valley streams, which have the greatest potential for fish production in the Pacific Northwest, will require reestablishment of natural watershed and riparian processes over the long term. “* (O)

Hall, J.L., and Wissmar, R.C. (2004). Habitat factors affecting sockeye salmon redd site selection in off-channel ponds of a river floodplain. *Transactions of the American Fisheries Society*, 133(6): 1480-1496.

Abstract: “*Sockeye salmon Oncorhynchus nerka exhibit diverse use of rivers, lake beaches, sloughs, and floodplains for spawning. Their ability to use these habitats has been reduced by loss of freshwater habitat. We investigated redd site selection by sockeye salmon in two off-channel ponds (one naturally created and one man-made) of the Cedar River, Washington, which has lost floodplain habitats as a result of flow regulation, flood control, and urbanization. The purpose of the study was to identify habitat preferences of adult sockeye salmon in off-channel ponds and provide insights for preserving and restoring off-channel areas. We examined the influence of water depth, subsurface flow, substrate, water temperature, bank cover, detrital depth, distance to shore, and woody debris on redd site selection using geographic information systems, logistic regression, and electivity indices. Redds were most frequently constructed in areas with upwelling water, moderate water depths (10–80 cm), and gravel or cobble substrates. However, the importance of these attributes varied between ponds. Upwelling water was the most significant attribute influencing redd site selection in Wetland 79 (the naturally created pond). In upwelling areas, females appeared to relax selection for substrates and water depths. Conversely, females in Cavanaugh Pond (the man-made pond) selected redd sites based on water depth and substrate, with little regard for upwelling. Possible explanations for the differences in attribute selection between ponds* *are subsurface hydrological connections and pond morphology. Our results indicate that projects that enhance and reestablish surface connections between existing floodplain side channels, wetlands, and ponds may provide more beneficial habitat for sockeye salmon than created habitats. Restoration of naturally created areas may also allow sockeye salmon and other fish and wildlife species to exhibit diversity in an altered river system with limited habitat types. "* (E)

Hartman, G.F. and Brown, T.G. (1987). Use of small, temporary, floodplain tributaries by juvenile salmonids in a west coast rain-forest drainage basin, Carnation Creek, British Columbia. *Canadian Journal of Fisheries and Aquatic Sciences,* 44(2): 262-270.

Abstract: "*Seasonal movement of trout (Salmo clarki and S. gairdneri) into and out of three tributaries which drain areas ranging from 15 to 100 ha within the lower Carnation Creek catchment basin were monitored periodically from 1972 to 1985. The number of trout entering the three tributaries relative to total trout was as high as the number of coho salmon (Oncorhynchus kisutch) entering these tributaries relative to total coho. The percentage of the salmonid population represented by trout was highest in the two largest tributaries and lowest in the smallest. Trout were most clearly associated with nonvegetated sand and gravel bottom portions of the three tributaries. Coho were associated with this habitat too, but they also frequented portions of the tributaries that were vegetated and had a mud substrate. In the two largest tributaries, trout were represented by more age classes than were coho salmon. The paper considers some of the implications of use of small drainages by trout to habitat managers. "* (O – N)

Hawley, S. (2011). Recovering a lost river removing dams rewilding salmon revitalizing communities. Beacon Press, Boston.

Book Summary: "*In the Pacific Northwest, the Snake River and its wilderness tributaries were – as recently as a half century ago – some of the world's greatest salmon rivers. Now, due to four federal dams, the salmon population has dropped close to extinction. Steven Hawley, journalist and self-proclaimed "river rat," argues that the best hope for the Snake River lies in dam removal, a solution that pits the power companies and federal authorities against a collection of Indian tribes, farmers, fishermen, and river recreationists. The river's health, as he demonstrates, is closely connected to local economies,* *freshwater rights, and energy independence. Challenging the notion of hydropower as a cheap, green source of energy, Hawley depicts the efforts being made on behalf of salmon by a growing army of river warriors. Their message, persistent but disarmingly simple, is that all salmon need is water in their rivers and a clear way home.*" (N, despite the publications and content, other documents provide equivalent, nonbiases, scholarly information)

Jeffres, C.A., Opperman, J.J., and Moyle, P.B. (2008). Ephemeral floodplain habitats provide best growth conditions for juvenile Chinook salmon in a California river. *Environmental Biology of Fishes*, 83(4): 449-458.

Abstract: "*We reared juvenile Chinook salmon for two consecutive flood seasons within various habitats of the Cosumnes River and its floodplain to compare fish growth in river and floodplain habitats. Fish were placed in enclosures during times when wild salmon would naturally be rearing in floodplain habitats. We found significant differences in growth rates between salmon reared in floodplain and river enclosures. Salmon reared in seasonally inundated habitats with annual terrestrial vegetation experienced higher growth rates than those reared in a perennial pond on the floodplain. Growth of fish in the non-tidal river upstream of the floodplain varied with flow in the river. When flows were high, there was little growth and high mortality, but when the flows were low and clear, the fish grew rapidly. Fish displayed very poor growth in tidally influenced river habitat below the floodplain, a habitat type to which juveniles are commonly displaced during high flow events due to a lack of channel complexity in the main-stem river. Overall, ephemeral floodplain habitats supported higher growth rates for juvenile Chinook salmon than more permanent habitats in either the floodplain or river. Variable responses in both growth and mortality, however, indicate the importance of providing habitat complexity for juvenile salmon in floodplain reaches of streams, so fish can find optimal places for rearing under different flow conditions.*" (E)

Naiman, R.J., Decamps, H., and McClain, M.E. (2010). Riparia: ecology conservation and management of streamside communities. Academic Press, Burlington.

The book is summarized as: "*This book describes the underlying water conditions and* *geologies that support viable riparia, illustrates the ecological characteristics of riparia, and discusses how riparia are used by human cultures as well as how riparia can be used to sustain environmental quality. In recent years riparian management has been widely implemented as a means of improving fisheries, water quality, and habitat for endangered species. This book provides the basic knowledge necessary to implement successful, long-term management and rehabilitation programs.*

** Treats riparian patterns & processes in a holistic perspective, from ecological components to societal activities*
** Contains over 130 illustrations and photos that summarize this complex ecological system*
** Synthesizes the information from more than 6,000 professional articles*
** Sidebars provide a look into ongoing research that is at the frontiers of riparian ecology and management*" (E)

Roni, P., Pess, G., Becchie, T., ad Morley, S. (2010). Estimating changes in coho salmon and steelhead abundance from watershed restoration: how much restoration is needed to measurably increase smolt production. *North American Journal of Fisheries Management*, 30(6): 1469-1484.

Abstract: "*Using existing data from evaluations of habitat restoration, we estimated the average change in coho salmon Oncorhynchus kisutch and steelhead O. mykiss parr and smolt densities for common in-channel (culvert removal, large wood placement, boulder placement, and constructed logjams) and floodplain restoration techniques (constructed side channels and reconnected floodplain habitats). We then used these numbers and a Monte Carlo simulation to predict changes in fish numbers in a model watershed for two restoration scenarios: (1) restoration of all accessible habitat within the watershed and (2) restoration of the average amount historically implemented in Puget Sound watersheds (8% of total restorable areas). Mean increases in coho salmon parr or smolt density after restoration ranged from 0.19 to 2.32 parr/m for in-channel techniques and from 0.34 to 1.70 parr/m^2 for floodplain techniques. Increases in steelhead parr or smolt density ranged from −0.06 to 0.71 fish/m and from 0.03 to 0.06 fish/m^2 for in-channel and floodplain techniques, respectively. Under restoration scenario 1, the predicted mean increase in numbers was 1,459,254 (117%) and 285,302 (140%) for coho salmon parr and smolts and 93,965 (65%) and 28,001 (125%) for steelhead parr and smolts. Under scenario 2, the predicted* *mean increase in parr and smolts was 59,591 (5%) and 15,022 (7%) for coho salmon and 1,733 (1%) and 1,195 (5%) for steelhead. The percentage of floodplain and in-channel habitat that would have to be restored in the modeled watershed to detect a 25% increase in coho salmon and steelhead smolt production (the minimum level detectable by most monitoring programs) was 20%. However, given the large variability in fish response (changes in density or abundance) to restoration, 100% of the habitat would need to be restored to be 95% certain of achieving a 25% increase in smolt production for either species. Our study demonstrates that considerable restoration is needed to produce measurable changes in fish abundance at a watershed scale."* (E)

-------, Morley, S.A., Garcia, P., Detrick, C., King, D., and Beamer, E. (2006). Coho salmon smolt production from constructed and natural floodplain habitats. *Transactions of the American Fisheries Society*, 135:1398-1408.

Abstract: "*We examined existing smolt trapping data from 30 constructed and natural floodplain habitats to determine whether the number (production), density, and length of coho salmon Oncorhynchus kisutch smolts varied by project type and area. At 13 of the 30 sites we conducted detailed physical surveys to examine how morphology (shoreline irregularity), depth, and cover influenced smolt density and length. Mean smolt production for all sites averaged 2,492, density 0.37 smolts/m2, and length 98.9 mm. We found no significant difference in smolt production or density between natural and constructed sites or among project types. Smolt length differed by project type and morphology, excavated ponds (gravel pits and mill ponds) producing significantly larger smolts than constructed groundwater or natural channels. Smolt production was positively correlated with wetted area. Smolt length was negatively correlated with density and distance from salt water, suggesting that sites further inland with cooler water temperatures had higher densities and smaller fish. Site perimeter, shoreline irregularity, depth, and percent cover were not significantly different among habitat types at intensively sampled sites, nor were they correlated with smolt production or smolt density. However, multiple regression analysis indicated that shoreline irregularity and percent cover explained 70% of the variation in smolt length."* (E)

Rosenfield, J.S., Raeburn, E., Carrier, P.C., and Johnson, R. (2008). Effects of side channel structure on productivity of floodplain habitats for juvenile coho salmon. *North American Journal of Fisheries Management*, 28: 1108-1119.

Abstract: "*Numerous artificial side channels have been constructed in British Columbia and the Pacific Northwest to compensate for habitat loss from floodplain development. We reviewed data from published studies on natural and restored side channel habitats to determine how design features influence productive capacity for juvenile coho salmon Oncorhynchus kisutch. Average density and biomass of coho salmon parr were significantly higher in stream-type side channels (3.4 parr/m2 and 8.01 g/m2, respectively) than in pond- type side channels (0.8 parr/m2 and 2.37 g/m2). Although total parr biomass was three times higher in stream- type side channels, average parr weight was 47% lower, suggesting greater density-dependent limitation of growth from higher recruitment of juveniles to stream-type habitats. Parr abundance declined from late summer to early spring in both side channel types but appeared to decrease more quickly in stream-type side channels, suggesting greater self-thinning in stream-type habitat from mortality or immigration to slower pond or main-stem habitat as fish sought lower velocities for overwintering. Fish density in a single off-channel complex that contained both stream and pond habitats (fish were able to move between habitats) was also higher in stream habitats, although fish were significantly larger in pond habitats than in stream habitats. Parr density in stream-type side channels was constant with increasing channel size, whereas density in pond-type side channels was a decreasing function of side channel area. Smolt production data were more limited and variable, and production was not significantly different between stream- and pond-type side channels. Smolt density (smolts produced/m2 of channel habitat) was also a decreasing function of total side channel area, indicating that the optimal side channel habitat size (or pond size within a side channel complex) was below 5,000–10,000 m2. Side channels that incorporate a diversity of flowing- and standing-water areas are most likely to provide the variety of habitats (i.e., spawning, summer rearing, and overwintering) required by salmonids to complete their life cycle.*" (E)

Sommer, T.R., Harrell, W.C., and Nobriga, M.L. (2005). Habitat use and stranding risk of juvenile chinook salmon on a seasonal floodplain. *North American Journal of Fisheries Management*, 25(4): 1493-1504.

Abstract: “*Although juvenile Chinook salmon Oncorhynchus tshawytscha are known to use a variety of habitats, their use of seasonal floodplains, a highly variable and potentially risky habitat, has not been studied extensively. Particularly unclear is whether a seasonal floodplain is a net “source” or a net “sink” for salmonid production. To help address this issue, we studied salmon habitat use in the Yolo Bypass, a 24,000-ha floodplain of the Sacramento River, California. Juvenile salmon were present in the Yolo Bypass during winter–spring; fish were collected in all regions and substrates of the floodplain in diverse habitats. Experimental releases of tagged hatchery salmon suggest that the fish reared on the floodplain for extended periods (mean = 33 d in 1998, 56 d in 1999, and 30 d in 2000). Floodplain rearing and associated growth are also supported by the significantly larger size of wild salmon at the floodplain outlet than at the inlet during each of the study years. Several lines of evidence suggest that although the majority of young salmon successfully emigrated from the floodplain, areas with engineered water control structures had comparatively high rates of stranding. Adult ocean recoveries of tagged hatchery fish indicate that seasonal floodplains support survival at least comparable with that of adjacent perennial river channels. These results indicate that floodplains appear to be a viable rearing habitat for Chinook salmon, making floodplain restoration an important tool for enhancing salmon production.* “ (E)

-------, Nobriga, M.L., Harrell, W.C., Batham, W., and Kimmerer, W.J. (2001). Floodplain rearing of juvenile chinook salmon: evidence of enhanced growth and survival. *Canadian Journal of Fisheries and Aquatic Sciences,* 58(2): 325-333.

Abstract: “*In this study, we provide evidence that the Yolo Bypass, the primary floodplain of the lower Sacramento River (California, U.S.A.), provides better rearing and migration habitat for juvenile chinook salmon (Oncorhynchus tshawytscha) than adjacent river channels. During 1998 and 1999, salmon increased in size substantially faster in the seasonally inundated agricultural floodplain than in the river, suggesting better growth rates. Similarly, coded-wire-tagged juveniles released in the floodplain were significantly larger at recapture and had higher apparent growth rates than those concurrently released in the river. Improved growth rates in the floodplain were in part a result of significantly higher prey consumption, reflecting greater availability of drift invertebrates. Bioenergetic modeling suggested that feeding success was greater in the floodplain than in the river, despite increased metabolic costs of rearing in the significantly warmer floodplain. Survival indices for coded-wire-tagged groups were somewhat higher for those released in the floodplain than for those released in the river, but the differences* *were not statistically significant. Growth, survival, feeding success, and prey availability were higher in 1998 than in 1999, a year in which flow was more moderate, indicating that hydrology affects the quality of floodplain rearing habitat. These findings support the predictions of the flood pulse concept and provide new insight into the importance of the floodplain for salmon.* " (E)

Whitway, S.L., Pascale, M.B., Zimmermann, A., Venter, O., and Grant, J.W.A. (2009). Do in-stream restoration structures enhance salmonid abundance? A meta-analysis. *Canadian American Journal of Fisheries and Aquatic Sciences*, 67: 831-841.

Abstract: "*Despite the widespread use of stream restoration structures to improve fish habitat, few quantitative studies have evaluated their effectiveness. This study uses a meta-analysis approach to test the effectiveness of five types of in- stream restoration structures (weirs, deflectors, cover structures, boulder placement, and large woody debris) on both sal- monid abundance and physical habitat characteristics. Compilation of data from 211 stream restoration projects showed a significant increase in pool area, average depth, large woody debris, and percent cover, as well as a decrease in riffle area, following the installation of in-stream structures. There was also a significant increase in salmonid density (mean effect size of 0.51, or 167%) and biomass (mean effect size of 0.48, or 162%) following the installation of structures. Large differences were observed between species, with rainbow trout (Oncorhynchus mykiss) showing the largest increases in density and biomass. This compilation highlights the potential of in-stream structures to create better habitat for and increase the abundance of salmonids, but the scarcity of long-term monitoring of the effectiveness of in-stream structures is problematic.* "

CHENA:

Coles-Ritchie, M. (2009). *A review of riparian functions and management: with a focus on the Fairbanks North Star Borough, Alaska.* Retrieve January 2013 from http://www.tvwatershed.org/content/images/stories/reports_and_pubs/Coles-

Ritchie%202009%20A%20Review%20of%20Riparian%20Functions%20and%20Management.pdf.

This is a review that has the objectives of reviewing: (1) increase understanding of the value of riparian areas, (2) findings summarized from scientific literature on buffer effectiveness, and (3) regulations and methods used by the government and other functions of riparian communities. The goal of the document is to influence citizens and governments within Fairbanks North Star Borough to better manage riparian zones. Riparian is described (areas alongside streams and rivers) as well as the distinct landforms and vegetation communities comparative to uplands. The importance in understanding the dynamic nature of riverine communities, their processes, and the adjacent floodplains are not only for flooding but also for erosion control, migration patterns, and deposition of sediments. A statement, "*there is a natural give and take between the river and the riparian area,*" best describes the relationship of the waterways with its neighboring communities on land. The riparian function focused on in this review are: streambank stabilization, floodwater storage, contaminant filtering, habitat for fish and wildlife, and recreational and aesthetic values. (G)

-------. (2008). *Online resources for riparian management practices: with a focus on the Fairbanks North Star Borough, Alaska.* Retrieved January 2013 from http://www.tvwatershed.org/content/images/stories/reports_and_pubs/Coles-Ritchie%202008%20Online%20resources%20for%20riparian%20management.pdf

This is an online list of resources based on topics of: a) regulations (US and Alaska), b) Alaska (streambank protection, Tanana Watershed, miscellaneous), c) ecology and functions of riparian areas, streambanks, d) riparian management for homeowners and communities, d) riparian management in rural settings, e) riparian buffer effectiveness (review), f) riparian buffers (recommended widths), g) programs that support riparian protection, h) watershed management, i) stormwater management, and j) bibliographies. The resources are useful, relevant, and pertinent to Chena Watershed, River, and its tributaries. (E)

Ihlenfeldt, N., and Howard, K.M. (2006). *Restoration of sloughs in the Fairbanks North Star Borough (Tanana River Watershed)*. (Technical Report no. 06-02). Retrieved January 2013 from http://www.adfg.alaska.gov/static/home/library/pdfs/habitat/06_02.pdf.

The document states sloughs are important for Arctic grayling for spawning and rearing habitat. Graying are essential to fisherman to Interior Alaska; however, urbanization and development along the sloughs, impairs of grayling habitat (rearing, spawning). Five sloughs were mentioned: Chena, Beaver Springs, Pildesdriver, Twentythree Mile, and Noyes.
Four of these (Chena, Twentythree Mile, Piledriver, and Noyes) are listed as those important in migration of anadromous and resident fishes like chinook, chum, round whitefish, northern pike, longnose suckers, slimy sculpin, Alaska blackfish, and arctic lamprey.

Many agencies over the years have administerd studies, plans, identifying goals, and funding to restore have worked. A Chena Slough Technical Committee (CSTC) formed in 2000 that focused on the Chena Slough, which worked on culvert replacement at crossings on non-maintained ADOT/PF road crossings of Chena Slough. A three-phase implementation phase plan was implemented, which the first focused on assessment and reestablishment fish passage.

The Alaska Department of Natural Resources in 2001 surveyed nine road crossings of the Chena Slough that showed fish passage was blocked in situations where culvert discharges were less than fish passage flow (70 cfs). Fish passage failures were identified and recommendations for the three-phase program were made. The completion of phase one is summarized with the focus on the restored sites along the Chena Slough, Beaver Spring Slough. Twentythree Mile Slough, and Piledriver Slough. (E –G).

Karle, K.F. (2003). *Evaluation of bioengineered stream bank stabilization in Alaska.* (FHWA-AK-RD-03-03). Retrieved February 2013 from http://www.dot.state.ak.us/stwddes/research/assets/pdf/fhwa_ak_rd_03_03.pdf.

Abstract: "*This report documents and presents the results of a study of the use of bioengineered erosion control structures on Alaskan streams and rivers. Field investigations of hydraulic and vegetation conditions at eleven study sites around the State of Alaska were conducted to determine the performance* *of these structures. Root wads, live staking, brush layering, and coir logs were the primary bioengineering methods used for erosion control at the study sites. A one-dimensional numerical computer model was applied at each site to estimate the magnitude of average bed and bank shear stresses (tractive force) apparent to the erosion control structures at the 50-year and 100-year design flood levels. Discharge records and field flood indicators were checked to correlate structure condition to flow history. Damage at existing structures was attributed to flowing ice, undermining of toe protection, buoyancy effects, and failure of construction fabrics. Root wad structures in good condition were located in areas with high boat wake occurrence, but low channel tractive forces. The findings of the study suggest the types of bioengineered erosion control structures studied have not been proven to offer reliable bank erosion protection during flooding conditions on channels with high tractive forces."*

The findings of the literature review conducted were related to design, construction, and performance of bioengineered streambank stabilization structure, which this paper has created a literature review and information specific to Alaska. Much of the information provided also includes information on bioengineering. Conclusively, Karle suggests that bioengineering (BECs) is inadequate protection from toe erosion in flooding conditions, which is where the structure is. The erosion could lead to further failure of BECs as the designs do not self-healing. He states that a proper riprap structure could provide strength. The unique northern climate also accounts for problematic types of materials used or environmental factors. Positives on root wads and willow (brush layer sites) cuttings show greater promise of protection of banks, i.e. boat wakes. Karle stresses for more research to improve BECs, and until then areas of low erosion potential. (E*)

Post, R.A. (1998). *Lower Chena River watershed management strategies and information needs*. Retrieved from January 2013 from http://www.adfg.alaska.gov/static/home/library/pdfs/habitat/98_06.pdf

ADF&G received cost-share funding from "State and Tribal Wetland Protection Grant" administered by EPA Clean Water Act (Section 104(b)(3)) produced a management plan for the Lower Chena River (Moose Creek Sam and Chena's confluence). A multiagency consensus prior the project, plan, and Public Forum hosted that is presented to the local community. Volunteers are encouraged from the community for the planning team for the project. The team developed procedures for its meetings, developed watershed management strategies based on topics – water quality, channel problems, flooding and drainage, and wetland management-, and identify information need for a draft management plan. (G – O)

Rozelle, N. (2003). *Fixing the fatal flaw of Fairbanks.* (#1663) Retrieved December 2012 from http://archive.is/SsqA.

The Geophysical Institute UAF presented this article at a public service with UAF research community, as it was mentioned in the document. A summary of this article is impounding the Chena at high flows to avoid water flooding of the Chena River of which the Army Corps of Engineers through the Chena River Lakes Flood Control Project have management and direct it to the Tanana River; thus, the ability to modify the levels of the Chena River. (N)

AKUSCOE (U.S. Department of the Army Alaska District Corps of Engineers). (1988). *Chena River Lakes Project, Fairbanks, Alaska: water control manual*. Retrieved January 2013 from http://www.tvwatershed.org/content/images/stories/reports_and_pubs/1988_Chena_River_Lakes_Project_Water_Control_Manual.pdf

The document delves into the Chena River Lakes Project, which consists of diversion dams, floodway, levee system along the Tanana River, and interior drainage network between Chena and Tanana Rivers. It was indicated that migratory fish species are affected at dam sites and within river systems. Operations of flood control projects have negative effects on Chena River fisheries, especially long-duration of flood events. Loss of fish resulted from entrapment in the riprap, ponds, and pools of the floodway. Trapped adult salmon may occur in the oxbow lakes along Chena River. (O)

-------. (1997). *Chena River watershed study: reconnaissance report.* Retrieved January 2013 from http://www.tvwatershed.org/content/images/stories/reports_and_pubs/Chena%20River%20Watershed%20Study.pdf

The Chena River Watershed study was administered December 1970 with the purpose of to guide a decision as to advisability of further Federal planning on land and water resources issues and solution. The information was made on a reconnaissance level. The focus is on hydrological zone of influence within the watershed. (N)

ONLINE SOURCES:

Admiraal, D.M. (2007). *Stream bank stabilization using traditional and bioengineering methods: a literature review.* Retrieved December 2012 from http://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&ved=0CDkQFjAA&url=http%3A%2F%2Fnlc.nebraska.gov%2Fepubs%2FR6000%2FB016.0131-2007.pdf&ei=FTbaUKKwFOveigKs2IGgAQ&usg=AFQjCNEwhn7fMCYpJLuaj6zh3PWO23at-A&bvm=bv.1355534169,d.cGE

This literature review addresses stream bank erosion and mechanisms to slow it done by traditional and bioengineering techniques. The document is divided into four sections exploring failure of mechanisms, traditional structural methods for erosion control, bioengineering methods for erosion control, and work done on combined methods. The review goes in great detail about each section. The wearing of steep stream banks and fluvial activity were determined as causes of erosion, which solutions were suggested to focus on fluvial erosion. Another focus recommended was on weaker layers of sediment for stability in order to control erosion rates. Bioengineering techniques are successful when both biotechnical and non-biotechnical, which also successful below water level. Within these areas, it was found that bioengineering also allows establishment and success of native species are more likely to be established and successful than non-native species. In studies, it was determined that black willow was most successful plant for this method of bank stability (bioengineering). The review also lists plants successful in the restoration, primarily in Nebraska area. This excellent review also provides numerous tables and figures. (E)

Coles-Ritchie, M. (2008). *Online resources for riparian management practices: with a focus on the Fairbanks North Star Borough, Alaska*. Retrieved December 2012 from http://www.tvwatershed.org/content/images/stories /reports_and_pubs/Coles-Ritchie%202008%20Online%20resources%20for%20riparian%20management.pdf

This document specifically list online references focused on riparian management and stream bank protection of Alaska and general basic knowledge. The divisions of these sources are by: regulations (US, Alaska); Alaska (misc); ecological and functions of riparian areas; stream bank protection (Alaska, general, programs for riparian protection); riparian management (residential/commercial, rural); riparian buffer (width recommendations, effectiveness), watershed management, stormwater management, and bibliographies. In conclusion, this is a great reference or resource for all directions and interests of stream bank ecology. This would be an excellent reference for further information. (E)

Correll, D. (1999). *Vegetated stream riparian zones: their effects on stream nutrients, sediments, and toxic substrates.* Retrieved December 2012 from http://www.puyallup.wsu.edu/agbuffers/pdf/vegetated_stream_riparian_zones.pdf.

The document concisely lists articles around vegetative stream riparian zone and water quality effects as a bibliography. Literatures on hyphorheic zone and floodplain/stream channel interactions were in the newer editions, which had included to the buffer strip research. The citations have been cross-examined for content and other relevant citations. The articles from research library citations have been included in the bibliography. The studies listed have excluded large woody debris and application of municipal sewage /industrial/ mining effluent to riparian zones. Water quality was included, which encompassed nutrients, suspended sediments, organic matter, and characteristics (pH, etc). The author is very descriptive in how articles where selected and which ones would have a description. The author adds a code for topics as abbreviation, which is added to the citations. (G)

East Kitsap Nearshore Assessment. Appendix E: Fish habitat utilization literature review. Retrieved December 2012 from http://www.kitsapshoreline.org/Appendix_E_Literature_Review.pdf

This literature review is actually an annotated bibliography. The articles included in the document include urban shoreline fish distribution, use of pocket estuaries in basins, juvenile salmon population linkage with estuary restoration, and history of marine life of salmon. (E – G)

Kite, J.S. (2004). Geology/Geography 621: Advanced fluvial geomorphology course: fluvial geomorphology annotated bibliography. Retrieved December 2012 from http://www.geo.wvu.edu/~kite/geol621bibliography.html

This annotated bibliography can be assumed to be associated with the geology/geography class. The articles Kite annotates include natural river classification, i.e. Rogen et al., as well as alternatives and reactions. Articles also were annotated on stream design as well as river continuum concept. Fluvial geomorphology and adaption to stream as it relates to fish and plants was in a section of articles summarized. The author of the bibliography closes with stream notes that are quarterly publication. These publications include riparian vegetation, stream function, aquatic organism passage, indicator of chronic sedimentation or toxic exposure, and scaling plotting. Reference reaches and hydraulic geometry data section was also included in the bibliography. A historical look at hydraulic, hydrology, and bedload as it relates to water resources research, flash floods, as well as hazards or depositions. Dating methods are also annotated from articles. Articles also summarized included human-impacts on streams. (O)

Montana Water Center. (2005). Wild fish habitat initiative: restoration bibliography. Retrieved December 2012 from http://wildfish.montana.edu/biblio/default.htm.

This bibliography focuses on restoration and assist scientists or project managers working on fish habitat restoration of the intermountain west. This is a very useful scours that allows various fish habitat restoration techniques to exchange between biologist and project managers. The collection includes books, book chapters, restoration manuals, journals articles, conference proceedings, dissertations, government documents, and technical reports. There is a search and browse link that allows the reader to find or skim through resources available on the site. (E)

National Trails Training Partnership. (2008). *Wildlife and environmental issues: resources for Riparian Restoration Projects.* Retrieved December 2012 from http://www.americantrails.org/resources/wildlife/WildBiblioRestore.html.

This bibliography lists documents on riparian restoration and revegetation projects, programs and techniques as well as standards in the western United States. The main focuses of these documents are on California. This is a helpful site for basis information not specific to Alaska. Overall this site would not be good for referencing. (N)

Stream Restoration Bibliography. (2005). Retrieved December 2012 from http://www.keystonestreamteam.org/docs/NSCD_Biblio.pdf

The bibliography lists references for articles or a document not cited. The document is divided into sections. For instance, recent publications (2004 to 2005) is followed by references of the noncited document. The bibliography also dedicates a section of references for evaluating stream restoration projects and Pennsylvania-related reference. This bibliography is useful for additional information on stream restoration and assessing restoration efforts. (O – N)

USGS (US Geological Survey) and US Department of the Interior. (2012*). USGS Water Resources*

Links for 19040506 – Chena River. Retrieved December 2012 from http://water.usgs.gov/lookup/getwatershed?19040506

This is a site that provides links to additional information on sections on the Chena River as well as other watersheds, including reports, latitude/longitude, hydrologic unit, depth, altitude, and available data. Information on projects through publications and data are also available on Tanana River, Yukon, and Region 19 Alaska. Available real-time streamflow data, monthly data, groundwater and GIS spatial data are accessible from this site on Chena River. Also provided are food and drought information through waterwatch USGS and NWIS. The site provides hydrological and geochemical information that would be useful for departments of transportation, land use planners, and wildlife agencies. The overall page provides various raw data and information relevant to the Central Alaska.

The website allows for watershed information to be accessed from links posted along the left column enabling one to search for information, case studies or data. A useful search is for active project, for instance, or databases to obtain what the researcher is looking for specifically. Analysis is another useful search link that brings up watershed analysis by USGS, US Department of Agriculture, Environmental Protection Agency, US Bureau of Reclamation, Tennessee Valley Authority, Clean Water Action, and Clean Water Fund. The information can be portrayed as graphs, charts, reports, and reviews. Overall the website is great resource useful for raw and hard data as well as publications for central Alaska. (G – E)

Wenger, S. (1999). *A review of the scientific literature on riparian buffer width, extent, and vegetation.* Retrieved December 2012 from http://www.rivercenter.uga.edu/service/tools/buffers/buffer_lit_review.pdf

Riparian buffer protection plan is the main focus of the document, which primarily is centered in Georgia. Formulated buffer delineation derived from reviewing materials allowed for establishing riparian buffer width, extent, and vegetation was based on reviewed materials for the document. Findings in this document suggest through long-term studies 30 m (100ft) wide buffers along stream, which trap sediments. Phosphorus control requires management of its sources; buffers also controls nitrogen. The findings of the document suggest optimal aquatic habitat to be between 10 to 30 m (35-100 ft) of native forested riparian buffer, which should be protected as they provide critical organic matter for these aquatic ecosystems. Existing models for appropriate buffer width were found to be impractical due to too much data or not being calibrated and verified. Thus, the authors determined buffer slope and wetland presence as essential factors in determining width of stream buffers.

The resulting options proposed for buffer guidelines were three that differed in base width (100ft with 2ft per 1% of slope; 50ft with 2ft per 1% slope; fixed 100ft) and conditions; however, all options include native forests. It is also clarified in the article of that the measurement of the buffer is one side that accounts for certain stream footage, which if a 50ft or 100ft buffer may need to be much larger. The document suggests reducing impervious surfaces and pollution management. In conclusion, this will provide habitat for aquatic and terrestrial wildlife as well as optimal elemental absorption, i.e. phosphorus, nitrogen, etc.

The document is divided into sections for easy navigation for information use of reader. These divisions include sediment, nutrients/contaminants, habitat influences, and riparian guidelines. Each of these sections provides a literature review or summary. As mentioned, this excellent resource provides scientific basis for riparian buffers for policy created by Georgian local governments. The articles, unfortunately, is outdated (thirteen years old). (G – E)

Wildland Hydrology. (2011). *Wildland hydrology reference materials.* Retrieved December 2012 from http://www.wildlandhydrology.com/html/references_.html.

This bibliography provides additional information on articles, documents, reports, manuals or guides, etc. on the following topics: basic manuals, restoration, stream classifications, TMDL (total maximum daily load), river assessment and monitoring, morphology, etc. The focus of this webpage is to provide reference materials for "wildland hydrology" geared toward students and site users. The site also offers courses, books, and basic information on wildland hydrology, at all levels of knowledge. These are accessible from bulleted tabs. In conclusion, this website is very useful and user-friendly. (O – G)

Wood, L. (2001). *Geomorphologically – based stream restoration annotated bibliography*. Retrieved December 2012 from http://www.uvm.edu/~pbierman/classes/gradsem/2001/meander.doc

This annotated bibliography reviews articles used for a particular class. The document reviews seven documents focused on impaired and restoration of urban and rural watersheds. An example is of an article of evaluating stream restoration. The paper is written as a class assignment. (N)

Background- Additional references:

Clewell, A.F., and Aronson, J. (2007). *Ecological restoration: principles, values, and structure of an emerging profession*. Island Press: Washington, D.C.

Merz, J.E., and Moyle, P.B. (2006). Salmon, Wildlife, And Wine: Marine-Derived Nutrients In Human-Dominated Ecosystems Of Central California. *Ecological Applications,* 16:999–1009

Schindler, D.E., Scheuerell, M.D., Moore, J.W., Gende, S.M., Francis, T.B., and Palen, W.J. (2003). Pacific salmon and the ecology of coastal ecosystems. *Frontier of Ecology and Environment,* 1(1): 31-37.

APPENDICES: FORMS, SURVEYS, TECHNIQUE SUMMARY TABLES, AND OTHER DOCUMENTS:

The attached diagrams, pictures, forms, documents, articles, and pages from the above-annotated bibliography follows within this section. These pages or sections provide additional information to supplement, add.