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ASSESSING RIPARIAN ECOSYSTEM CONDITION AND MONITORING RECOVERY FROM NATURAL AND ANTHROPOGENIC DISTURBANCE

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ASSESSING RIPARIAN ECOSYSTEM CONDITION AND MONITORING RECOVERY

FROM NATURAL AND ANTHROPOGENIC DISTURBANCE

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ABSTRACT

Riparian ecosystems are the transition zones between river systems and uplands. They provide many valuable ecological functions including creating habitat for wildlife, stabilizing banks from erosion and providing a buffer that prevents excess nutrients from entering streams. Fires and other disturbances alter the function of these ecosystems. Currently, there is a lack of broadly used standardized assessments and monitoring methods in riparian areas within our current water policy framework. This study aims to examine this gap in riparian ecosystem protection by reviewing the assessment methods currently in use, selecting one method for field testing, and analyzing the effort involved in using that method as a potential tool for the citizen science model to compare three riparian systems with different recovery times since last fire.

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I. INTRODUCTION

Assessing the condition of river systems is an old endeavor dating back to the 1800's with European pollution studies that identified aquatic organisms that indicate environmental degradation. Since that time, measuring and monitoring riparian ecosystem health has relied heavily on indicator species as principal analytic and monitoring tools. In the 1970's single species indicators were replaced with community-level analysis of the aquatic community. With the rise of ecosystem science, a wider landscape approach to assessment was introduced. In line with the idea of broader landscape ecology, for this study the term "riparian" will refer to the streams and floodplain as well as the riparian buffers adjacent to the floodplain. Riparian zones are visually defined by a greenbelt with a characteristic suite of plants, such as cottonwood trees and willows, that are adapted to and depend on the shallow water table. To address this entire zone, there are currently many assessment tools used that rely on multiple characteristics of community composition and structure to assess riparian ecosystem health.

Even before the creation of the EPA and passage of the Clean Water Act, states in the U.S. used a combination of physical, chemical and biological parameters to assess whether water bodies supported their beneficial uses. In the early years of the CWA chemical water quality received the most attention since chemical pollution was often the greatest threat to human uses of water. However, in the decades following the seventies, a growing interest in conserving native fish and aquatic communities led to the use of more integrated assessments that assessed biological communities and physical habitat as well.

There have been two general types of biological indicators used. These are community structure (more commonly used) and community function. Examples of community structure attributes are dominant species, species amount and taxonomic diversity. Examples of functional attributes include element cycling rates, primary productivity, biomass turnover and community respiration. Though functional measures have been useful at analyzing the condition of terrestrial plant communities, structural measures have been shown to have advantages at detecting known system statuses in aquatic ecosystems (Bain et al., 2000). Structural measures are easier to measure, easier to relate to, and can integrate conditions over a longer period of time than do functional measures. Most assessment methods in use aim to address the concept of ecosystem integrity as it relates to legislative mandates (e.g., Clean Water Act) and as a scientific term. Karr and Dudley (1981) use the term "ecosystem integrity" to refer to a system's "wholeness" or more specifically an "ecosystem's capability of supporting and maintaining a balanced, integrated, adaptive community of organisms having a species composition, diversity, and functional organization comparable to that of natural habitat in the region." The term 'natural', in this definition, is essential as the main criteria against which all scores and values are compared. However, there is difficulty in defining natural ecosystem attributes since detailed historical records are rare, along with the reality that there are few ecosystems that have not been altered or disturbed by humans. This does not change public desire to restore ecosystems to a former more 'natural' state and the need to find consensus on specific objectives to be achieved.

Ecosystem management must go beyond assessing an area at a single point in time. The spatial and temporal scales used in ecosystem assessment methods have broadened over time. To better understand ecological dynamics, regular monitoring must be included in assessment. Ecological monitoring is defined as "maintaining regular surveillance by making measurements at regular time intervals over an indefinite, but usually long period of time." There are two fundamental reasons for monitoring ecosystems; first to establish a baseline that represents the present status of an ecosystem; and second, to detect changes over time, mainly deviations from the established baseline. Linked to these reasons is the need to examine why changes occur (Vaughn et al., 2001). The acquisition of long-term monitoring data records of changes in ecosystems over time is critical in recognizing and understanding how ecosystems respond to various disturbances.

Established assessment methods show that ecologists and resource managers not only have a wide range of tools to measure the quality of riparian ecosystems, but those tools are flexible and can be customized to match the needs of a particular objective, or location. However, developing and implementing ecosystem-scale assessment tools is challenged by a lack of specification and consistency of management goals nationwide.

As Costanza et al. stated in their paper about the value of ecosystem functions, "to say that we should not do valuation of ecosystems is to deny the reality that we already do, always have and cannot avoid doing so in the future" (pg. 68, 1998). Though assigning a value is difficult, it is essential to safeguarding ecosystems. To provide their valuable services, streams must be able to maintain their natural communities and processes. Historically, there has been a disregard and devaluing of these vital ecosystems and a current lack of motivation in preserving them despite the widespread knowledge of their importance and accessibility to useful assessment methods.

To highlight this deficiency in current U.S. policy, it is important to look at what has been happening in the EU and their approach to riparian ecosystem protection. In 2000, the EU enacted the Water Framework Directive, which is a legally binding document requiring member states to implement water management measures that achieve 'good' overall quality of European water bodies within 15 years. To determine the condition of water bodies, assessment and monitoring methods need to be approved and implemented as a monitoring tool to assist in updates. This Directive will be further explained later in this paper.

Purpose: The purpose of this paper is to increase understanding of riparian ecosystem values, conservation policy and tools for assessing the condition of these ecosystems. The target audience includes agencies such as the Montana DEQ, watershed groups and landowners that want to assess and evaluate riparian areas in their watersheds.

Objectives:

1. Review value of riparian ecosystems and their responses to natural and human disturbances.
2. Review how US water quality policy addresses conserving the health/condition of riparian ecosystems.
3. Review how riparian ecosystem ‘health’ or condition is assessed in the US and Europe.
4. Select an assessment method that appears to most clearly address key riparian condition parameters and apply that method to three stream reaches in the Flathead headwaters that represent a range of recovery times since fire.
5. Evaluate the method’s feasibility and usefulness (considering training and field time and within site variability of results) and its possible use in the citizen science model.
6. If justified, recommend further testing of the method.

This study is organized into several chapters as follows:

Riparian Ecosystem Values, Policy and Condition Assessment and Monitoring Tools:

This chapter addresses the following ideas:

- The importance of riparian ecosystems and the functions provided.
- The importance of monitoring ecological disturbance.
- A description of U.S. and EU approach to riparian ecosystem protection.
- A description of the riparian habitat assessment methods available and implemented by governmental agencies in the U.S and EU and their strengths and weaknesses.

Study Design: This chapter describes this unique area and the reasons that it is suitable for this study. This chapter also describes a riparian habitat assessment and monitoring tool developed by riparian ecologists in the southwest U.S. and used to assess the condition of three reaches on the North Fork Flathead River following two separate severe fire events.

Results: Presents the habitat assessment scores of all survey sites on the North Fork Flathead River.

Discussion: Discusses habitat assessment scores and how they relate to the theoretical framework of riparian ecosystem assessment and monitoring and research objectives as well as an analysis of the feasibility of the tool used on the North Fork Flathead River.

Conclusion: Presents the main conclusion from this study.

II. RIPARIAN ECOSYSTEM VALUES, POLICY AND CONDITION ASSESSMENT AND MONITORING TOOLS

A. Theoretical Context for Assessment and Monitoring

1. Riparian Ecosystem Values and Services

Riparian ecosystems are among the most diverse and dynamic habitats and they provide many ecosystem services including:

Wildlife habitat: These areas offer key habitat components to an array of species and can serve as refuge for wildlife (Naiman and Decamps, 1997). In-stream structures, including the presence or absence of pools, riffles, thalwegs and runs affect the diversity of aquatic plants and animals. Woody debris from riparian areas add structure to in-stream habitats as well as allochthonous organic matter as a food source (Tuckett and Koetsier, 2016).

Nutrient buffer: Riparian areas are effective in controlling nonpoint source pollution by removing nutrients, especially nitrogen, phosphorous and sediment (USDA, 1997).

Temperature Buffer: Riparian areas host many ecologically significant plants that offer shelter and shade to a variety of organisms. Riparian tree canopies contribute to the reduction of stream temperatures, which is needed for cold-water aquatic species. Additionally, riparian vegetation can serve as a buffer to extreme cold temperatures.

Bank stability: The deep binding roots from riparian plants contribute to bank stability by upholding soil structure (Johnson, 2004).

Floodplain Values: Floodplains absorb water and energy from flooding and recharge groundwater (Krause et al., 2007).

Economic Value: Rivers provide water and fertile alluvial plains that sustain humans and have historically been a central place in the rise of human civilizations. Floodplains have provided nutrient rich farmland as well as water for irrigation. Currently, rivers continue to be closely connected with great cities while creating unique urban environments. In less developed regions, where rivers have maintained their natural characteristics, fishing, boating and other forms of recreation are valued. In both cases, tourism on rivers are an important financial resource.

2. Disturbance Theory and Riparian Systems

Understanding how and why ecological communities change over time has been a persistent theme in ecology (Cooper, 1913, Watt, 1947 and Odum, 1969). White and Pickett (1985, pg. 4) define disturbance as "any relatively discrete event that disrupts the structure of an ecosystem, community, or population, and changes resource availability or the physical environment". And according to Monica Turner (2010, pg. 2834), "disturbances alter system state and the trajectory of an ecosystem, and thus they are key drivers of spatial and temporal heterogeneity. Disturbances happen over relatively short intervals of time; hurricanes or windstorms occur over hours to days, fires burn for hours to months, and volcanoes erupt over periods of days or weeks. Disturbances may be abiotic (e.g., hurricanes, tornadoes, or volcanic eruptions), biotic (e.g., the spread of a nonnative pest or pathogen), or some combination of the two (e.g., fires require abiotic conditions suitable for ignition and burning as well as a source of adequate fuel, which is biotic)." A disturbance regime, as opposed to a disturbance event, refers to the temporal and spatial dynamics over an extended period of time. The components of a disturbance regime include: spatial distribution of disturbances; frequency, return interval and rotation period; disturbance size, intensity and severity (Turner, 2010).

Although implicitly discussed earlier, the idea of disturbance and succession did not become a focal point until the late 1970's (Turner, 2010). During this time, and going into the early

1980's, research focused on disturbance as a key process that structures ecological systems across numerous scales. In 1985, the book *Natural Disturbance and Path Dynamics* by Pickett and White ushered in a period of focused attention to natural disturbances in a wide range of systems and emphasized spatial heterogeneity in ecosystems. Along with the growing interest in disturbance, ecologists in North America became interested in landscape ecology and the causes and consequences of spatial heterogeneity (Turner, 2010). Compared to European landscapes, which are typically long-altered by humans, North American landscapes are comprised of natural and semi-natural regions, where disturbance dynamics are relatively visible. During the 1980's several large-scale natural disturbances, including Mount St. Helens in 1980 and the fires in Yellowstone in 1988, created public interest and extensive media attention. Additionally, human-induced disturbances such as oil spills, the Exxon Valdez in 1989 and the Deep Horizon in 2010, have been given public attention. Along with the media attention, large disturbances have garnered a growing scientific interest to predict future effects of disturbance, natural and human-induced, by understanding disturbance dynamics.

Many ecologists, including Turner, emphasize the importance of studying disturbance while disturbance regimes are changing globally. Turner (2010, pg. 2835) stated that "studies of disturbance can provide unique insights into ecological patterns and processes. In addition, disturbances will interact with other key drivers of global change and strongly affect ecological systems and humanity. Disturbance is a key component of ecological systems, affecting terrestrial, aquatic, and marine ecosystems across a wide range of scales." In tandem with changing disturbance regimes, in 2005 the Millennium Ecosystem Assessment highlighted the consequences of human-caused disturbances, including; habitat change, invasive species, climate change, increasing nutrient availability and over-exploitation of resources. The Assessment also reported an increase of floods and wildfires in North and South America, Europe, Asia, Africa and Oceania. It has been clear, for the western U.S., that the frequency and severity of wildfires has increased in recent decades as a result of earlier snowmelt, lengthening fire seasons and warming temperatures (Westerling et al., 2006).

When disturbances threaten human life and property, the costs of disturbance and preventing disturbances can be crippling. Federal firefighting costs, suppression only, have increased nearly 10 times over the past three decades, costing nearly 2 billion a year (NIFC, 2017). Ironically, fire suppression in some forests, such as ponderosa pine, which were historically characterized by frequent, low-severity fires, have caused those forests to accumulate unnaturally high fuel loads, increasing the risk of high-severity fires (Allen et al., 2002). Similarly, levees and other restrictive structures intended to minimize flooding may, in fact increase flood frequency and magnitude downstream (Poff et al., 2007). Societal trends have demonstrated a focus on controlling frequent, less severe disturbance events while actually increasing the likelihood of infrequent, higher severity events. It is essential to enhance the understanding of the causes and consequences of disturbances. With this knowledge, ecologists can better assist resource managers and policy makers to improve human safety and property loss.

Adding to the importance of a base understanding of ecological disturbance, is the phase of rapid change that many disturbance regimes are currently experiencing. Because of climate change and other global drivers, profound changes in disturbances regimes are likely to occur within this century (Turner, 2010). With this in mind, the past may not predict the future, but the knowledge acquired over the past few decades will be an important contribution to anticipating disturbance responses of changing ecological systems.

There is an immense need for policy makers and resource managers to understand how ecosystems respond to natural and human-induced disturbances in order to anticipate the effects of shifting risks. Ecological information collected over long periods of time can provide crucial insights into changing ecosystems. The data from implementation of ecosystem assessments and monitoring tools can offer the following to the understanding of disturbance:

- Documented baselines against which change or extremes can be evaluated (Keeling et al., 1996).
- Evaluations of ecological responses to natural or experimental disturbance (Schindler et al., 1985).
- Detection and evaluation of changes in ecosystem structure and function (Danell et al., 2006).
- Generation of new and important questions concerning ecological dynamics and disturbance (Persson et al., 2009).
- Guidance for evidence-based environmental legislation and regulations, including standards.

One ecological concept used to gauge a system's response to disturbance and changing environments is resilience. Resilience is sometimes generally defined as the magnitude of disturbance that can be absorbed by the system without changing dramatically (Holling, 1973). Some ecologists define resilience as the ability of a system to recover quickly after being altered by a disturbance and resistance as an ability to resist change in the face of disturbance, while others refer to both of these properties as resilience, as it is in this study.

Resiliency is more specifically described by these three characteristics given by Harrison et al (2006).

- The amount of change the system can undergo and still retain the same controls on function.

- The degree to which the system is capable of self-organization.

- The ability to build and increase the capacity for learning and adaptations.

According to the Resilience Alliance, the amount of resilience a system possesses relates to the magnitude of disturbance required to disrupt the system, causing a dramatic shift to another state that is controlled by a different set of processes (2017).

It appears that biological diversity plays a substantial role in ecosystem resilience (Peterson et al., 1998). For example, diversity of functional groups will help an ecosystem to quickly recover after disturbance. A functional group is a set of species that co-exist in a given community and have similar functional characteristics related to an ecosystem. In addition, the species diversity within these functional groups is important in maintaining ecosystem services (Luck et al., 2003). Specifically, it is the variability in responses to environmental change within functional groups that is critical to ecosystem resilience. This property is known as “response diversity” and is defined as “the diversity of responses to environmental change among species that contribute to the same ecosystem function” (Elmqvist et al., 2003, pg. 488).

Though many ecosystems regularly experience disturbance regimes that operate across a range of spatial and temporal scales, all disturbances do not elicit the same response. Natural disturbances tend to be rhythmic with distinctive magnitude and frequency distribution. Human activities have a tendency to transform rhythmic disturbances into chronic disturbances and then contribute to the formation of “compounded disturbances” where multiple disturbance events affect a location in quick succession, creating a new situation which is more than the sum of its parts (Bengtsson, 2003). In order to sustain desirable states of ecosystems when facing compounded perturbations, it is essential that diverse functional groups of species remain available for renewal and reorganization (Lundberg and Moberg, 2003). Biological diversity as a source of renewal and reorganization following disturbances is currently being threatened by the human-caused simplification of the planet and subsequent loss of species. Ecosystems can be severely changed when sets of key species are lost or when nonnative species invade (Vitousek and Walker, 1989). Furthermore, the sequence of species loss following disturbances may have significant implications for ecosystem functioning. For example, at the end of the most recent ice age, the loss of megaherbivores had a massive effect on boreal and tundra ecosystems (Zimov et al., 1995). More recently, overfishing has had a comparable effect on coastal ecosystems (Jackson et al., 2001). Ecosystems, where entire functional groups are lost or become irrelevant because of environmental change, are categorized by low response diversity. This is inarguably important, when these functional groups contribute essential ecosystem services, benefitting the well-being of humans. Riparian ecosystems are characterized by being exceptionally diverse and valuable for human well-being.

a. Fire Disturbance in Riparian Ecosystems

Since riparian ecosystems have evolved to adapt to and even depend on frequent fluvial disturbances for establishment, riparian biota provide classic examples of resilience (Table 1). In fact, recovery rates following disturbances can be relatively high compared to other ecosystems (Gecy and Wilson, 1990). However, one might wonder whether riparian ecosystems are as adapted to fire as to flood (see Table 1). Following the 1988 fires in YNP, Minshall et al. (2001) began studying their effects on stream properties and biota by comparing reference and burned streams in the first few years after fire. They found changes in the relative abundance of certain invertebrate functional feeding groups, transport and storage of organic matter, and movement of large wood. Postfire recovery rates of aquatic biota were faster than they expected and seemed to be associated to the recovery of riparian vegetation. They suggested a high degree of ecological resilience in riparian and stream ecosystems, even asserting that these ecosystems experience more rapid recovery than in adjacent uplands, following fire.

Table 1: Ecological adaptations that promote persistence and recovery of riparian plant species following fire (Dwire and Kauffman, 2003).

Adaptation	Function	Example
Adaptations that facilitate Survival		
Epicormic Sprouting	Regrowth from dormant buds on branches and stems protected by bark	Cottonwoods (Populus spp.), Oregon ash (Fraxinus latifolia), oaks (Quercus spp.), hawthorn (Crataegus spp.)
Basal Sprouting	Regrowth from subterranean buds on root, bulbs, lignotubers and rhizomes	Willows (Salix spp.), aspen (P. tremuloides), camas (Camassia quamash), sedges (Carex spp.), grasses
Thick Bark	Protection of cambial tissues from heat damage	Ponderosa pine (P. ponderosa), redwood (S. sempervirens)
Adaptations that facilitate recolonization		
Windborne seeds	Deposition and establishment on post-fire soils	Willows, cottonwoods, willow herbs (Epilobium spp.)
Water-dispersed Propagules	Dispersal of seeds or vegetative propagules to burned locations	Cottonwoods, willows, alders (Alnus spp.), sedges, rushes (Juncus spp.)
Fire-enhanced Flowering	Increased reproductive effort in the years following fire	Camas, blueberries (Vaccinium spp.), many shrubs, and fruit herbaceous dicots, and grasses
Refractory Seed Buried in Soils	Resistant seed coat requires fire or scarification to germinate	Lupine (Lupinus spp.), manzanita (Arctostaphylos spp.), Ceanothus spp.
On-plant Seed Storage	Seed storage in cones in canopy released post-fire	Lodgepole pine (P. contorta)

However, while resilient to natural disturbance regimes, many riparian ecosystems will degrade with the reduction of natural disturbances. For example, throughout North America, water diversion and flood restricting projects have resulted in noticeable losses in riparian floodplain vegetation (Howe and Knopf, 1991). More severe anthropogenic perturbations, such as overgrazing, clear-cutting and dams may alter an ecosystem enough to change the dynamic equilibrium to a new system state. This new equilibrium can be characterized by different structure (e.g., loss of woody component), different composition (e.g., dominance of non-native species), change in productivity (e.g., shifts in biomass), and a change in ecosystem functions (e.g., water quality) (Richardson et al., 2007).

Fortunately, after cessation of severe perturbations, resilient riparian ecosystems typically display recovery to their pre-disturbance state with measurable changes in structure, composition or function that occurs naturally. While working towards restoration of riparian ecosystems, the cessation of anthropogenic perturbations may actually be all that is necessary.

b. Monitoring Disturbance Regimes and Restoration Efforts

Before implementing "restoration measures", we monitor disturbance succession and regimes since there is variation in ecosystem recovery time and path. Without monitoring, there could be a waste of limited funds or even a worsening of degradation by forcing the system to stay at a desired state of succession.

Rivers and streams are inherently complex ecosystems. In addition, studying these systems is difficult because of their relatively large spatial scales. Watersheds are typically transboundary (i.e., cross state or country lines). Because of the variation in ownership along streams, many require special consideration, or permission from various entities, public and private. Although point-in time assessment can be useful, the timing can be inopportune with regards to capturing significant events within the system. In addition, fluvial systems demonstrate a unique link between aquatic and terrestrial environments as they integrate changes across the landscape. For these reasons, it is imperative that assessing and monitoring these systems be able to show changes in both spatial and temporal scales.

Monitoring also allows scientists and resource managers to learn about the dynamics of disturbance and succession in ecosystems. And possibly challenge long-held views of ecosystem behaviors. For example, ecologist Monica Turner has been conducting extensive monitoring in YNP following the fires in 1988 when severe fires burned under conditions of extreme drought and high winds, creating worldwide attention on wildfire. The fires in 1988 affected 36% of the park, burning 793,880 acres. At the time, many ecologists claimed that the size and severity of the fires was a result of past fire suppression methods. Turner et al. (2003) found that there was no evidence to support this claim. It has been found that in forests that naturally experience a crown-fire regime, which includes subalpine and boreal forests, fires are influenced more by climate than variation in fuel loads (Littell et al., 2009). The general public and media made claims that the park was ruined by the large, severe fires, and had concerns about the ability of the ecosystem to recover. It soon became clear that YNP was remarkably resilient and the severe fires were not an ecological catastrophe (Turner et al., 2003). Turner's research revealed an important discovery of increased heterogeneity of the Yellowstone landscape after what had been considered a catastrophic disturbance that was expected to homogenize the area. The fires had created a complex spatial mosaic of patches varying in shape, size, and severity (Turner et al., 1994, Figure 1).

Figure 1: Aerial view in October 1988 of the landscape mosaic produced by the Yellowstone fires (Turner, 2010).

In summary, Turner's monitoring and research led to discoveries about heterogeneity, scale, spatial and temporal thresholds. She catalyzed new paradigms in ecology within two categories. Here are the six key conceptual contributions:

Disturbance and Landscape Dynamics:

1. Even very large disturbances do not homogenize the landscape; rather, disturbances typically create heterogeneity in space and time.

2. Equilibrium is a scale-dependent concept, and equilibrium is but one of a suite of dynamics that can be observed in ecological systems.

3. Condition under which spatial pattern matters for ecological responses can often be identified, although determining when spatial heterogeneity can and cannot be ignored remains challenging (Turner, 2010).

Disturbance and Ecosystem Processes:

4. Post-disturbance heterogeneity can establish a mosaic of process rates and feedbacks.
5. Spatial legacies of disturbance for ecosystem structure and function can persist for decades to centuries.
6. Contrary to current views, not all ecosystems are nutrient leakers after disturbance, and a wider range of potential biogeochemical responses to disturbances, including nutrient retention, may not be uncommon (Turner, 2010).

Turner (2010) is careful to say that YNP is unique and that other ecosystems may not be as resilient to unusual disturbances, resulting in qualitative changes. She attests that future research in ecological disturbance should address questions related to disturbances as catalysts of rapid ecological change, interactions among disturbances, relationships between disturbance and society, and feedbacks from disturbance to other global drivers.

c. Changing Disturbance Regimes

The study of disturbances, which is facilitated by long-term monitoring, will continue to contribute to the understanding of disturbances and help to anticipate the causes and consequences of changing disturbance regimes.

It is apparent that the potential for catastrophe lies at the intersection of natural disturbance and human development, as we have recently seen in the widespread forest fires of the western U.S. and in the effects of Hurricane Harvey in Texas. Increasing population density and subsequent development of infrastructure in areas that are prone to natural disturbances are challenging, particularly for disturbances that are of high severity and low frequency. In fact, the population growth trend shows an increase in areas that flood or burn regularly, intensifying the risk to life and property (Hammer et al., 2009). Addressing the vulnerability of disturbance-prone areas requires an understanding of current and changing risk. Development planners and policy makers need to understand disturbance dynamics to anticipate the effects of changing risks. Answers to address this may be encouraging development in areas of lower risk, engineering to reduce vulnerability and increasing resilience in social and ecological systems.

In the case of flooding by river systems, restoring connections between rivers and floodplains by redesigning or removing extensive levee networks will actually reduce, rather than increase flooding. Addressing the effects of changing disturbances regimes in riparian ecosystems so as to continue to benefit from these systems will require an effort by policy makers to reconsider their current management approaches.

d. Human Disturbances vs. Natural Disturbances

All ecosystems have a "natural" disturbance regime that they have evolutionarily adapted to and, in some cases, can maintain ecosystem integrity despite severe large-scale disturbance events. Natural disturbances play a key role in maintaining ecosystem structure and processes (e.g., nutrient recycling and initiating succession). For example, some northern forests would convert to bogs without windthrow disturbances that exposes mineral soil seedbeds. Numerous other forest types are maintained by periodic fire disturbances (Turner et al., 2003). In a natural ecosystem, if similar or different types of disturbances recur with some regularity, then a regime is established that may produce predictable consequences which can be characterized by type, frequency/return interval, and seasonal timing of disturbances. Without the relatively expected consequences of disturbance regimes, to which an ecosystem has been evolutionarily adapted, it is difficult to predict consequences of disturbances that fall outside of this system (ie. exotic disturbances).

Human-caused disturbances are considered exotic to ecosystems and can be exogenous (climate change) or endogenous (clearcutting or strip-mining). In general, exotic disturbances disrupt system integrity and cause the system to shift to other operating states. Human-caused disturbances can affect natural disturbance regimes by rescaling and making disturbances smaller or larger, less or more frequent or intense (Romme et al., 1995) in the following ways:

- By creating biogeographic barriers (e.g., roads, canals, or park boundaries defined by change in habitat) that alter the spread of disturbances.
- Using vegetation treatments designed to manipulate fuel loads and vegetation continuity that modify the size, frequency and intensity of disturbances such as wildfires.
- Livestock grazing can alter fuel loads sufficiently to reduce the frequency and size of wildfires.
- Using vegetation treatments to meet timber objectives can modify the frequency of other disturbance processes such as mass soil movements (e.g., landslides and mudslides).

Human-caused disturbances on ecological communities generally reduce standing biomass and simplify community structure with reduced perennial species, overall losses of native species and increased number of non-native species. Another typical result of human-caused disturbance is an increase in bare and impacted soils, which has been shown to greatly reduce the succession rates of ecosystems by reducing the number of residuals, defined as individual organisms, or their propagules, that survive a disturbance event (Menges and Quintana-Ascencio, 2003).

It is self-evident that human-caused disturbances, in the form of conversion of natural habitats by the increase of pastures, agricultural lands, built areas and infrastructure will continue with population growth and less than 13% of the Earth's land surface protected (Hanski, 2011).

This amplifies the need for conservation planning with the consideration of species survival in human-disturbed areas.

B. Key Water Policy for Riparian Conservation in the U.S. and EU

Though the Federal Water Pollution Control Act of 1948 was the first major act to address the growing problem of widespread water pollution, it was poorly designed and achieved little. In 1972, the Act was severely amending and became commonly known as the Clean Water Act (CWA). With the adoption of the act, Congress announced its broad objectives of maintenance and restoration of "the chemical, physical, and biological integrity of the Nation's waters." The 1972 amendments include (EPA, 2017):

- The establishment of a basic structure for regulating pollutant discharges into the waters of the U.S.
- Giving the EPA the authority to implement pollution control programs such as setting wastewater treatment standards for industry.
- Maintaining existing requirements to set water quality standards for all contaminants in surface waters.
- Making it unlawful for any person to discharge any pollutant from a point source into navigable waters, unless a permit was obtained under its provisions.
- Funding the construction of sewage treatment plants under the construction grants program.
- Recognizing the need for planning to address the critical problems posed by nonpoint source pollution.

Section 303 of the CWA is fundamental to achieving acceptable water quality by implementing federal regulation of nonpoint sources of pollution. Water Quality Standards and Implementation Plans explains the statutory requirements for water quality standards in this way: "Water quality standards" specify a water body's "designated uses" and "water quality criteria," considering the water's "use and value for public water supplies, propagation of fish and wildlife, recreational purposes, and agricultural, industrial, and other purposes ...." § 303(c)(2). It is up to states to set water quality standards for all waters within their boundaries regardless of the source of pollution. If a state fails to do this, or the state's standards fail to meet the requirements of the ACT, the EPA will set the standards for the state §§ 303(b), (c) (3-4). In addition, section 303 requires states to identify and compile a list of waters for which certain "effluent limitation are not stringent enough" to implement the applicable water quality standards. The states must prioritize rankings for listed waters and develop Total Maximum Daily Loads (TMDLs), which is a calculation of the maximum amount of a pollutant a waterbody can assimilate while still meeting quality standards (CWA § 303(d)). To ensure that polluted waters are monitored and assessed, states are required to update and resubmit the impaired waters list every two years.

The result of this structure is that the CWA leaves to the states the responsibility of developing plans to attain water quality standards, while providing federal funding to implement state plans.

Another major decree within the CWA was the implementation of pollution control programs by establishing and maintaining requirements in water quality standards for all contaminants in surface waters. Implementing and authorizing discharge permits became the sole responsibility of the EPA, unless delegated to states or tribes. These permits are known as the National Pollutant Discharge Elimination System. The permits regulate point sources that discharge pollutants and are required by every individual, industry, corporation, and state that can cause water

pollution. The permit system was created to force otherwise noncomplying states and industries to be carefully watched. Section 309 under the CWA gives the EPA power to file civil and criminal charges against any 'person' who violates not only the permit, but also the CWA in general.
In CWA § 101(a)(7) Congress found that, to achieve its declared objective to restore and maintain the Nation's waters, "it is the national policy that programs for the control of nonpoint sources of pollution be developed and implemented in an expeditious manner so as to enable the goals of this chapter to be met through the control of *both* point and nonpoint sources of pollution." Further, under this amendment, states had to locate and name waterways they were unable to clear from the list and come up with ways to control the pollutants in those areas (EPA, 2017). In the forty-five years since the enactment of the CWA, notable progress was made to improve water quality nationwide, primarily by regulating point source chemical pollution.

The U.S. Forest Service (USFS), an agency within the U.S. Department of Agriculture, has played a large role in managing U.S. waterways, especially in the western states. The USFS manages 193 million acres including 155 national forest and 20 grasslands in 43 states and Puerto Rico. Historically, there has been a balancing act between utilizing resources for economic reasons and maintaining environmental standards that drive protection of wildlife and recreation services of citizens.

In 1982, the National Forest System Land Management Planning Rule (planning rule) was established. This set of regulations aimed to start a process to develop, revise and adopt management plans required by the Forest and Rangeland Renewable Resources Planning Act of 1974 on National Forest system lands including; wilderness, wild and scenic rivers, national recreation areas and trails. According to the USFS, the "resulting plans shall provide for multiple use and sustained yield of goods and services from the National Forest System in a way that maximizes long term net public benefits in an environmentally sound manner" (USFS, 1982, Sec. 219.1).

Of particular interest to this study is Section 219.23 addressing water and soil resources. It states that forest planning shall provide for (USFS, 2017):

- "General estimates of current water uses, both consumptive and non-consumptive, including instream flow requirements within the area of land covered by the forest plan;
- Identification of significant existing impoundments, transmission facilities, wells, and other man-made developments on the area of land covered by the forest plan;
- Estimation of the probable occurrence of various levels of water volumes, including extreme events which would have a major impact on the planning area;
- Compliance with requirements of the Clean Water Act, the Safe Drinking Water Act, and all substantive and procedural requirements of Federal, State, and local governmental bodies with respect to the provision of public water systems and the disposal of waste water;
- Evaluation of existing or potential watershed conditions that will influence soil productivity, water yield, water pollution, or hazardous events; and
- Adoption of measures, as directed in applicable Executive orders, to minimize risk of flood loss, to restore and preserve floodplain values, and to protect wetlands."

In May 2012, this planning rule was revised from the 1982 framework that would allow the USFS (2012, pg. 1) to "meet modern and future needs, taking into account new understanding of science, land management, and the all-lands context for managing resources. It focuses on outcomes, rather than outputs, and would help units identify their unique roles in the broader landscape and create land management plans to guide proactive contributions to ecological, social, and economic sustainability." The use of the term "ecological sustainability" is a shift from past management plans and depicts a recent understanding of landscape ecology and a focus on environmental protection, rather than industrial interests of using public resources. Several highlights of the most recent planning rule, as they apply to this study of ecological disturbance research and a need for monitoring our riparian areas include (USFS, 2012, pg. 2):

- "Improved ability to respond to climate change and other stressors through an adaptive framework of assessment, planning and monitoring and new provisions intended to improve resiliency of ecosystems on each unit.
- An all-lands approach to land management planning for NFS lands, recognizing that many management issues, such as fire, water, and wildlife, will require an understanding of what is happening both on and off the National Forest System.
- Increased protections for water resources, watersheds, and riparian areas, including requirements to identify watersheds for priority restoration; maintain and restore aquatic ecosystems, watersheds, water quality and water resources including public water supplies, groundwater, lakes, streams, and wetlands; maintain and restore riparian areas; and provisions for best management practices for water quality.
- New requirements for a unit and landscape-scale monitoring program based on the latest science, strengthening the role of monitoring so that units can better track changing conditions and measure progress towards meeting objectives in the plan.
- New requirements to use and document the use of the best available scientific information to inform the assessment, plan decisions, and monitoring program."

The revised planning rule claims to reduce the time and cost involved in plan revision, allowing the FS to update more plans with the same amount of resources.

One way to evaluate how well the U.S. addresses water protection at the landscape level is to compare it to a policy passed in the European Union (E.U.). In December 2000, the European Water Framework Directive (WFD) became the central foundation for any water policy-related action by the E.U. Some key principles framing the content of the WFD include (WFD, 2000):

- "water is not a commercial product like any other but, rather, a heritage which must be protected, defended and treated as such" (pg.1);
- "sustainable management and protection of freshwater resources" (pg. 3) will be achieved by the implementation of an "integrated Community policy," (pg. 9, 18) which will be based on the prudent and rational use of natural resources and on principles such as the precautionary principle, preventive action, rectification of environmental damage and payment of costs by polluters (pg. 11);
- improving the aquatic environment primarily concerns the quality of water, which is influenced by quantitative aspects (pg.19);
- common definitions of the status of water, using technical specifications ensuring a coherent community approach (pg. 49), are needed and environmental objectives must be set to ensure good status (pg. 25, 26) which will be achieved through the political coordination of decisions (pg. 35) and through ecological coordination of measures at the river basin scale (pg. 36);
- finally, implementation may be flexible in regard to timetables and costs, (pg. 31) and derogations and exemptions to the general model may be set. In all cases, all these should be made on the basis of appropriate, evident, and transparent criteria.

Within this framework, all member states must assess all water bodies including; groundwater, coastal and transitional waters, rivers and lakes. Member states must attain or maintain “good status” as defined by good ecological and chemical status and to complete the following:

- elaborate the type-specific reference conditions of water bodies (Annex II, 1.3 WFD),
- define the quality targets for the ecological status assessment,
- pre-classify the different types of water bodies (natural, heavily modified or artificial) (Annex II, 1.1 WFD), and
- assess them in terms of current status achievement or failure, and risk (Annex II, 1.4 and 1.5 WFD).

As it applies, Member States must identify the appropriate competent authority for the application of the rules of this Directive for any international river basin district within its territory. For all river basin management plans, a general preliminary description of all river basins shall include (WFD, 2000):

- Mapping of the location and boundaries.
- Mapping of the ecoregions and surface water body types within the river basin.
- Identification of reference (unaltered) conditions for all surface water body types.

Each Member State derives its own technical specifications and methods for analysis and monitoring within the framework of WFD as it applies to their geographic location. The timetable for monitoring takes place at varying intervals, from months to years based on technical knowledge. Member States must submit assessment of progress made towards achieving environmental objectives which includes monitoring results for the period in GIS map form, and an explanation for any objectives not reached (WFD, 2000).

Throughout the history of the U.S., water policy issues have evolved with scientific evidence and public opinion (see Appendix A for more detailed history). However, in my opinion, there remains a deficiency in an active, coordinated effort that acknowledges the ecological, rather that economical value of riparian areas, as is apparently in the EU WFD. Management and protection of river watersheds has required coordinated action by a range of stakeholders including governmental agencies at the federal, state and more local levels. Under the CWA, there has been widespread water quality assessing and monitoring on U.S. streams, however a mandatory, regularly implemented ecological assessment is not included. The USFS planning process gives states federal funding to bring water bodies up to particular standards, though this is only implemented on certain federal lands. It is my assertion that this needs to be implemented on all our waterbodies, particularly on all streams and rivers. I argue that the protection of all watersheds needs to be under a federal umbrella, perhaps as an amendment to the CWA, where the assessment and monitoring of all streams, including riparian zones, is mandatory.

Recognition of the adverse effects of human impacts on river systems, coupled with a rise in environmental awareness, has driven initiatives for river restoration as part of river management schemes. The recognition of the harmful effects of river channelization and pollution, coupled with a move towards more environmentally sensitive river management and river restoration has created a demand for methods which examine the existing condition or `health' of river systems, and identify the conditions that may have been expected had there been no impact. River restoration projects have required tools to assess the present stream condition within selected stretches of river so their physical habitat availability can be compared before and after restoration, to evaluate the effectiveness of the efforts (Habersack and Nachtnebel, 1995).

Tompkins and Kondolf have asserted that the “science and practice of restoration could be significantly improved by greater assessment of ecological effectiveness” (2007). In their evaluation of river restoration efforts in California, they determined that low-effort data collection and analyses could yield valuable information on restoration effectiveness for whole classes of projects.

Since additional assessments and monitoring may be expensive for agencies to implement, citizen science using low-effort data collection may be used as a tool to fill the gaps and make restoration projects more successful in fulfilling water quality policies. The citizen science model involves a dispersed network of public volunteers to assist in professional research using methodologies developed by professionals or in collaboration. The volunteers can play a role in data collection over large areas and over long periods of time (Cooper et al., 2007). In addition, the use of dispersed participants creates the capacity for ambitious scale projects such as watershed-based monitoring schemes as well as localized research projects (Wilderman et al., 2004). Citizen science has the potential to increase environmental stewardship with environmentally motivated volunteers with informal, non-classroom based science education. The effectiveness of citizen science involvement comes when participants can contribute to new management recommendations based on their results while continuing monitoring projects.

Since the success of citizen science involvement is dependent on the assessment and monitoring tools used, it is important to explore what is currently available, addresses the required ecological parameters, and yet is suitable for citizen scientists.

C. Evaluating Assessment and Monitoring Tools used in the U.S. and EU

There are a variety of riparian habitat assessment approaches ranging from qualitative methods using visually scored indicators, primarily designed to grade the in-stream and adjacent riparian habitat (Barbour et al., 1999) to highly quantitative methods designed to describe the geomorphic condition of streams as well as the habitat condition for biota. (Kaufman and Robison, 1997). Six assessment tools used in the U.S. or EU are summarized in Table 2 and will be discussed in this section.

Table 2: Summary of riparian habitat assessments used in the U.S.

Agency/Year of Development	**Purpose**	**Scores**	**Problem(s) for the purpose of this study**
U.S. Fish and Wildlife Service (USFWS)/2001	To identify potential problems. Prioritize areas with stable streams and degraded vegetation for increased success in restoration projects.	Ranging from 1-20; 4 Categories: Poor, Marginal, Suboptimal and Optimal	-No reference streams -Limited number of Indicators -Not designed to be a monitoring tool
U.S. Forest Service (USFS) U.S. Bureau of Land Management (BLM) Montana Natural Resource Conservation Service (NRCS)/2015	This assessment method considers hydrologic, vegetative, and geomorphic attributes and processes to assess a riparian area's condition at a point in time.	The agency ID team determines whether the stream is: Properly Functioning Condition, Functioning-at risk or non-functional	-No reference streams -Not designed to be a monitoring tool -Must be implemented by a highly experienced team -Extensive/Expensive
Montana Department of Environmental Quality (DEQ)/2005	To assess the ecological integrity (wetland condition), identify potential stressors, and to rank restorability.	Overall score ranging from 0 (poor) to 1 (excellent)	-No reference streams -Relatively small assessment area -Not designed to be a monitoring tool
Montana Department of Transportation (MDT)/2008	To evaluate functions and values in order to mitigate impacts from highways and other linear projects, such as pipelines and transmission lines.	Placed into categories ranging 1-4.	-No reference streams -Not designed to be a monitoring tool -Must be implemented by trained wetland professionals
Germany LAWA/2001	The objective in using this assessment is to improve ecological quality status within a timeframe given by the WFD by describing the broader ecomorphological appearance of the river or stream.	The overall score ranges from 1 (undisturbed model) to 7 (totally disturbed). Between two extreme conditions is the "development purpose" or goal to move the condition further to the model	-Designed for a geographical location that doesn't represent the natural condition of the study reaches.
Rapid Stream-Riparian Assessment/2006	To evaluate the existing conditions along a particular reach of a river to determine which components of the riparian ecosystem differ from a similar but unimpacted reference conditions, and to create a yardstick to objectively monitor any future changes within the system	The overall scores ranges from 1 (highly impacted) to 5 (non-impacted) and is based on an average of 5 categories. The scores can be scaled to the individual reach based on the reference reach.	Assessment tested in this study

1. U.S. Fish and Wildlife Service: Riparian Corridor Rapid Assessment Method

This assessment was developed for federal lands to increase the probability of success for riparian restoration projects, with a focus on bank stability. The method is a short-term decision-making tool to identify poor quality riparian corridor areas. According to developers, Starr and McCandless (2001), "it focuses on identifying existing problems based on observation and not on a function, structure, and process analysis." The method is intended for use by trained practitioners with experience in identifying bankfull indicators and a basic understanding of watershed-based assessment procedures (2001, pg.1). The components of the field assessment include:

- Bank Stability: based on bank erosion potential method developed by David Rosgen (1996).
- Stream Stability: evaluates active vertical and lateral stream adjustment and floodplain/stream connectivity.
- In-stream Habitat: evaluates the amount and availability of physical habitat for fish, aquatic insects and invertebrates.
- Velocity/Depth Regime: evaluates the variability of stream velocities and depths.
- Shading: evaluates the degree to which a stream is shaded by vegetation.
- Water Appearance: evaluates water turbidity and potential pollutants.
- Nutrient Enrichment: evaluates the amount of algae and macrophytes within a stream that generally indicates the severity of excessive nutrients.
- Riparian Vegetation Zone: evaluates riparian habitat conditions for wildlife and the ability of the vegetation to buffer impacts from adjacent land use activities.
- Riparian Zone Nutrient Uptake Potential: evaluates the potential of the riparian zone to buffer the introduction of sediment and nutrients into a stream system.

Each assessment component receives an individual rating that varies from "Poor" to "Optimal." Scores from 1-20 are grouped into 5 categories. The tallied assessment scores are combined to obtain an overall assessment score. This score describes the stream area's general condition and the potential need for restoration projects.

Since this assessment was designed to compare an area's general condition relative to others in order to prioritize restoration projects, there are deficiencies for this project's use. These deficits include:

- No use of reference streams.
- Relatively few indicators (9).
- Not designed to be a monitoring tool.

2. USFS, BLM, NRCS: Proper Functioning Condition for Lotic Areas (PFC)

Three federal agencies, the USFS, BLM and NRCS, assess stream riparian ecosystems using the method known as the Proper Functioning Condition for Lotic Areas (PFC). This assessment method considers hydrologic, vegetative, and geomorphic attributes and processes (17 in total) to assess a riparian area's condition at a point in time (PFC, 2015). There are three rating categories based on the assessment form including:

- Proper Functioning Condition (PFC): A properly functioning riparian area with adequate vegetation, landform, and woody material.
- Functional-at risk (FAR): Hydrologic, vegetative, or geomorphic attributes make them susceptible to impairment.

- Nonfunctional (NF): Inadequate vegetation, landform, or woody material to dissipate stream energy associated with high flows.

According to the guidebook (PFC, 2015, pg. 4) the PFC assessment is designed to:

- Assess the function of perennial and intermittent streams and their associated riparian areas.
- Be used on most stream and river systems, regardless of size.
- Be used only by an experienced ID team of resource specialists.
- Provide a consistent approach for assessing the physical functioning of riparian areas.
- Help establish and prioritize management and restoration activities.
- Provide a focused and effective foundation for determining resource values and developing management goals.
- Communicate fundamental riparian concepts to a wide variety of audiences.

The PFC assessment (PFC, 2015, pg. 5) is not designed to:

- Assess the function of ephemeral systems.
- Assess specific resource values, or scores, or be the sole method for assessing the health of a riparian area.
- Assess the function of streams where human alterations have created artificial channels.
- Be used by inexperienced personnel without an ID team.
- Monitor conditions and trends.

3. Montana Department of Environmental Quality (EPA Guidance): Wetland Rapid Assessment Method

This particular method was developed in Montana with the guidance from the EPA. According to the EPA (2005, pg. 4), "the development of a wetland rapid assessment method is a prerequisite to the accomplishment of state program objectives including reporting on wetland status and trends and identifying wetlands that need restoration and protection." EPA asserts that the development of assessment indicators can be based either on the response of a wetland to stressors (e.g., hydrology, vegetation, water quality and soils) or the stressors themselves (disturbances). It has been separated into three levels including:

- Level 1: Landscape Assessment using Geographic Information Systems (GIS) and remote sensing data.
- Level 2: Rapid Assessment using relatively simple metrics for collecting data at specific wetland sites.
- Level 3: Intensive Site Assessment based on the outcome of the rapid assessment.

The rapid assessment provides a score, or rating that shows where the area falls on the continuum that ranges from "full ecological integrity" (least impacted) to "highly degraded". The length of the assessment unit is 100 meters streams (1^{st} and 2^{nd} order) and 200 meters for streams and rivers (3^{rd} order and larger) and is intended for use by trained field technicians. This method is meant to be used as a field-based flagging tool combined with a landscape level assessment (Level 1) to help identify and prioritize wetlands within a watershed or eco-region that need additional protection or restoration and that have potential and capability of success (Apfelbeck and Farris, 2005).

Since this assessment is used to base a particular stream's need and potential for restoration, the deficiencies for this particular study include:

- No reference streams.
- Relatively small assessment area.
- Not designed to be a monitoring tool for post-restoration monitoring.

The MT DEQ also uses a stream assessment protocol, Water Quality Assessment Monitoring, that assesses riparian areas. This assessment collects water chemistry and biological samples, and assesses physical characteristics and habitats at the reach scale. Using a reference stream to scale the scores, streams are put into 3 categories (not impaired, moderately impaired, severely impaired) (MTDEQ, 2005). Though this is a very complete assessment, it is not appropriate for the citizen science model since it is not rapid, requires expensive equipment and users with high expertise.

4. Montana Department of Transportation: Montana Wetland Assessment Method (MWAM)

The Montana Wetland Assessment Method (MWAM, 2008) was designed to evaluate functions and values of wetlands associated with linear projects, including highways, pipelines and transmission lines. The objective is to "provide a rapid, economical, and repeatable wetland evaluation method applicable to Montana (and other western states)" (MWAM, 2008, pg.1) that:

- "meets the needs of local regulatory agencies in terms of rating wetland functions and values for the majority of proposed wetland disturbance-related projects and wetland mitigation projects in the state, particularly highway projects;
- minimizes subjectivity and variability between evaluators;
- allows for the comparison of different wetland types;

- provides a means of rating wetlands to facilitate the prioritization of impact avoidance and minimization measure; and
- incorporates current and relevant information on wetland functions".

The result of the assessment is a relative rating for up to 12 functions including (MWAM 2008, pg. 3):

- Habitat for federally listed or proposed threatened or endangered plants or animals.
- Habitat for plants or animals rated S1, S2, or S3 by the Montana Natural Heritage Program.
- General wildlife habitat.
- General fish habitat.
- Flood attenuation.
- Long and short-term surface water storage.
- Sediment/shoreline stabilization.
- Production export/terrestrial and aquatic food chain support.
- Groundwater discharge/recharge.
- Uniqueness.
- Recreation/education potential.

The scores for the 12 individual functions vary but there is an overall rating given to the assessment area. The overall ratings are called categories ranging from 1-4, where Category 1 wetlands are considered "exceptionally high quality" and Category 4 wetlands provide little wildlife habitat and are often disturbed. This method is designed to be applied by professionals in the wetland science field. The area of study for this method varies with the extent of the project.

5. E.U. Assessment Protocol

In Europe, the introduction of the Water Framework Directive marked a notable increase in the number of new assessment methods. As a result of an increasing need to use catchment-wide and process-oriented approaches, there was a significant increase in morphological and hydrological methods. Riparian zones are an essential component of the riverine system whose lateral and vertical structures depend on hydromorphological processes. Yet, the development of methods for assessing riparian zone conditions is recent (Belletti et al., 2015). Since the choice of method and subsequent assessment outcome affects decision making on ecological status and need for rehabilitation, European countries must use methods which have been formally approved within the WFD. The member states implement a range of cost-effectiveness measures (‘programmes of measures’ or PoMs) in their river management plans (RBMPs), which are updated every six years. They are required to implement assessment/monitoring tools that will assist in the program updates. According to the European organization, Reform Rivers, the WFD requires adequate assessment of stream and river habitat quality include biological, physio-chemical and hydromorphological elements. Presently, there is a variety of different methods with differing indices available. For example, Germany uses the Eco-morphological Survey for Large Rivers, Austria uses the Austrian Habitat Survey, and the U.K. uses the River Habitat Survey. Each method uses a number of parameters (channel, bank, floodplain) with a scoring system to evaluate the status of streams (Furse et al., 2006). All these methods use a hierarchical structure to assess the current state compared to a reference state. The reference state is defined as a state without human influences or “undisturbed conditions”. Remote sensing data is used, as well as the assessment, to map the watershed condition.

a. German Assessment Framework

In Brandenberg, Germany, Länder Arbeitsgemeinschaft Wasser (LAWA), the German Working Group on water issues of the Federal States, used a river classification system and habitat assessment in accordance with the WFD. The objective in using this assessment is to improve ecological quality status within a timeframe given by the WFD.

This assessment describes the broader ecomorphological appearance of the river or stream. The ecological value is based on in-stream and floodplain factors. The designation of value corresponds with the presence of natural features and all assessments are compared with that "ideal" reference value (Kamp et al., 2004). The set of parameters and how they relate to the overall "River Habitat Quality" is shown in Figure 5.

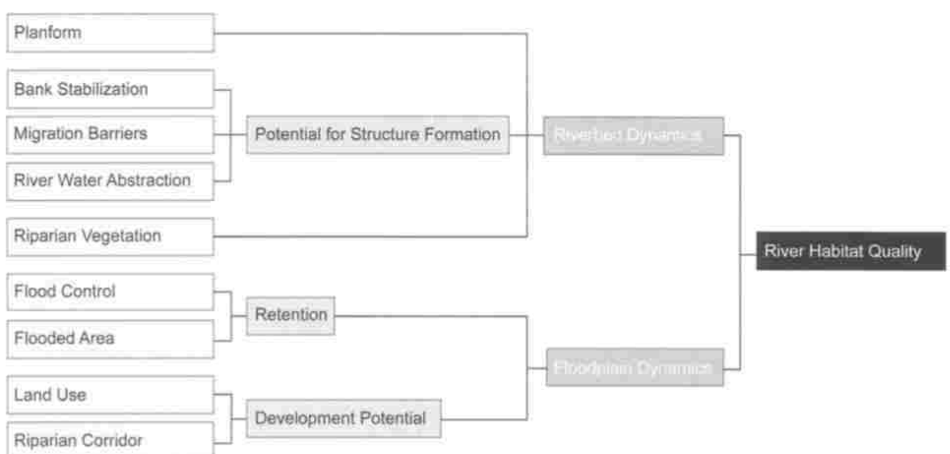

Figure 2: General organization of river habitat assessments in Germany (Kamp et al., 2004).

The score is obtained by comparing the stream condition to an "undisturbed" model numerically with "7" representing totally disturbed. Between two extreme conditions is the "development purpose" or goal to move the condition further to the model (Figure 6).

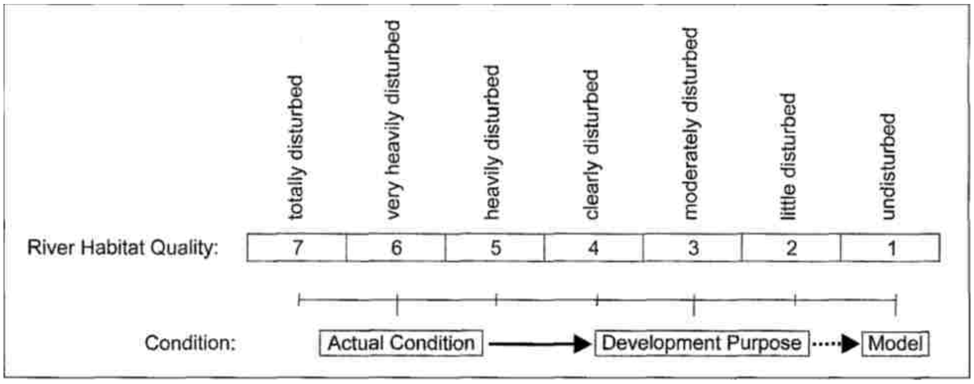

Figure 3: The relationship between model 'reference' sites, actual condition and development purposes for river habitat assessments in Germany (Kamp et al., 2004).

The results of the river habitat assessment are presented in a river habitat map that documents the actual ecological and hydromorphological quality of rivers in Brandenburg. This method was developed to map entire rivers that are hundreds of kilometers long in 1-km survey units. Additionally, the maps provide a foundation for future planning and river management. The map further provides a basis for future planning activities in water conservation and river management (Kamp et al., 2004).

6. Reasons for Assessments in the U.S.

Though there are many ecological assessments available, there is no general widespread requirement in the U.S. of regular implementation of ecological assessments, as in the EU as a result of the WFD. Reasons for U.S. agencies to apply these assessments include one or more of the following factors (L. Broberg, personal communication, November 3, 2017):

- “Wild and Scenic River Assessments in Forest Planning and Resource Management Plan revision: the USFS planning rules and perhaps the Wild and Scenic Rivers Act require these reviews of river qualification for designation as a WSRA segment.
- Inland Native Fish Strategy (INFISH) for USFS: requirements put in place by the USFS to meet their obligations under the National Forest Management Act, that requires that all waterbodies be protected from changes in sedimentation and water temperature or serious adverse effects to fish populations, the old USFS 1982 planning rules that required them to maintain viable populations of forest vertebrates (this included fish), the new 2012 USFS planning rules provisions about ecological integrity, and USFWS requirements under the Endangered Species Act for listed fish (e.g., bull trout).
- National Environmental Policy Act: for projects and plans would require analysis of the environmental impacts on river habitat. The assessments serve as analysis for each of these levels.
- National Forest Planning: many forests are adopting Riparian Conservation Areas or some other internal designation to conserve fish habitat to meet the obligations noted above.”

In addition, the Clean Water Act requires all U.S. states to assess the condition of all state waters every two years and list those waterbodies that are not meeting standards and identify causes and sources and remedies of impairment in what is called a Total Maximum Daily Load (TMDL) or water quality restoration plan. The biennial report is called the 305b report and the list of impaired water bodies is called the 303d list. Impairment is based on violation of water quality standards and extent of deviation from reference conditions.

Water resource management policies and assessment methods have evolved with new scientific evidence. However, in my view, U.S. policies are not in line with current knowledge of riparian habitat importance or with much of the global community that has implemented broad ecological protections, in the form of assessment and monitoring, on these areas. In addition, the assessment tools previously described may not work in the citizen science model that could be vital in the future of environmental stewardship. To be used in this model, the requirements for the riparian habitat assessment would be:

-rapid
-able to be widely implemented geographically
-science supported
-able to be implemented by assessors with a range of expertise, with proper training
-designed as a monitoring tool
-repeatable by different users

With these characteristics in mind, I propose that the following assessment tool may be appropriate not only for governmental use, but citizen science as well.

D. The Rapid Stream-Riparian Assessment: A potentially superior assessment tool

The Rapid Stream-Riparian Assessment (RSRA) protocol was developed by a group of six ecologists in 2006 with the help of various governmental agencies and academic institutions. *Peter Stacey* is a Research Professor in the Department of Biology, University of New Mexico, Albuquerque. He has conducted numerous studies on the ecology and population dynamics of birds that utilize riparian habitats. *Allison Jones* is the conservation biologist at the Wild Utah Project. *James C. Catlin* is also with the Wild Utah Project. He is the project coordinator of the Wild Utah Project, and specializes in habitat analysis for a variety of species at risk. His current research efforts focus on how livestock grazing affects wildlife habitat and forage availability in both riparian zones and uplands. *Don A. Duff* is an aquatic ecologist retired from the U.S. Forest Service.

His career experience has been in aquatic and riparian habitat management and native fishes recovery, and he has directed many stream-riparian restoration projects. *Lawrence E. Stevens* is an entomologist and riparian ecologist with the Museum of Northern Arizona. *Chad Gourley* is a fluvial geomorphologist who has directed a number of riparian restoration projects in the western United States. This group of authors sought to provide a method to objectively determine the functional condition of both aquatic and riparian components of small and medium sized streams in the arid southwest and, with possible modifications, in other semi-arid regions.

According to Stacey et al. (2006, pg. 12), this protocol "provides a standardized method to evaluate the existing conditions along a particular reach of the river, to determine which components of the stream-riparian ecosystem differ from what would be expected within the reach under geomorphologically similar but unimpacted reference conditions, and to create a yardstick to objectively monitor any future changes within the system that result either from active restoration programs or from allowing the system to follow its current trajectory under existing management programs." Along with the requirement of a reference area assessment, is the potential for this method to be used to monitor stream functionality and succession. While Stacey et al (2006) is not a peer reviewed publication, since six professional scientists collaborated on the work, I feel that it is well-vetted.

As the name describes, this assessment is meant to be completed in a relatively short amount of time and without expensive equipment, which allows the user to efficiently survey a number of different reaches along the same stream to provide a better understanding of both varying conditions and trends that exist within the particular watershed.

The RSRA protocol applies a qualitative assessment based on quantitative measurements (Stacey et al., 2006, pg. 12). It focuses on five functional components including:

1. "Non-chemical water quality and pollution (temperature and filamentous algae).

2. Stream channel and flood plain morphology and the ability of the system to limit erosion and withstand flooding without damage.
3. Presence of habitat for native fish and other aquatic species.
4. Vegetation structure and composition, including the occurrence and relative dominance of exotic or nonnative species.
5. Suitability as habitat for terrestrial wildlife, including threatened or endangered species."

Within each of these 5 components, the RSRA further evaluates between two and seven variables (summarized in Table 3). These variables are measured along the entire study reach (1 km) or along the 200 m nested sample transects. The variables are assigned a score from 1-5, using scoring levels that can be scaled to the individual reach based on the reference reach. A score of "1" indicated a highly impacted, non-functional ecosystem for that particular variable. A score of "5" indicates a non-impacted, functioning ecosystem that one would expect to find in the reference reach. While some individual variables may receive an extreme score of "1" or "5", it is unlikely that all categories, for that particular reach, will receive that rating. Therefore, it is important to view all scores together when interpreting the results. For example, most of the scores in one functional category (e.g., vegetation structure and composition) may be high, while one other variable may be low. For restoration planning, a relatively simple action to address the one deficiency may be all that is required. By concurrently examining the different features in the riparian ecosystem, it is possible to see specific areas where restoration programs may be effective, as well as gain an overall picture of the current health of the ecosystem.

The RSRA developers assert the importance of this protocol as a monitoring tool by assessing current habitat conditions rather than hypothesizing future states as other riparian assessments such as the BLM's Proper Functioning Condition assessment. Stacey (2007, pg. 15) state that:

> *"this approach is used because stream-riparian systems are highly dynamic and they are often subject to disturbances (e.g., large floods) that can alter successional trends and make predictions of future conditions on an individual reach highly problematic. By evaluating only current conditions, this protocol can be used as a powerful tool for monitoring and measuring future changes in the functional status of the system. For example, if a reach is rated as in poor condition with respect to a particular set of parameters, reevaluating the system using the identical protocol in subsequent years gives one the ability to measure the effectiveness of any management change or active restoration program and to undertake corrections if the restoration actions are found to be not producing the desired changes. This type of adaptive management approach can be extremely difficult if the evaluation and monitoring measures are based primarily upon the expectations of some future, rather than current, condition."*

Table 3: RSRA indicator variables and the reasons for including them in the protocol (Stacey et al., 2006).

CATEGORY AND VARIABLE	**JUSTIFICATION FOR INCLUSION IN THE RSRA ASSESSMENT**
Water Quality: **Algal growth**	Dense algal growth may indicate nutrient enrichment and other types of pollution which may result in decreased dissolved oxygen in the water column and affect invertebrates and the ability of fish to spawn.
Water Quality: **Channel shading and solar exposure**	Solar exposure affects stream temperature and productivity. Decreased streambank vegetation cover, increased channel width, and reduced stream depth increases exposure, raises water temperatures and impacts aquatic life. Native trout usually require cool stream temperatures.
Hydrogeomorphology: **Floodplain connection and inundation frequency**	Channels that are deeply downcut or incised result in a reduced frequency of overbank flooding into the adjacent flood plain during peak runoff or stream flows. The absence of flooding lowers water tables, reduces nutrient availability in the floodplain, decreases plant germination, growth and survivorship, and may lead to the loss of riparian vegetation and the invasion of upland species.
Hydrogeomorphology: **Vertical bank stability**	Steep and unstable vertical banks dominate many southwestern streams, limiting the physical dynamics of aquatic ecosystems and increasing erosion and sediment loads through sloughing off of soils during high flow events. Steep banks may limit wildlife access to water.
Hydrogeomorphology: **Hydraulic habitat diversity**	Fish and aquatic invertebrate diversity and population health is related to habitat diversity. Features such as oxbows, side channels, sand bars, gravel/cobble bars, riffles, and pools can provide habitat for different species or for the different life stages of a single species.
Hydrogeomorphology: **Riparian area soil integrity**	Riparian soils reflect existing stream flow dynamics (e.g., flooding), management practices, and vegetation. It affects potential vegetation dynamics and species composition, as well as wildlife habitat distribution and quality.
Hydrogeomorphology: **Beaver activity**	Beavers are keystone species in riparian systems because they modify geomorphology and vegetation, and reduce variance in water flows and the frequency

	of floods. Beaver dams anda djacent wet meadows provide important fish and plant nursery habitat.
Fish/Aquatic Habitat Qualifier: **Loss of perennial flows**	Fish and most aquatic invertebrates require perennial or constant flows to survive. Streams that were originally perennial but are now ephemeral no longer provide habitat for these species unless there are refuges that never dry out (e.g., permanent pools).
Fish/Aquatic Habitat: **Pool distribution**	Fish use pools, with reduced current velocity and deep water, to rest, feed and hide from predators. Many species use gravel-bottomed riffles to lay their eggs. The number, size, distribution, and quality of pools, and pool to riffle ratios indicate the quality of fish habitat. 1:1 pools to riffle ratios are generally considered to be optimum.
Fish/Aquatic Habitat: **Underbank cover**	Underbank cover is an important component of good fish habitat, used for resting and protection from predators. A number of aquatic invertebrates also use these areas. Underbank cover usually occurs with vigorous vegetative riparian growth, dense root masses, and stable soil conditions.
Fish/Aquatic Habitat: **Cobble embeddedness**	Low levels of gravel and boulder embeddedness on the channel bottom increase benthic productivity and fish production. The filling of interstitial spaces between rocks with silt, sand, and organic material reduces habitat suitability for feeding, nursery cover, and spawning (egg to fry survival) by limiting space and macroinvertebrate production. Increased embeddedness often reflects increased sediment loads and altered water flow patterns.
Fish/Aquatic Habitat: **Diversity of aquatic invertebrates**	The density and composition of aquatic invertebrates are strong indicators of stream health, including temperature stresses, oxygen levels, nutrients, pollutants, and sediment loads. Larvae and adult macroinvertebrates provide critical food for fish and other nvertebrate and vertebrate species in stream-riparian ecosystems.
Fish/Aquatic Habitat: **Large woody debris**	The amount, composition, distribution and condition of large woody debris (LWD) in the stream channel and along the banks provides important fish habitat for nursery cover, feeding, and protective cover. Streams with adequate LWD generally have greater habitat diversity, a natural meandering shape and greater resistance against high water events.
Fish/Aquatic Habitat: **Overbank cover and Terrestrial invertebrate habitat**	Overhanging terrestrial vegetation is essential for fish production and survival, providing shade, bank protection from high flows, sediment filtering, and input of organic matter. Overbank cover also is important for terrestrial insect input (drop) into streams, which is a key source of food for fish.
Riparian vegetation: **Plant community cover and structural diversity**	High cover and structural diversity of riparian vegetation generally indicates healthy and productive plant communities, high plant species diversity and provides direct and secondary food resources, cover, and breeding habitat for wildlife. This affects avian breeding and foraging patterns in particular. Good structural diversity can also reduce flood impacts along banks.
Riparian vegetation: **Dominant shrub and tree demography (recruitment and age distribution)**	The distribution of size and age classes of native dominant species indicates recruitment success, ecosystem sustainability, and wildlife and fish habitat availability. When one or more age classes of the dominant species are missing, it indicates that something has interrupted the natural process of reproduction and individual plant replacement. In time, this may lead to the complete loss of the species in the area as older individuals die off and are not replaced by younger plants.

Riparian vegetation: **Nonnative herbaceous and woody plant cover**	Non-native plant species profoundly influence ecosystem structure, productivity, habitat quality, and processes (e.g., fire frequency, intensity). Strong dominance by non-native plants may eliminate key attributes of wildlife habitat quality, and may limit ungulate and livestock use.
Riparian vegetation: **Mammalian herbivory impacts on ground cover**	Ungulate herbivores can affect riparian soils, ground cover, and general ecosystem condition. Utilization levels >10% in riparian zones retard vegetation replacement and recovery. Moderate and higher levels of grazing almost always increase soil compaction and erosion.
Riparian vegetation: **Mammalian herbivory impacts on shrubs and small trees**	Ungulate herbivores can affect recruitment of woody shrub and trees by clipping or browsing the growing tips of the branches. Continued high levels of utilization lead to the death of the plant and over time can cause the loss of all shrubs and trees in a local area.
Terrestrial Wildlife Habitat: **Riparian shrub and tree canopy cover and connectivity**	Riparian shrubs and trees often grow in dense patches that provide food, thermal cover, predator protection and nesting or breeding habitat for terrestrial wildlife, including many invertebrates, amphibians, reptiles, birds and mammals. These patches are often absent in riparian areas that have been heavily utilized by livestock and other ungulates, or that have been damaged by other human activities. As a result, many native wildlife species may no longer be able to survive in the area. Patches of dense vegetation, both native and exotic, also plays a key role in trapping sediment during periods of over-bank flow.
Terrestrial Wildlife Habitat: **Fluvial habitat diversity**	Natural processes create a diversity of fluvial landforms, including terraces, bars, oxbows, wet marshes and fluvial marshes, which provide habitats for different species of terrestrial wildlife. Conversely, in a highly degraded system with extensive erosion and downcutting, there may be only a single fluvial form: a straight and single-depth channel and steep banks without vegetation

More detail on how this method is implemented in the field is included in the next section.

III. STUDY DESIGN

A. Study Area

Natural History of the North Fork of the Flathead

The North Fork of the Flathead River (fig.4) originates in southern British Columbia, Canada and flows southward 105 miles to its confluence with the Middle Fork of the Flathead River in northwestern Montana. The river occupies a northwest trending glacial valley and is bounded by rugged mountains with elevations ranging between 5,000 to 9,000 feet, in the Whitefish range to the west and in the Livingston range to the east. The area contains Glacier National Park to the east and Flathead National Forest with Stillwater and Coal Creek state forests to the west. The study area of the river system is predominantly alluvial and flows over coarse glacial drift and fluvio-glacial sediment underlain by Tertiary claystone, conglomerate and siltstone. River slopes range from 0.001 to 0.0055. The reaches used in this study average 0.0028.

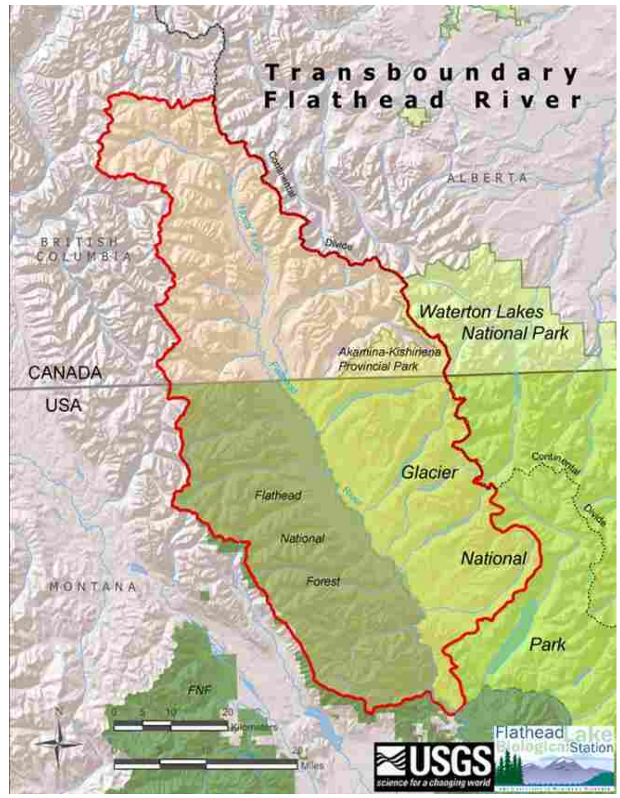

Figure 4: Map of the North Fork river watershed (USGS)

The Nork Fork watershed experiences a humid microthermal continental climate with winters dominated by northern continental polar air masses with Pacific Northwest Maritime influences. The majority of precipitation occurs as snowfall with the watershed covered by snow from mid-November to mid-April (Hauer et al., 2007).

Since the mid-1980's, studies in the Northern Rocky Mountains, including the North Fork watershed, show a substantial decline in peak snowpack conditions with warmer winters and springs, causing reduced and earlier snowmelt runoff. As a consequence, studies have also shown increasing summer stream temperatures and reductions in summer base flows in the streams and rivers in this region (Pederson et al., 2013). Climatologists predict average annual air temperature to increase by 1.1º C by the 2020's and 3.0º C by the 2080's with a continuation of changing hydrologic and thermal regimes (Mote and Salathé, 2010). In fact, recent studies have asserted that climate warming in the Rocky Mountains is occurring at up to three times the global average rate (Pederson et al. 2013).

The North Fork river floodplain supports forests dominated by spruce (*Picea spp.*) and cottonwood (*Populus trichocarpa*). Included to a lesser extent are aspen (*Populus tremuloides*), western larch (*Larix occidentalis*), Rocky Mountain juniper (*Juniperus scopulorum*) and lodgepole pine (*Pinus contorta*). Throughout the flood plain, small palustrine wetlands are characterized by rushes (*Juncus spp.*), sedges (*Carex spp.*) and horsetails (*Equisetum arvense*) (Allen, 1980).

The North Fork drainage is one of the few ecosystems in the conterminous 48 states that contains all its native mammalian predators, including gray wolves (*Canis lupus*), grizzly bears (*Ursus arctos ssp.*), black bears (*Ursus americanus*), mountain lions (*Felis concolor*), lynx (*Felis lynx*), coyotes (*Canis latrans*) and wolverines (*Gulo gulo*). Three of these predators are presently listed as species of special concern by the state of Montana (Montana Natural Heritage Program 2017). There are relatively numerous species of ungulates in the North Fork including moose (*Alces alces*), elk (*Cervus elaphus*), mountain goat (*Oreamnos americanus*), bighorn sheep (*Ovis canadensis*), white-tailed deer (*Odocoileus virginianus*), and mule deer (*Odocoileus hemionus*).

The North Fork is considered part of the Glacier Park Important Bird Area (IBA) by the Audubon Society and includes more than 275 recorded species of birds with fourteen nesting species of conservation concern. This includes the Peregrine Falcon (*Falco peregrinus*), Olive-sided Flycatcher (*Contopus cooperi*), Cassin's Finch (*Haemorhous cassinii*) and Brewer's Sparrow (*Spizella breweri*). This area is Montana's only known nesting area for Northern Hawk Owls (*Surnia ulula*) and is considered one of the best places in the state to find Harlequin Ducks (*Histrionicus histrionicus*) (Flathead Audubon, 2017).

Native fish species that inhabit the North Fork river are Westslope Cutthroat Trout (*Oncorhynchus clarki lewisi*), Bull Trout (*Salvelinus confluentus*), and Mountain Whitefish (*Prosopium williamsoni*). In the lower section of the river (below Camas creek) non-native Rainbow Trout (*Oncorhynchus mykiss*) are becoming increasingly common.

Fire History of the North Fork of the Flathead

This region has experienced several large-scale wildfires in recent decades, altering the fluvial geomorphology of the North Fork and its tributaries, as well as the surrounding landscape. The Red Bench Fire burned 38,000 acres of National Park, National Forest, and private land near Polebridge, MT in September 1988. In early September 2001, the Moose Fire burned from the Flathead National Forest over the North Fork river into Glacier National Park, burning a total of 71,000 acres. Historically, fire has been relatively infrequent along most areas of the North Fork. The fire regime, determined from stands dominated by lodgepole pine, is measured to be over 100-year intervals. There have been recent exceptions. Stand replacing fires burned in 1967 and 1988 (Red Bench Fire) are considered to be resultant of prolonged drought conditions.

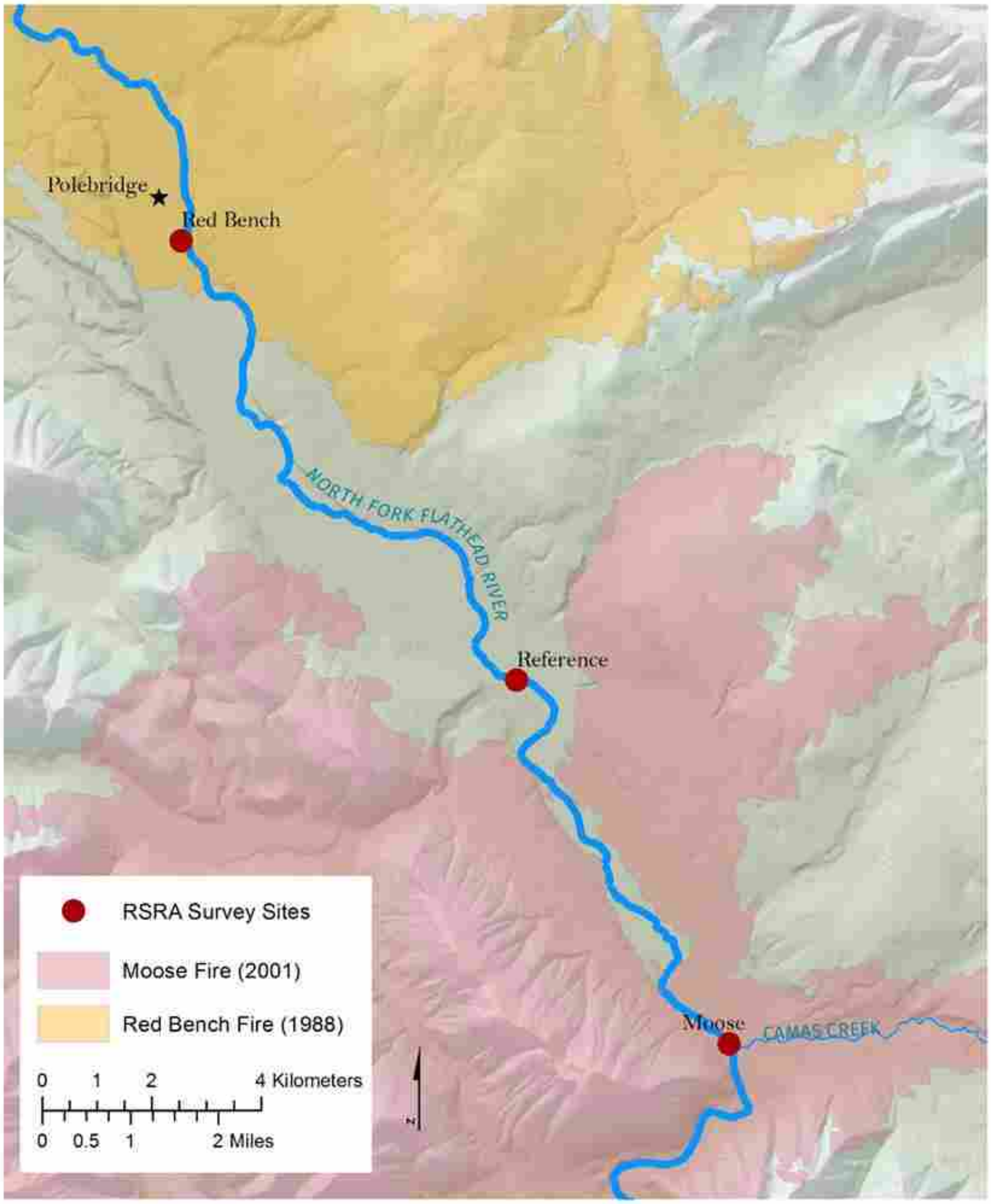

Figure 5: Map of the North Fork river study area and fire perimeters.

Human History of the North Fork of the Flathead

The original inhabitants of this area of northwestern Montana were the Kootenai. Prior to 1850, they hunted seasonally at Flathead Lake, where they competed with the Pend d'Oreilles. After that time, the Kootenai replaced or intermixed with the original population and lived there permanently (Malouf, 1952).

The Flathead Indian Reservation, in the lower Flathead Valley, was established following the Hellgate Treaty of 1855. The majority of the bands of Flathead (Salish), Pend d'Oreille and Kootenai tribes slowly moved onto the reservation. This opened the door to permanent non-Native American settlement of the valleys of western Montana, including the North Fork (Historical Research Associates, 1977).

The early homesteaders in the North Fork were attracted by the wildlife and natural meadows as well as timber and the potential for coal, oil and railroad development. Early settlement was concentrated on the east side of the river. In May of 1910, following the designation of Glacier National Park, the settlement abruptly shifted to the west side of the river. Following the construction of the west side road in 1912, Bill Adair moved his business and homestead claim near Hay Creek. His store is currently the Polebridge Mercantile and his homestead, the Northern Lights Saloon (Bick, 1986). Most of the current population of 132 permanent residents is concentrated in this area. There has been relatively little development since early settlement, and the community boasts of living an "off the grid" existence.

In October 1976, the North Fork from the Canadian border downstream to its confluence with the Middle Fork was designated as a Wild and Scenic River. This Act ensures that "certain selected rivers of the Nation which, with their immediate environments, possess outstandingly remarkable scenic, recreational, geologic, fish and wildlife, historic, cultural or other similar values, shall be preserved in free-flowing condition, and that they and their immediate environments shall be protected for the benefit and enjoyment of present and future generations" (Wild & Scenic Rivers Act, October 2, 1968).

For this study, the North Fork Flathead River presented several advantages.

1. Why this watershed and these three reaches selected:

- Proximity-this location was relatively close to my home in Missoula, MT.
- The relatively 'untouched' status of the river eliminated variables that could complicate results of assessment scores
- The varying fires that this area experienced represented different levels of succession

2. Why natural fire was used to evaluate this method's usefulness for assessing human impact:

- Because assessment tools are typically used to address anthropogenic disturbances, severe, stand-replacing fires could be used as a substitute for human disturbances since human-caused disturbances often removes vegetation.
- In the North Fork, the severity of these fires was not typical, but a result of prolonged drought. For this reason, this could, arguably, be considered an anthropogenic disturbance, as a result of climate change.

B. Field Method: Rapid Stream-Riparian Assessment (RSRA)

1. Summary of Field Instructions

Assessments should be completed between late spring and early fall, when the riparian vegetation is fully developed and when continuous surface water flows are most critical to wildlife. The best times of day for conducting the survey are from 10:00am to 2:00pm, when the sun is well overhead. Shadows cast over the stream at mid-day are used for one of the indicators. Assessments done consecutively to monitor an area should be done within one to two weeks of the same time from the previous assessment.

Each study area consists of:

- 1 km reach where data are collected.
- Two different but adjacent 200 m sample transects within the 1 km where specific quantitative data are collected: an in-stream transect and a riparian zone transect. The riparian zone transect is placed on the first terrace within a meter or so of the bankfull mark. Data are collected either once every 2 meters along the 200 meters (100 sample points, like algae or vegetation cover) or along the entire 200 meters (e.g., woody debris or amount of unstable banks).
- A second 200 m riparian zone sample transect for floodplains wider than 100 m.

Following is a summary of the categories, their indicators and the methods and tools used to calculate a score:

a. Water Quality

Indicator: *Algal Growth*

In the 200 m in-stream transect, walk in the channel about 1m from the water's edge and, using the ocular tube, every 2 m record the presence or absence of filamentous algae. Calculate the total percent cover of filamentous algae by dividing number of positive hits by the total number of data collection points along the transect.

Indicator: *Channel Shading and Solar Exposure*

Select three random but representative points along the entire 1 km study reach that are not visible from each other and visually estimate the amount of shading over the water surface that would occur at mid-day. Estimate the percent of stream shading within view both upstream and downstream of each observation point, and average those amounts. Record the time of day when this assessment is made (closest to mid-day is best).

b. Hydrogeomorphology

Indicator: *Floodplain Connection and Inundation*

The possibility that the stream will be able to escape its bank and flow over the floodplain during typical high flow events can be measured by the ratio of the height between the channel bottom and the historic terrace and the distance between the channel bottom and its first bank.

To calculate the historic floodplain to current bankfull ratio, choose three random but representative points along the entire 1 km study reach. Use a laser level to measure the distance between the bottom of the channel and current bankfull level. Then measure the distance or height of the beginning or closest part of the historic floodplain to the channel bottom. Next, divide the historic floodplain depth by current bankfull depth. Take the average of the three ratios to calculate the final score for this indicator. The final score indicates the level of connectivity between the stream and its floodplain; a high ratio (and low indicator score) demonstrates less potential for overbank flooding.

Indicator: *Vertical Bank Stability*

Within the 200 m in-stream transect, estimate the length of the channel bank where there are actively eroding, nearly vertical cut banks. Estimate the total amount of vertical cut banks on each side of the 200 m in-stream transect, and divide by 400 m to arrive at the percent cut banks.

Indicator: *Hydraulic Habitat Diversity*

Count the number of distinctive hydraulic channel features that would offer unique habitats in the overall 1 km reach walk-through. Look for features such as; riffles, scour pools, cobble or boulder debris fans, flowing side channels, backwaters, sand-floored runs, or other features that can provide different habitats for fish and other aquatic organisms. Note that this indicator only considers the richness of habitat types and not the evenness of those types.

Indicator: *Riparian Area Soil Integrity*

During the overall 1 km reach walkthrough, estimate the amount of soil disturbance, as a percent of the total area, in the riparian zone. Include both erosion from human activities (e.g., roads, trails) as well as damage from livestock and from native ungulates.

Indicator: *Beaver Activity*

Prior to conducting the field assessment, use existing records or recollections by local residents to determine if beavers were ever present on the reach. During the overall 1 km reach walkthrough, determine the extent of recent beaver activity within the last year, as indicated by tracks, drags, digging marks, cut stems, burrows, dams, and caches. For example, if beavers are no longer present but were historically, then score this indicator as 1. The historical presence of beavers is determined by using existing records or recollections by local residents to determine if beavers were ever present on the reach.

c. Fish/Aquatic Habitat

Indicator: *Riffle-Pool Systems- Number and Distribution*

Record the number of pools and riffles within the 200 m stream transect. For the purpose of this indicator, riffles need to have a cobble bottom.

Indictor: *Underbank Cover*

Underbank cover is the amount of bank that has at least 15 cm (6 inches) horizontal distance from the edge of the bank underwater into the undercut. Estimate the total amount of underbank cover along each bank of the 200 m in-stream transect, and divide by 400 m to arrive at the percent undercover bank.

Indicator: *Cobble Embeddedness*

To determine embeddedness, randomly select three riffle areas along the reach. Within each area, stand in the middle of the channel and randomly pick up from the bottom six rocks that are 3-8 inches in diameter and note the degree to which each rock was embedded within the substrate. For example, if the sediment line separates the rock halfway between top and bottom, the rating is 50% embedded. Take the average of the average of the rocks measured at each of the three sites to determine the final score.

Indicator: *Large Woody Debris*

Record the number of large woody debris pieces observed within the 200 m in-stream transects. This is wood that is not rooted and at least partially in the water or located in the active stream channel and that is at least 15cm in diameter and 1m in length.

Indicator: *Overbank Cover and Terrestrial Invertebrate Habitat.*

Estimate the distance along both banks of the 200m in-stream transect where there is vegetation (including grass, shrubs and trees) hanging over the channel. Calculate the total distance of overbank cover on each side of the 200 m in-stream transect, and divide by 400 m to arrive at the percent overbank cover.

d. Riparian Vegetation

Using the same starting point as the in-stream channel transect, measure along one of the banks a 200 m-long vegetation transect. Place the transect on the first terrace within a meter or so of the bankfull mark. Mark each end of the transect with a removable flag for easy location.

Indicator: *Riparian Zone Plant Community Structure and Cover*

The presence or absence of vegetation cover observed in each of the four structural layers (ground, shrub, middle canopy, and upper canopy) is recorded for the riparian transect. Using an ocular cross-hair tube, walk along the transect and every 2 m look directly up and down through the tube, and record the presence or absence of plant material (dead or alive) intersecting the vertical sight line of the cross-hairs in each structural layer. The line-of-sight through the ocular tube is meant to determine whether a ray of light originating directly overhead will strike any vegetation as it passes through each layer. Use the number of "hits" through the ocular tube for cover in each layer (out of what should be about 100 samples along the 200 m transect) to determine percent cover for that layer. Average the percent cover for the four layers to achieve an overall score.

Indicator: *Native Shrub and Tree Demography and Recruitment*

The distribution of age classes (seedlings, saplings or immature, mature, and snags) of the dominant riparian native species is determined during the 1 km reach walk-through. The observer comments on unexpected demographic conditions, such as the absence of particular age classes of expected dominant species, such as willows and cottonwoods.

Indicators: *Non-native Herbaceous and Woody Plant Species Cover*

During the 1 km reach walkthrough, visually estimate the percentage of cover provided by non-native shrub, tree, and herbaceous plant species. The cover by a plant is represented by the ground area that would be shaded by that plant if the sun were directly overhead.

Indicator: *Mammalian Herbivory (Grazing) on Ground Cover, Shrubs and Small Trees*

When recording the number of positive and negative cover hits for each structural layer on the riparian zone transect with the ocular tube, record each time you see evidence of mammalian herbivore impacts. Use the number of "hits" to estimate percent ground cover, shrubs, and small trees that has been grazed by herbivores.

e. Terrestrial Wildlife Habitat

Indicator: *Shrub, Mid and Upper Canopy Patch Density and Connectivity*

During the 1 km study reach walkthrough, visually estimate the frequency and connectedness of patches of all classes should be estimated during the overall study reach walkthrough. Include both native and non-native species for these scores.

Indicator: *Fluvial Habitat Diversity*

During the 1 km study reach walkthrough, record the different types of riparian landforms that can provide unique habitats for wildlife recorded during the overall study reach walkthrough. These include wet meadows, ox-bows, marshes, cut banks, sand bars, islands in the channel, etc. Note that this indicator only considers the richness of habitat types and not the evenness of those types.

VI. RESULTS

Each of the three study reaches is described and its scores in the 5 functional components explained. The descriptions include latitude, longitude, elevation and reference photos. The results for all three study reaches are summarized in Tables 4-8.

A. Reference Reach, North Fork Flathead River

This is a high gradient reach, located between Polebridge, MT and the confluence of Caras Creek. It is surrounded by pine forests, with a large number of very large, old cottonwoods. There are no noticeable human impacts on the reach, with the exception of a small dirt road located in the floodplain but away from the stream channel. Hence, this reach is suitable to serve as a reference reach for others streams of similar size and gradient in this elevation range in the North Fork watershed. Its characteristics are as follows:

- Non-chemical Water Quality was relatively “good” (3.5/5), although there was only moderate stream shading. However, given the elevation and gradient of the stream, there is probably only minor impact on water temperatures.
- Hydrogeomorphology was generally “good” (3.6/5), with the exception of floodplain connectivity. There are no levees along the stream channel. There were signs of recent beaver presence.
- Fish/Aquatic Habit was “excellent” (4.6/5). Notable was the amount of overbank and underbank coverage and the large amount of woody debris present in the stream channel.

- Riparian Vegetation was “good” to “excellent” (4.1/5) with the exception of ungulate grazing on shrubs and small trees. No non-native grasses, shrubs or trees, were recorded.
- Terrestrial Wildlife Habitat was “excellent” (4.5/5) with well-developed patches in all structural layers (shrub, mid-canopy and upper canopy tree layers).

Figure 6: Photo of upstream reference reach survey site, start location (July, 2016).

Figure 7: Photo of downstream reference reach survey site, end location (July, 2016).

Figure 8: Aerial location photo of reference reach survey site (NAIP Imagery)

Location of beginning of reach: 48º 41’ 25.28” N, 114º 16’ 46.46” W

Location of end of reach: 48º 41’ 07.76” N, 114º 11’ 17.72” W

Average Elevation: 3417 ft.

Assessed: July 2016

Reference Photos: Figures 8 and 9

Aerial Location Photo: Figure 10

Overall Score: 4.1

B. Red Bench Fire Area, North Fork Flathead River

This is a high gradient reach, located south Polebridge, MT. It is surrounded by pine forests, with many large cottonwoods. There are no noticeable human impacts on the reach, with the exception of a few houses west of the reach, in the floodplain. This reach experienced a severe wild fire in 1988, and has had no rehabilitation actions taken.

- Non-chemical Water Quality was relatively good (3.5/5), although there was only moderate stream shading. However, given the elevation and gradient of the stream, there is probably only minor impact on water temperatures.
- Hydrogeomorphology was relatively good (3.6/5), with the exception of floodplain connectivity. There are no levees along the stream channel. There were signs of recent beaver presence.
- Fish/Aquatic Habit was relatively good (3.4/5). The amount of overbank and underbank coverage and pool distribution were lacking. Notably good was the large amount of woody debris present in the stream channel, which is a positive impact of the fire.

- Riparian Vegetation was relatively good (3.9/5) with the exception of ungulate grazing on shrubs and small trees. Patches of non-native Russian olive trees were detected and recorded.
- Terrestrial Wildlife Habitat was relatively good (3.5/5) with under-developed patches in mid-canopy and upper canopy tree layers.

Figure 9: Photo of upstream Red Bench reference reach survey site, start location (July, 2016).

Figure 10: Photo of downstream Red Bench reach survey site, end location (July, 2016).

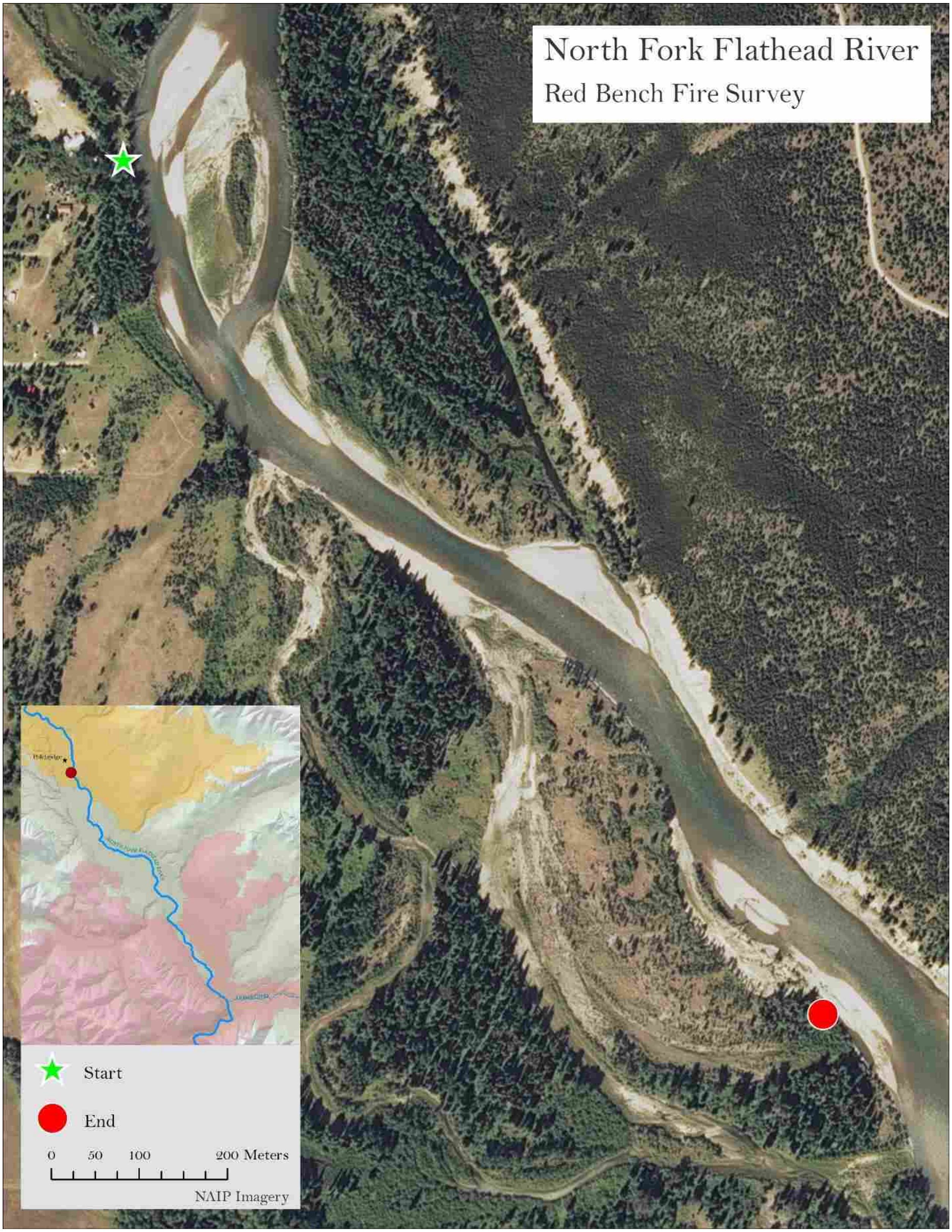

Figure 11: Aerial location photo of Red Bench survey site (NAIP Imagery)

Location of beginning of reach: 48º 45’ 46.09” N, 114º 16’ 46.46” W

Location of end of reach: 48º 45’ 13.89” N, 114º 16’ 05.92” W

Average Elevation: 3528 ft.

Assessed: July 2016

Reference Photos: Figures 11 and 12

Aerial Location Photo: Figure 13

Overall Score: 3.5

C. Moose Fire Area, North Fork Flathead River

This is a high gradient reach, located just north of the Caras Creek confluence. It is surrounded by shrubs and young pine and cottonwood trees. The ground is covered by downed, burned trees. There are no noticeable human impacts on the reach. This reach experienced a severe wild fire in 2001, and has had no rehabilitation actions taken.

- Non-chemical Water Quality was relatively poor (3.5/5), with only moderate stream shading. However, given the elevation and gradient of the stream, there is probably only minor impact on water temperatures. Algal growth was recorded along the reach.
- Hydrogeomorphology was relatively poor (2.2/5), with low scores in floodplain connectivity and vertical bank stability. There are no levees along the stream channel. There were no signs of beaver presence.
- Fish/Aquatic Habitat was relatively good (3.2/5) mainly because of the lack of cobble embeddedness and large amounts of woody debris in the stream, due to the fire. The amount of overbank and underbank coverage and pool distribution were lacking.

- Riparian Vegetation was relatively good (3.8/5) with the exception of ungulate grazing on shrubs and small trees.
- Terrestrial Wildlife Habitat was relatively good (2.8/5) with under-developed patches in mid-canopy and upper canopy tree layers.

Figure 12: Photo of upstream Moose reach survey site, start location (July, 2016)

Figure 13: Photo of downstream Moose reach survey site, end location (July, 2016).

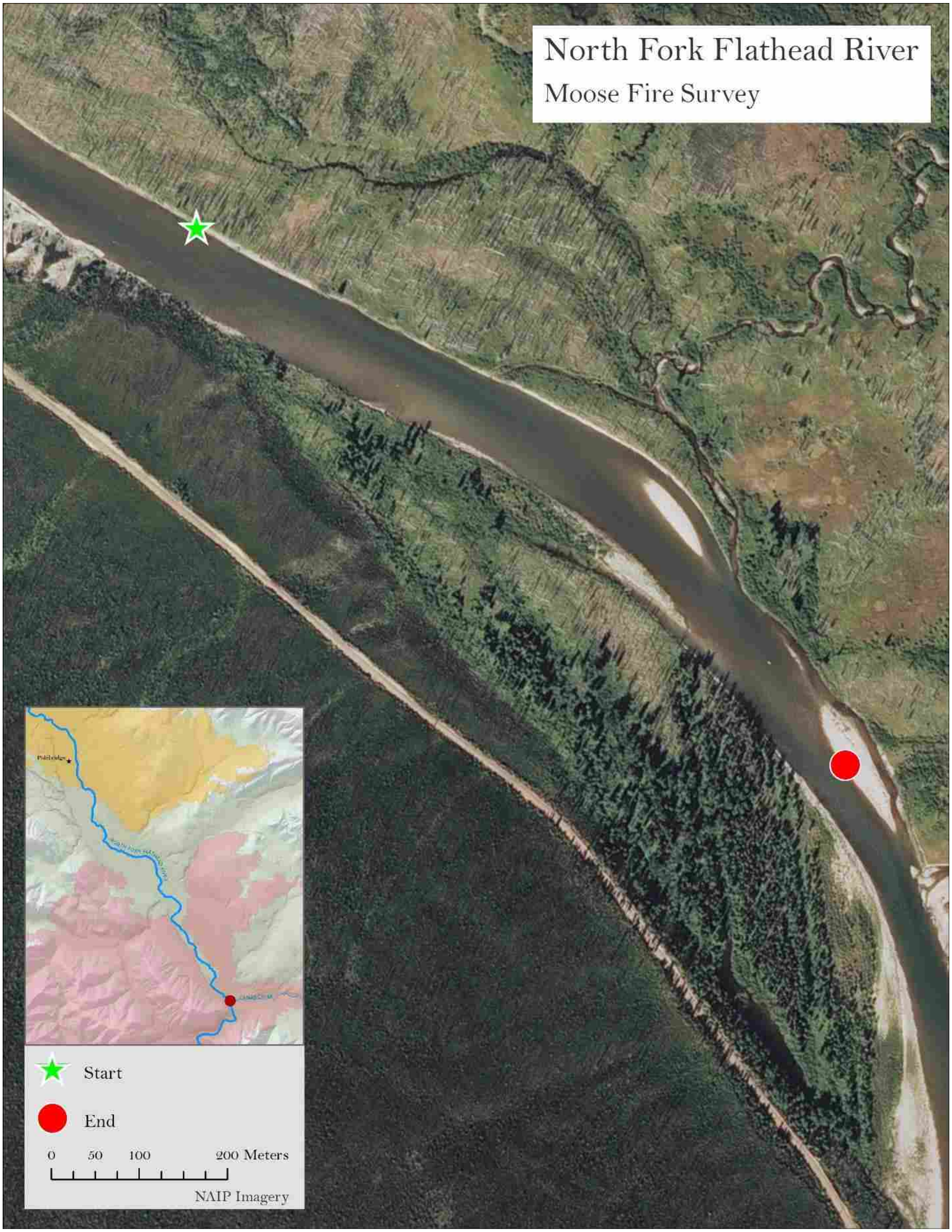

Figure 14: Aerial location photo of Red Bench survey site (NAIP Imagery)

Location of beginning of reach: 48º 38’ 08.92” N, 114º 09’ 08.53” W

Location of end of reach: 48º 37’ 49.56” N, 114º 08’ 32. 80” W

Average Elevation: 3362 ft.

Assessed: July 2016

Reference Photos: Figures 14 and 15

Aerial Location Photo: Figure 16

Overall Score: 2.9

Tables 4-8 summarize and compare scores for the 5 functional areas from the three study sites.

Table 4: Water Quality (non-chemical) scores for the North Fork reaches using RSRA

WATER QUALITY		**Reference Site**	**Red Bench Fire Site**	**Moose Fire Site**
1. Algal Growth	1 = >50% of stream bottom covered by filamentous algae 2 = 26-50% of bottom covered by filamentous algae 3 = 11-25% of bottom covered by filamentous algae 4 = 1-10% of bottom covered by filamentous algae 5 = no filamentous algae on stream bottom	No filamentous algae in stream	No filamentous algae in stream	Three “hits” in the 200 m transect
		% = 0 Score: 5	% = 0 Score: 5	% = 1.5 Score: 4
2. Channel Shading, Solar Exposure	1 = stream channel completely unshaded (0%) 2 = slight shading (1-15%) 3 = moderate shading (16-30%) 4 = substantial shading (31-60%) 5 = Channel mostly shaded (>60%)	> 5% stream channel shading at all three observation sites	> 5% stream channel shading at all three observation sites	0% stream channel shading at all three observation sites
		Ave. % = 2.5 Score: 2	Ave. % = 2.5 Score: 2	Ave. % = 0 Score: 1
	Water Quality Mean Score:	3.5	3.5	2.5

Table 5: Hydrogeomorphology scores for the North Fork reaches using RSRA.

HYDROGEOMORPHOLOGY		**Reference Site**	**Red Bench Fire Site**	**Moose Fire Site**
3. Floodplain Connection and Inundation	1 = >1.7 bankfull / depth ratio 2 = >1.5 -1.7 bankfull / depth ratio 3 = >1.4 - 1.5 bankfull / depth ratio 4 = >1.3 - 1.4 bankfull / depth ratio 5 = 1.0 - 1.3 bankfull / depth ratio	Ratios: 2.4 1.2 1.6	Ratios: 2.0 2.4 2.3	Ratios: 1.6 1.8 1.6
		Avg = 1.7 Score: 1	Avg = 2.2 Score: 1	Avg = 1.7 Score: 2
4. Vertical Bank Stability	1 = >90% of channel banks are vertically unstable (use the average of both banks) 2 = 61 - 90% of banks are unstable 3 = 31 - 60% of banks are unstable 4 = 5 - 30% of banks are unstable 5 = <5% of banks are unstable	Unstable banks in 200 m transect: 4 m	Unstable banks in 200 m transect:14 m	Unstable banks in 200 m transect:180 m
		2% unstable Score: 5	7% unstable Score: 4	90% unstable Score: 2
5. Hydraulic Habitat Diversity	1 = no diversity (variability) of stream form features 2 = low diversity, 2 habitat types present, 3 = moderate diversity, 3 types present, 4 = moderately high diversity, 4 types present, 5 = high diversity, 5 or more present.	Features present: high velocity run, low velocity run, active side channel, backwaters	Features present: edge water, lateral pool, high velocity run, cobble/boulder debris fan, backwaters	Features present: high velocity run, low velocity run, active side channel
		Features: 4 Score: 4	Features: 5 Score: 5	Features 3: Score: 3
6. Riparian Area Soil Integrity	1 = >25% of riparian soil surface disturbed 2 = 16 - 25% disturbed 3 = 6 - 15% disturbed 4 = 1 - 5% disturbed 5 = <1% disturbed	Geomorphically inconsistent erosion not observed in 1 km	Some geomorphically inconsistent erosion observed in 1 km (make shift boat launches)	Some geomorphically inconsistent erosion observed in 1 km
		<1% disturbed Score: 5	5-10% disturbed	10% disturbed Score: 3

			Score: 3	
7. Beaver Activity	1 = beavers not now present but were historically 2 = no beaver dams, a few signs of activity but none within the last year 3 = activity in past year but no dams 4 = beaver dams on some of the stream 5 = beaver activity and dams control stream	Recently cut stems were observed	Recently cut stems and a dam was observed in a back channel	No signs of beaver activity observed in 1 km
		Score: 3	Score: 4	Score: 1
Hydrogeomorphology mean score:		3.6	3.4	2.2

Table 6: Fish/Aquatic Habitat scores for the North Fork reaches using RSRA.

FISH/AQUATIC HABITAT		**Reference Site**	**Red Bench Fire Site**	**Moose Fire Site**
8. Riffle-Pool Distribution	1 = no riffle-pool habitat in stream transect 2 = one to several riffle-pool systems 3 = limited to moderate riffle-pool distribution in reach 4 = moderate to abundant riffle-pool distribution 5 = riffle-pools abundant (>50% of transect has pools connected by riffles)	Number of riffle-pool units in 200 m transect: 11	Number of riffle-pool units in 200 m transect: 4	Number of riffle-pool units in 200 m transect: 5
		Limited to moderate distribution Score: 3	One to several riffle-pool systems Score: 2	One to several riffle-pool systems Score: 2
9. Underbank Cover	1 = no underbank cover in 200m stream transect 2 = <10% transect has underbank cover 3 = 10 - 25% of transect has underbank cover 4 = 26 - 50% of transect has underbank cover 5 = >50% of transect has underbank cover	Underbank cover in 200 m transect: 121 m	Underbank cover in 200 m transect: 39 m	Underbank cover in 200 m transect: 9 m
		% Underbank coverage = 61% Score: 5	% Underbank coverage = 20% Score: 3	% Underbank coverage = 5% Score: 2

10. Cobble Embeddedness	1 = average of >50% of rock volume is imbedded in fine silt. (avg. of three sites) 2 = 41 - 50% of rock imbedded 3 = 26 - 40% of rock imbedded 4 = 20 - 25% of rock imbedded 5 = <20% of rock imbedded	Average embeddedness of three sites (six samples per site): <10% Score: 5	Average embeddedness of three sites (six samples per site): <10% Score: 5	Average embeddedness of three sites (six samples per site): <10% Score: 5
11. Aquatic Macro-invertebrate Diversity	1 = no aquatic (benthic) macroinvertebrates found 2 = 1 macroinvertebrate order present 3 = 2 macroinvertebrate orders present 4 = 3 macroinvertebrate orders present 5 = 4 or more orders present	N/A	N/A	N/A
12. Large Woody Debris	1 = no large woody debris (LWD) in transect 2 = <3 LWD pieces in transect 3 = 3 - 5 LWD pieces in transect 4 = 6 - 10 LWD pieces in transect 5 = >10 LWD pieces in transect	Pieces of LWD (at least 6" diameter and 3' length) in 200 m transect: 13 Score: 5	Pieces of LWD (at least 6" diameter and 3' length) in 200 m transect: 15 Score: 5	Pieces of LWD (at least 6" diameter and 3' length) in 200 m transect: 19 Score: 5
13. Overbank Cover and Terrestrial Invertebrate Habitat	1 = no grass, shrubs, or trees overhang water 2 = <10% of banks have grass, shrubs, or trees that overhang the water 3 = 10 - 25% of banks have overhanging veg. 4 = 26 - 50% of banks have overhanging veg. 5 = >50% of banks have overhanging veg.	Meters of vegetation hanging over bank in 200 m transect: 102 m % of stream transect = 51% Score: 5	Meters of vegetation hanging over bank in 200 m transect: 12 m % of stream transect = 6% Score: 2	Meters of vegetation hanging over bank in 200 m transect: 4 m % of stream transect = 2% Score: 2
Fish/Aquatic Habitat mean score:		4.6	3.4	3.2

Table 7: Riparian Vegetation scores for the North Fork reaches using RSRA.

RIPARIAN VEGETATION		**Reference Site**	**Red Bench Fire Site**	**Moose Fire Site**
14. Riparian Zone Plant Community Structure and Cover	1 = <5% average plant cover in riparian zone 2 = 5 - 25% average plant cover 3 = 26 - 50% average plant cover 4 = 51 - 80% average plant cover 5 = >80% average plant cover	% of layers for 200 m transects A and B (avg): Ground: 74% Shrub: 93% Mid-Canopy: 47% Upper-Canopy: 47%	% of layers for 200 m transects A and B (avg): Ground: 87% Shrub: 46% Mid-Canopy: 35% Upper-Canopy: 24%	% of layers for 200 m transects A and B (avg): Ground: 96% Shrub: 43% Mid-Canopy: 0% Upper-Canopy: 0%
		Avg % cover: 66% Score: 4	Avg % cover: 48% Score: 3	Avg % cover: 35% Score: 3
15. Shrub Demography and Recruitment	1 = no native shrubs present in study reach 2 = one age class present 3 = two classes present, one class with seedlings or saplings 4 = three age classes present 5 = all age classes present	All age classes present: seedling, immature, mature, old dead clumps	Three age classes present: seedling, immature, mature	Three age classes present: seedling, immature, mature
		Score: 5	Score: 4	Score: 4
16. Tree Demography and Recruitment	1 = no native trees present in study reach 2 = one age class present 3 = two classes present, one class with seedlings or saplings 4 = three age classes present 5 = all age classes present	All age classes present: seedling, immature, mature, snags	Three age classes present: seedling, immature, mature	Two age classes present: seedling, immature
		Score: 5	Score: 4	Score: 3

17. Non-native Herbaceous Plant Species	1 = >50% of herbaceous plant cover are not native species 2 = 26 - 50% herbaceous not native 3 = 11 - 25% herbaceous not native 4 = 5 - 10% herbaceous not native 5 = <5% of herbaceous cover not native	Percent of non-native herbaceous plants: <1% Score: 5	Percent of non-native herbaceous plants: <5% Score: 5	Percent of non-native herbaceous plants: <5% Score: 5
18. Non-native Woody Plant Species	1 = >50% of woody plant cover are not native species 2 = 26 - 50% of woody cover not native 3 = 11 - 25% of woody cover not native 4 = 5 - 10% of woody cover not native 5 = <5% of woody cover not native	Percent of non-native woody plant cover: <1% Score: 5	Percent of non-native woody plant cover: 10% Russian olive trees 1-3 m height Score: 4	Percent of non-native woody plant cover: <1% Score: 5
19. Mammalian Herbivory (grazing) Impacts on Ground Cover	1 = >50% of plants impacted by grazing 2 = 26 - 50% of plants impacted 3 = 11 - 25% of plants impacted 4 = 5 - 10% of plants impacted 5 = <5% of plants impacted	Percent of plants impacted by grazing in 200 m transect: 24% Score: 3	Percent of plants impacted by grazing in 200 m transect: <5% Score: 5	Percent of plants impacted by grazing in 200 m transect: <5% Score: 5
20. Mammalian Herbivory (browsing) Impacts on Shrubs and Small Trees	1 = >50% of plants impacted by grazing 2 = 26 - 50% of plants impacted 3 = 11 - 25% of plants impacted 4 = 5 - 10% of plants impacted 5 = <5% of plants impacted	Percent of shrubs and small trees impacted by browsing in 200 m transect: 30% Score: 2	Percent of shrubs and small trees impacted by browsing in 200 m transect: 31% Score: 2	Percent of shrubs and small trees impacted by browsing in 200 m transect: 46% Score: 2

Riparian Vegetation mean score:	4.1	3.9	3.8

Table 8: Terrestrial Wildlife Habitat scores for the North Fork reaches using RSRA.

TERRESTRIAL WILDLIFE HABITAT		**Reference Site**	**Red Bench Fire Site**	**Moose Fire Site**
21. Shrub Patch Density	1 = no shrub patches in stream reach 2 = few,isolated small shrub patches 3 = more patches but still isolated 4 = few large open areas between large patches 5 = almost continuous dense shrub cover	Almost continuous dense shrub cover	Few large open areas between large patches	Almost continuous dense shrub cover
		Score: 5	Score: 4	Score: 5
22. Mid-Canopy Patch Density	1 = no mid-canopy shrub or tree patches in reach 2 = few isolated small patches in mid canopy 3 = more patches but still isolated 4 = few large open areas between large patches 5 = almost continuous dense mid-canopy cover	Few large open areas between large patches	More patches but still isolated	Few isolated small patches in mid canopy
		Score: 4	Score: 3	Score: 2
23. Upper Canopy Patch Density	1 = no upper-canopy trees present in reach 2 = few isolated small patches in upper canopy 3 = more patches but still isolated 4 = few large open areas between large patches 5 = almost continuous dense upper-canopy cover	Few large open areas between large patches	Few isolated small patches in upper canopy	No upper canopy trees present in reach
		Score: 4	Score: 2	Score: 1

24. Fluvial Habitat Diversity	1 = no other fluvial habitat besides the stream channel 2 = one other type of fluvial habitat present 3 = two other types present 4 = three other types present 5 = four or more other types present	Four geophysical features observed: floodplain ponds, land and isolated sand or gravel bars, marsh, stable cutbanks Score: 5	Four geophysical features observed: large and isolated sand or gravel bars, marsh, stable cutbanks, beaver pond Score: 5	Two geophysical features observed: large and isolated sand or gravel bars, stable cutbanks Score: 3
Terrestrial Wildlife Habitat mean score:		4.5	3.5	2.8

VII. DISCUSSION

A. Training, Equipment and Field Time Required to Perform Assessments

A challenge facing physical habitat assessment methods is the trade-off between collecting enough information to describe the physical habitat characteristics along the reach, and making the procedure too cumbersome and time consuming. Though the developers recommend highest efficiency with three trained people working together, there were only two untrained people, myself and an assistant, performing the assessments for this study. Though the first assessment took nearly a day (8 hours) to perform, the following assessments went relatively quicker (5-6 hours). The equipment required to complete the field work was minimal, as well as the impact on the area.

B. Assessment Parameter Evaluation (Variability and Subjectivity)

Following are descriptions of parameters for each category that, in my opinion, were effective, may need adjustments, or parameters that I thought were too subjective to be useful.

Water Quality parameters:
(See Table 4 for reference)

The algal growth parameter attempts to assess the level of nutrient loads to a stream from the level of algae in the stream. While heavy algae growths are indicative of sufficient nutrient levels to support that growth, low levels of algal biomass are not necessarily indicative of low levels of nutrient loading. Algal levels may be limited by other factors (insufficient light, frequent scouring, heavy grazing, toxic pollutants or suboptimal temperature conditions).

The channel shading parameter evaluates the degree to which the channel is shaded by shrubs, understory, and canopy vegetation. This parameter is measured at peak leaf-out time of year (summer) and time of day (mid-day). This assessment does not consider whether the stream is cold water (typically less shading) or warm water. It also does not consider the width of the stream. Because the reference reached scored only 3.5/5 for this parameter, special scaling, or scoring may be required for this particular type of stream.

Though both parameters to assess water quality are useful indicators and can be easily measured by a variety of expertise, the width and temperature need to be considered. This could be remedied by scaling the scores to the reference site.

Hydrogeomorphology:
(See Table 5 for reference)

All three sites, including the reference site, scored poorly for the floodplain connection and inundation parameter. This could be an indication that geomorphological characteristics of this cobble-dominated, high-gradient stream with a relatively undeveloped floodplain require different scoring parameters. It could also indicate user error when taking measurements. The ranked scoring of the vertical bank stability parameter of the three sites that vary in successional phase seems to indicate that this could be a good measure of ecosystem function. However, the difference of 10 m between the reference site (4 m) and the Red Bench site (14 m) of bank instability within a 200 m stretch may not be enough of a difference of an entire point. The hydraulic habitat diversity parameter requires that the user have some knowledge in geomorphological features. In addition, since streams can vary widely in the number of natural features, this parameter should be scaled to number of features in the reference site.

The riparian area soil integrity parameter is well-suited to a rapid assessment that is meant to be implemented by users with a wide range of expertise. However, this can be too subjective and the percentage variability between scores 3 and 5 may be too narrow (3 = 6 - 15% disturbed, 4 = 1 - 5% disturbed and 5 = <1% disturbed). The beaver activity parameter is a relatively simple and important parameter to measure if known to be the area after initial research. The user will need to research existing records or recollections by local residents to determine if beavers were ever present on the reach and have minor training in identifying beaver signs.

Though all the categories are important as indicators of hydrogeomorphological health, the floodplain connectivity parameter may require modification based on stream type. In addition, since the range of values is so slight and can be susceptible to user error, it may be necessary to take more than three measurements on the survey site.

Fish/Aquatic Habitat parameters:
(See Table 6 for reference)

The underbank cover and overbank cover and terrestrial invertebrate habitat parameters appear to be good quantifiable indicators of riparian ecological health and resulted in scores representing different levels of succession. The large woody debris parameter had interesting results. All sites scored the maximum number 5 though the reference had the smallest amount of LWD observed. This is a beneficial consequence of the type of disturbance (stand-replacing fire) that the sites experienced.

The riffle-pool distribution parameter does not have a quantifiable number of features for each score, other than >50% for optimal rating. The terms “moderate” and “abundant” are used, which could be easily misinterpreted and not repeatable by different assessment users. Cobble embeddedness, was basically unusable as a measure for this particular stream. The optimal score for all reaches was not necessarily a result of ecological health but of the high velocity and gradient of the stream. Aquatic macro-invertebrate diversity was not appropriate for this geographical location. Since the assessment was developed for use in the southwest U.S., the species described in the guidebook were unlike those found in the North Fork Flathead River. This could be modified to suit any location, however, using expertise of local macroinvertebrate specialists.

Riparian Vegetation parameters:
(See Table 7 for reference)

I found no major concerns with most of the parameters in this category. The measurements were relatively simple and straightforward. However, it was unclear whether the riparian zone plant community structure and cover was measuring the diversity or amount of plant cover since the Red Bench and Moose sites scored the same (3) with widely varying structure compositions. Also, a user's lack of knowledge of non-native plant species may be a concern when making observations for non-native species parameters and could require extra training.

Terrestrial wildlife habitat:
(See Table 8 for reference)

The patch density observation parameters are relatively simple but susceptible to user subjectivity. Similarly to the hydraulic habitat diversity parameter, streams can vary widely in the number of geophysical features. The parameter fluvial habitat diversity should be scaled to number of features in the reference site since the number used in this scoring system not be representative of all riparian ecosystem types

C. Overall Feasibility and Usefulness of RSRA

In evaluating the overall feasibility of the RSRA, it's important to review the criteria stated earlier. To be used in the citizen science model, the requirements for the riparian habitat assessment would be:

-Rapid: The time taken to complete an assessment evaluating 1 km of river length was less than a day and became quicker with more experience.

-Able to be widely implemented geographically: Modifying some of the parameters to meet the geomorphological features and biological species specific to an area could make this assessment useable in diverse areas in the U.S., as well as scaling the scores to the reference site.

-Science supported: Though the parameters are good indicators of ecological function, the scoring system may not properly reflect functional differences between sites.

-Able to be implemented by assessors with a range of expertise: I am confident that, with training (2 full assessment walk-throughs) this assessment could be used by people with a range of expertise.

-Designed as a monitoring tool: Though it is possible for any assessment to be used as a monitoring tool if regularly repeated, the financial costs and time needed must be considered. Since this assessment can be done rapidly, doesn't require expensive equipment and may fit into the citizen science model, it could be used as a relatively inexpensive monitoring program.

-Repeatable by different users: This is an important requirement that was not evaluated in this study although the subjectivity of several parameters was noted.

D. Additional testing needed before using method

A problem associated with ecological assessments is the need for objective and repeatable field observations. Coincidentally, a reason why there is easily acquired information on riparian habitats is that they can be visually recognized from the river bank. Nevertheless, the effectiveness of habitat assessment and monitoring depends on the ability of surveyors to consistently observe and recognize habitat units. Many parameters in RSRA have a subjective, visually attained element. Though one of the developers, Peter Stacey, asserts that "after years of work, we have found that the protocol is both reliable and consistent-- after some initial training, different groups of people tend to get identical or nearly identical scores on the same reaches when measured at the same time, and the scores are identical or nearly identical when taken by the same group on the same reach in different years" (personal communication, July 5, 2016). Though this is encouraging, it is important, if this method is to be used in a broader scheme, to further test the consistency with a range of participants.

E. Resiliency of Riparian Ecosystems following Fire Disturbance Detected by RSRA

Unlike many rivers in the U.S., the North Fork has not had a history of human use or modification. It can be assumed that all conditions are natural and/or a result of the severe fires that occurred in the region. Since the area is historically adapted to fire disturbance, the pattern of ecological improvement through time is expected. Though the assessment is rapid and the sample size relatively small, there were interesting differences that could still be observed and measured in the three sites.

The amount of woody shrub and tree cover varied in the three reaches. This reflects the amount of time since the severe stand-replacing fires. The reference had patches of low, mid, and upper-canopies. The Red Bench reach had patches of low and mid-canopies, where the Moose reach had only patches of low-canopy trees, though the seedling were present and growing well. This indicates that the riparian woody plant community has the potential for rapid recovery following severe fires.

The absence of non-native vegetation is typically a good indicator of a healthy riparian forest with moist soils. The Red Bench reach had the only observed non-native Russian olive patches. This could be an indication of poor connectively between the channel and the flood plain, causing drier soils.

All reaches scored excellent on the amount of large woody debris, promoting the fish/aquatic habitat. This could be a beneficial result of having fires regularly in riparian areas.

This relatively quick recovery of severe fires on the North Fork could be attributed to riparian species' range of disturbance adaptations. These include the adaptations that enable the survival of the vegetation on site, such and thick bark and sprouting. It also includes those that contribute to recolonization in burned areas, such as water dispersal and reproductive responses (Kauffman, 1997). For example, most cottonwood, aspen and willow species produce root suckers.

Aspen trees, in particular, have roots that are stimulated to produce numerous suckers when they are top-killed by fire (Sheppard and Smith, 1993). Though this protocol was not intentionally designed to detect changes in fires disturbance, it was able to measure many important differences that reflect varying levels of succession.

VIII. CONCLUSION

Moving forward, coordinated research that addresses interactions and feedbacks among physical processes, re-growth of riparian vegetation, and changes in aquatic communities following disturbance and following rehabilitation efforts is needed to prescribe and monitor effective rehabilitation projects following anthropogenic disturbances, including changing disturbance regimes due to climate change.

As ecologist Monica Turner stresses as a goal of her research, there is a need to understand how complex natural systems interact with their environments and how their communities change in time and space. For such studies, I suggest a long-term monitoring effort. This is simply defined as “field-based measurements collected continuously for at least 10 years” (Lindenmayer and Likens, 2010). This suggested long-term monitoring effort on all U.S. riparian areas will serve as both scientific research of ecological disturbances and as an effort to address a current gap in water policy.

In the forty-five years since the enactment of the CWA, notable progress was made to improve water quality nationwide under the CWA. However, since a wider ecological habitat assessment is not included in water quality monitoring, efforts fall short.

The Montana DEQ asserts, in the most resent Montana Water Quality Monitoring and Assessment Strategy report, that “a high priority long-term goal is to integrate wetlands resources into the state’s water monitoring and assessment activities as part of the routine approach to sampling” (2009, pg. 18). This currently unfulfilled objective includes baseline condition assessments and voluntary restoration monitoring to be integrated with other department monitoring activities. Since, in my analysis, the assessment tools currently being used in MT are not designed to be monitoring tools and may not work in the citizen science model, I elected to test another method that claimed to have the needed qualifications.

The RSRA survey was tested on three reaches at different successional stages to see if it could be used as an assessment and monitoring tool in a future scheme of riparian ecosystem protection. With further testing for user consistency and possible scoring modifications, this method has the potential to be used in the citizen science model to provide a low budget option to address gaps in agency assessments and create a benchmark for baseline conditions. If repeated as a monitoring tool, the changes tracked over time can inform current management practices, or active restoration programs.

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APPENDIX A:

U.S. WATER POLICY HISTORY

1. Industrial Age (late 18th century-late 19th century): Eastern U.S.

Prior to 1789, in the U.S., alterations on waterways were funded privately. In 1787, at the constitutional convention, Benjamin Franklin advocated for federal funding for these internal "improvements", but was unsupported. Ultimately, the Constitution gave states the responsibility. However, because of poor economic conditions in many states, Congress was forced to fund specific projects, starting in 1802 (Reuss and Walker, 1983).

In the early nineteenth century, artificial canals were used to more directly connect the interior riverine system to the sea. The idea, promoted by policy makers was to "free rivers from their natural courses and to direct them into channels that would serve the economic ends of the nation" (Larson, 1987, pg. 354). The construction of the Erie Canal in 1817, 364 miles long, prompted a canal boom which attracted more federal dollars to future projects. But by the 1840's, expensive canal enlargement programs and competition from railroads brought this boom to an end (Sheriff, 1996).

During the early stages of the American Industrial Revolution, water was an important source of energy. Aside from the waterwheel, the dam was the most essential component of a mill. These early dams were low, simple structures designed to raise the stream level and create a storage reservoir. Consequently, the dams obstructed navigation and log floats, as well as impeded the seasonal movement of fish, becoming the focus of water rights litigation. Prior to the nineteenth century, common law doctrines were generally based on the natural flow of water, and courts seldom favored the use of water to run machinery or irrigate, placing strict limits on its appropriation (Andrews, 1999). Water mills challenged these prevailing interpretations of water rights of riparian owners.

Typically, water rights controversies pitted downstream riparian landowners against upstream owners whose dams obstructed the natural flow of water for mills or irrigation, or upstream mill owners against downstream landowners flooded by a dam.

Since navigation rights had priority on streams large enough for vessels, the parts of water law concerning this activity were the least controversial. But as power needs increased, especially in New England, government officials began to favor mill owners. Favor was also given to capitalists wanting to divert water to build canals (Hunter, 1979).

The phrase ‘reasonable use’, was used as a balancing test when challenging riparian water rights and weighing the detriment to riparian owners downstream. By the mid 1800’s most courts favored “reasonable use” over prior appropriation since it interfered with economic development. However, most of these debates involving mill dams and canals gradually disappeared with the advent of the steam engine and railroad (Hunter, 1979).

Figure 3: Oil painting by Thomas Cole, View from Mount Holyoke, Northampton, Massachusetts, after a Thunderstorm—The Oxbow, 1836.

In a burgeoning country, rivers were a romantic symbol depicted in artistic landscapes (Graf, 1993, see Figure 3). It is clear, however, by the treatment of them that they were more often regarded as untapped resources waiting to be harnessed and exploited for human gain. Following the neoclassical tradition of early America, "The 'proper' channel for a river is not necessarily the one it has carved for itself: By means of canals and locks it can be guided by men along a straight and level line, thereby improving upon natural design. Therefore, rivers were most attractive when they yielded to humanity's needs, whether as mechanisms of transportation or as sites for nascent towns." (Seelye, 1991, pages 8-9) As noted by historian Theodore Steinberg (1991, pg. 16), regarding the attitude towards this important resource at the time:

> *"As the [nineteenth] century progressed, a consensus emerged on the need to exploit and manipulate water for economic gain. A stunning cultural transformation was taking place, a shift in people's very perception of nature. By the latter part of the nineteenth century, it was commonly assumed, even*

> *expected, that water should be tapped, controlled, and dominated in the name of progress-a view clearly reflected in the law."*

The compulsion to "improve" waterways was encouraged by the profound changes transforming a young nation. This attitude persisted as America expanded westward.

2. Scientific Era (prior to 1950's) Western U.S.: Doctrine of Prior Appropriation

> *"We had pushed aside foreign countries and native peoples. Now we would push aside the desert."* Bruce Reichert - The Bureau that changed the West

The history of water resource management in the Western United States have been described by three phases: (1) Scientific Era (prior to 1950's), (2) Economic Era (1950's), and (3) Environmental Era (late 1950's to present) (National Resource Council, 2004).

In the eastern U.S., water is an essential resource. However, control over water did not define the central character of that region as it has in the west. The scarcity of water in the arid west played a pivotal role in regional growth and development as well as in the larger political framework (Lee, 1988).

As multitudes of Americans headed west, bills were introduced in congress addressing irrigation and reclamation of "unproductive land", as early as 1867. In 1877, the Desert Land Act linked grants of public land to irrigation. The revised Federal Desert Land Act, also called the Carey Act, was passed by congress in 1894. Since, Congress deemed individual settlers inadequate to construct irrigation systems, the act gave permission to private companies to assemble irrigation systems and to then profit from the sale of water to irrigators. However, because of a lack of engineering skill and finances, western companies pushed for further action by the government to build and fund larger projects (Bakken, 2000).

It is clear by the statement given by Tom L. Cannon, secretary of the St. Louis Manufacturers Association in 1900, that the industrial and commercial community was putting pressure on the federal government to act on and fund water infrastructure projects in the west. Mr. Cannon stated:

> *"I believe in the Federal government improving its own property for the benefit of the people composing the government....If it is right for the Federal government to build harbors along the sea coast and great waterway channels in different sections, it is right for the Federal government to improve that great American Desert and reclaim arid America through irrigation. I believe in making this country not only the greatest agricultural country in the world, and the greatest manufacturing country in the world, but I believe in making it the seat of a financial empire and becoming a creditor of all nations instead of a debtor.... If we build storage reservoirs in the mountains of the West and control the water supply for irrigation purpose..."* (Los Angeles Times, 1900).

Ushering in a new century and a new phase of land management, and responding to the pressure of industry, newly elected U.S. president Theodore Roosevelt proclaimed in his inaugural address in 1901, regarding the nation's rivers:

> *"Great storage works are necessary to equalize the flow of streams and to save the flood waters. Their construction has been conclusively shown to be an undertaking too vast for private effort. Nor can it be best accomplished by the individual State acting alone. Far-reaching interstate problems are involved and the recourses of single States would often be inadequate. It is properly a national function, at least in some of its features. It is as right for national government to make the streams and rivers of the arid region useful by engineering works for water storage as to make useful the rivers and harbors of the humid region by engineering works of another kind .... The reclamation of the unsettled arid public lands presents a different problem. Here it is not enough to regulate the flow of streams. The object of the government is to dispose of the land to settlers who build homes upon it. To accomplish this object water must be brought within their reach.... The pioneer settlers on the arid public domain chose their homes along streams from which they could themselves divert the water to reclaim their holdings. Such opportunities are practically gone. There remain, however, vast areas of public land, which can be made available for homestead settlement, but only by reservoirs an main-line canals impracticable for private enterprise. These irrigation works should be built by the government for actual settlers, and the cost of construction should so far as possible be repaid be the land*

> *reclaimed… The policy of the national government should be to aid to irrigation in the several States and Territories in such manner as will enable the people in the local communities to help themselves, and as well stimulate needed reforms in the State laws and regulations governing irrigation."* The Washington Post (1901).

With the passing of the National Reclamation Act the following year, along with the creation of the Reclamation Bureau, the view of rivers being entities to be governed by humans for economic and social growth took a leap to large scale, widespread infrastructure. This act funded irrigation projects for the arid lands of twenty states in the American West. Multitudes of rivers were transformed as government engineers built dams and reservoirs. The water provided by the Act allowed for much of the western U.S. to be settled and even become a leading agricultural area globally. This contented a growing society's requirements for water in the form of irrigation, hydropower electricity, as well as structures such as levees to control flooding and dredging to support transport. In addition, building these structures required prerequisite construction, such as roads and railroads. The projects were to be financed through a Reclamation Fund, funded by the sale of federal lands and by selling water to the irrigators. The Bureau's intention was to help local economies by constructing water projects to deliver water to arid areas and boost agricultural activities. However, as a result of political pressure from state legislators, Congressmen and Senators to obtain water projects, numerous dams were constructed in areas with little agricultural potential (Miller and Miller, 1992).

Along with the Reclamation Act, the U.S. Congress passed multiple laws known as the Flood Control Act (FCA), as a result of several major floods between 1849 and 1936. Flood mitigation projects were administered by the United States Army Corps of Engineers. During the New Deal, the Flood Control Act of 1936 authorized the Army Corps to control flooding in the western U.S., creating competition between the Army Corps and the Bureau of Reclamation. As a consequence, the acquisition of projects by each agency was connected to their political power in the region and the support of the President, legislators and related committees as these projects could potentially benefit the district, economically and politically. Together, the Bureau of Reclamation and the Army Corps built the vast majority of federal dams in the U.S., serving a variety of purposes. Historically, the Army Corps dams supported flood control and navigation while the Bureau of Reclamation dams served water storage and delivery requirements. For both agencies, hydropower became an important secondary function. This power production, in particular, gave dams a reach far beyond the site of construction, transforming hinterland into metropolises. Regional development programs were believed to have social and economic benefits, particularly for the underprivileged, especially in the years of the Great Depression (Koppes, 1987). Massive federal dam and irrigation projects meant jobs and long-term financial security for farmers tending irrigated land and for communities needing stable water resources. In the short term, many jobs were created. The estimated number of workers employed at any one time at Grand Coulee Dam was 7,000; more than 5,200 at Hoover Dam; and 10,500 at Fort Peck Dam. It has also been estimated that water projects in the U.S resulted in 26,000 miles of channeled waterways; 58,000,000 acres of irrigated land, 30,000,000 kilowatts of hydroelectricity; and flood control through 400 large dams (Palmer, 1986).

3. Economic Era (1950's)

The following era was relatively short and spanned most of the 1950's. It focused on underscoring cost/benefit ratios when implementing new projects along streams. The new infrastructure projects required consideration and justification rather than being fixated on engineering feats. In 1950, the Green Book was proposed by a federal interagency committee that laid out the cost/benefit requirements for new projects, which influenced projects and planning for the decade. However, this was never officially adopted by Congress due to the rapid focus shift to the Environmental Era (Russel and Baumann, 2009).

Harnessing rivers to facilitate humankind had been the major objective of water policy up to this point. The government regularly moved local communities and entire Native American tribes from land. This forced relocation of people in combination with vanishing wilderness created a shift in water management goals towards integrating social and environmental factors (Billington et al., 2005).

4. Environmental Era (late 1950's-present)

> *"Beginning in the 1960s, an increasingly urbanized, educated society focused more on recreation, environmental preservation, and water quality than on irrigation, navigation, or flood control."* Wallace Stegner, Myths of the Western Dam

During the late 1950's and 60's the tone and focus of environmental concern changed dramatically. National projects viewed as possibility and economic hope were now being evaluated in terms of decreasing riparian vegetation and fish population, water evaporation loss, erosion of channels, displacement of native peoples, and urban sprawl. Economic value and safety also came into question as infrastructure aged. There was a sobering awareness that the U.S. was the second most dammed country in the world, after China, where most major rivers were controlled by some 386 combinations of dams and diversions. Focus shifted from damming to the preservation of undammed rivers (Palmer, 1986). Water quality and related issues were a significant context for change in dealing with consequences of steam alterations in the new environmental era. Water issues of salinity and silting received little attention before the 1960's. Now a variety of questions arose about the water quality resulting from dam and reservoir construction and the impacts of intensive irrigation.

By their nature, dams and reservoirs changed the riparian ecology by altering the seasonal variability in rivers. Changes occurring by altering a free-flowing environment to a lake environment (reservoir), drowns native flora and fauna, encourages evaporation, concentrates salts and can sometimes create mud flats. The water released from the bottom of reservoirs is likely to be low in oxygen, threatening river life downstream. Dams with deep reservoirs can alter water temperature with stratification. The upper strata become warmer, while little light or oxygen reaches the lower strata. This change can create an unhealthy environment for native cold-water fish and can then allow the habitat to be taken over by non-native species. Aside from the problems related to the construction of dams and reservoirs, environmentalists began touting problems such as the poisoning of water by herbicides and pesticides (Pisani, 1998).

A symbol that epitomized this shift in American environmental consciousness was the idea of Earth Day where it was declared by its founders: "On April 22, [1970], a generation dedicated itself to reclaiming the planet. A new kind of movement was born-a bizarre alliance that spans the ideological spectrum from campus militants to middle Americans. Its aim: to reverse our rush toward extinction" (Environmental Action, 1970).

The new Nixon Administration gave its blessing to Earth Day. In fact, the President, in his first State of the Union message, declared, "Clean air, clean water, open spaces-these should be the birthright of every American." In January 1970, Nixon signed the National Environmental Policy Act (NEPA) of 1969, though many were cynical since the President opposed the bill until it cleared the congressional conferees. Nonetheless, the bill was a shift in governmental protocol by forcing federal bureaus and agencies to consider environmental effects before approving, funding or carrying out projects. With respect to river management, NEPA encouraged the Bureau of Reclamation and the Army Corps to give more attention to environmental considerations and give environmental agencies more say in the process. In addition, through the reviews of Environmental Impact Statements (EISes), substantial opportunity was given to citizen participation. Later that year, it was declared that the evaluation of impact statements and pollution control programs would be the responsibility of a new governmental body, the Environmental Protection Agency (EPA). Initially, the responsibilities of the EPA included divisions of air and water pollution, pesticides, solid waste and radiation, leaving the Departments of Commerce and Interior in charge of other natural resource programs. Despite the hesitant start of NEPA and limitations in EPA's authority, national environmental policy underwent a substantial shift (Andrews, 1995).

Further evidence of the change in public consciousness and political support for more environmental protection resulted in the following federal legislation: the Wilderness Act of 1964, the Fish and Wildlife Coordination Act in 1965, the National Preservation Act in 1966, the Wild and Scenic Rivers Act of 1968, the Endangered Species Act of 1973.

5. Clean Water Act

Though the Federal Water Pollution Control Act of 1948 was the first major act to address the growing problem of widespread water pollution, it was poorly designed and achieved little. In 1972, the Act was severely amending and became commonly known as the Clean Water Act (CWA). With the declaration of the policy, Congress announced its broad objectives of maintenance and restoration of "the chemical, physical, and biological integrity of the Nation's waters." The 1972 amendments include (EPA, 2017):

- The establishment of a basic structure for regulating pollutant discharges into the waters of the U.S.
- Giving the EPA the authority to implement pollution control programs such as setting wastewater treatment standards for industry.
- Maintaining existing requirements to set water quality standards for all contaminants in surface waters.
- Making it unlawful for any person to discharge any pollutant from a point source into navigable waters, unless a permit was obtained under its provisions.
- Funding the construction of sewage treatment plants under the construction grants program.
- Recognizing the need for planning to address the critical problems posed by nonpoint source pollution.

Section 303 of the CWA is fundamental to achieving acceptable water quality without implementing federal regulation of nonpoint sources of pollution. Water Quality Standards and Implementation Plans explains the statutory requirements for water quality standards in this way: "Water quality standards" specify a water body's "designated uses" and "water quality criteria," considering the water's "use and value for public water supplies, propagation of fish and wildlife, recreational purposes, and agricultural, industrial, and other purposes ...." § 303(c)(2). It is up to states to set water quality standards for all waters within their boundaries regardless of the source of pollution. If a state fails to do this, or failure of states's standards to meet the requirements of the ACT, will result in the EPA setting the standards for the state §§ 303(b), (c) (3-4). In addition, section 303 requires states to identify and compile a list of waters for which certain "effluent limitation are not stringent enough" to implement the applicable water quality standards. The states must prioritize rankings for listed waters and develop Total Maximum Daily Loads (TMDLs), which is a calculation of the maximum amount of a pollutant a waterbody can assimilate while still meeting quality standards, for these waters (CWA § 303(d)). To ensure that polluted waters are monitored and assessed, states are required to update and resubmit the impaired waters list every two years.

The result of this structure is that the CWA leaves to the states the responsibility of developing plans to attain water quality standards, while providing federal funding to implement state plans.

Another major decree within the CWA was the implementation of pollution control programs by establishing and maintaining requirements in water quality standards for all contaminants in surface waters. Implementing and authorizing discharge permits became the sole responsibility of the EPA, unless delegated to states or tribes. These permits are known as the National Pollutant Discharge Elimination System. The permits regulate point sources that discharge pollutants and are required by every individual, industry, corporation, and state that can cause water pollution. The permit system was created to force otherwise uncomplying states and industries to be carefully watched. Section 309 under the CWA gives the EPA power to file civil and criminal charges against any 'person' who violates not only the permit, but also the CWA in general. A 'person' is defined as "an individual, corporation, partnership, association, state, municipality, commission, or political subdivision of a state, or any interstate body and may issue a civil 6 penalty-not to exceed $25,000 per day for each violation (EPA, 2011).

During the following decade, the CWA, under the authority of the EPA was able to make great reductions in pollution discharged into waterways by point sources. Until the early 1980's, environmental protections and concerns were on the rise. It was when Ronald Reagan came into office that these concerns started to shift at the federal level. During this time, the former precautionary method concerning environmental policies and enforcement methods was switched to the cost/benefit analysis approach. The precautionary method was a way to protect the public from environmental exposures. Under this system, regulatory authorities were required to "take action or adopt measures in order to avoid, eliminate, or reduce risks to health and the environment" (Christoforou, 2010, pg.17). In contrast, using the cost/benefit analysis approach, regulators had to first prove that something was harmful to the public or environment, and secondly provide a way in which the cost of mitigating the threat would not be expensive. If either of these are not proven by the regulator, the risk of exposure is not deemed harmful. The cost/benefit analysis views environmental concerns and regulation in monetary values. This is inherently flawed, not only because the values put on environmental protections are artificial numbers, but because the possible "costs" of the future are not factored in (Ackerman and Heinzerling, 2002). As in many areas of environmental policies, the CWA was stuck in the cross roads of economic efficiency and powerful interest groups. The seemingly original intent of the CWA of having clean waterways and promoting the common good, was now bound by cost.

Adopting the usage of the cost/benefit analysis was the first step in the deregulating efforts of the Reagan administration. Next, the enforcement powers of the EPA were also weakened. Since Reagan was unable to rewrite environmental legislation, he used his powers as chief executive to change the direction of policy (Weiner, 2004). Reagan used his "administrative presidency" to control staffing in the EPA. The EPA, and the Departments of Agriculture, Interior, and Energy were staffed with non-environmentalists and/or non-environmental scientists, leaving environmental policies in danger of being removed. The EPA and other environmental agencies were seen as "excessively interfering with the market and not taking sufficient account of the economic costs of regulation" (Krämer, 2004, p. 56). Reagan's executive order 12291 now required the EPA to (Peters and Woolley, 1981):

- "Describe the potential benefits of the rule, including any beneficial effects that cannot be quantified in monetary terms, and the identification of those likely to receive the benefits;
- Describe the potential costs of the rule, including any adverse effects that cannot be quantified in monetary terms, and the identification of those likely to bear the costs;
- Determine the potential net benefits of the rule, including an evaluation of effects that cannot be quantified in monetary terms;
- Describe an alternative approach that could substantially achieve the same regulatory goal at lower cost, together with an analysis of this potential benefit and costs."

Despite the above policy changes to the implementations of the CWA of 1972, the U.S. House of Congress and Senate have been able to pass some amendments that extend environmental protections to streams and rivers, such as the Water Quality Act of 1987. This extended the number of toxins that the EPA oversaw and put more pressure on states regarding non-point source pollution. In CWA **§** 101(a)(7) Congress found that, to achieve its declared objective to restore and maintain the Nation's waters, "it is the national policy that programs for the control of nonpoint sources of pollution be developed and implemented in an expeditious manner so as to enable the goals of this chapter to be met through the control of *both* point and nonpoint sources of pollution." Further, under this amendment, states had to locate and name waterways they were unable to clear and come up with ways to control the pollutants in those areas (EPA, 2017).

In the forty-five years since the enactment of the CWA, notable progress was made to improve water quality nationwide, primarily by regulating point source chemical pollution.

However, less attention has been paid to inputs from nonpoint sources, though the control of both point and nonpoint sources of pollution is a stated goal of the CWA. The statute clearly defines point source while nonpoint source remained undefined. The statute defines point source to include: [A]ny discernable, confined and discrete conveyance, including but not limited to any pipe, ditch, channel, tunnel, conduit, well, discrete fissure, container, rolling stock, concentrated animal feeding operation, or vessel or other floating craft, from which pollutants are or may be discharged. The CWA also explicitly states that a point source "does not include agricultural storm water discharges and return flows from irrigated agriculture." The exclusion of a definition of nonpoint sources clearly impacts the control over these impacts on water quality, especially given the new focus on whole ecosystem science.

The CWA created expansive areas of federal accountability in water pollution control. However, concerns voiced by stakeholders, importantly by the National Governors' Conference, that the variability in water quality problems was not agreeable to rigid federal standards. The influence of these voices caused the majority of the decision-making process up to the states, particularly over, the already vaguely defined, nonpoint pollution sources (Guercio, 2011).

6. The Clean Water Rule

In 2015, the Obama Administration published the Clean Water Rule (CWR) under a provision of the CWA. The EPA and Army Corps sought to clarify water resource management by further defining the scope of federal water protection more consistently, particularly over streams and wetlands. Specific details about the CWR provided by the EPA are outlined below (EPA, 2017):

- “Defines more clearly the tributaries and adjacent waters that are under federal jurisdiction and explains how they are covered: A tributary, or upstream water, must show physical features of flowing water – a bed, bank, and ordinary high water mark – to warrant protection. The rule provides protection for headwaters that have these features and have a significant connection to downstream waters. Adjacent waters are defined by three qualifying circumstances established by the rule. These can include wetlands, ponds, impoundments, and lakes which can impact the chemical, biological or physical integrity of neighboring waters.
- Carries over existing exclusions from the Clean Water Act: All existing exclusions from longstanding agency practices are officially established for the first time. Waters used in normal agricultural, ranching, or silvicultural activities, as well as certain defined ditches, prior converted cropland, and waste treatment systems continue to be excluded.
- Reduces categories of waters which are subject to case-by-case analysis: Before the rule, almost any water could be put through an analysis that remained case-specific, even if it would not be covered under CWA. The rule limits use of case-specific analysis by providing certainty and clarity of protected vs non-protected water. Ultimately the rule saves time and avoids further evaluation and the need to take the case to court.
- Protects US "regional water treasures": Specific watersheds have been shown to impact downstream water health. The rule protects Texas coastal prairie wetlands, Carolina and Delmarva bays, western vernal pools in California, pocosins, and other prairie potholes, when impacting downstream waterways.”

This provision to the CWA has been contested in litigation since 2015, and in 2017, the Trump Administration announced its intent to review, rescind or revise the CWR (USACE and EPA, 2017), effectively eliminating any chance of implementation.

7. The BLM and the Western U.S. Rangelands

The Bureau of Land Management (BLM), an agency within the U.S Department of the Interior, manages more than 247 million acres of public lands. Most of the public lands are located in these western states: Alaska, Arizona, California, Colorado, Idaho, Montana, Nevada, New Mexico, Oregon, Utah, Washington and Wyoming, where livestock grazing in authorized on approximately 150 million acres which include many waterways (BLM, 2017). Prior to grazing legislation enactment, livestock grazing on federal public lands was effectively unregulated with widespread overgrazing resulting in resource deterioration. To address this, Congress enacted a series of statutes focused on rangeland improvement. The first, in 1934, was the Taylor Grazing Act (TGA). The major goals of the Act were improvement of range conditions and stabilization of the western livestock industry. However, by the 1970's, it became clear by the poor condition of rangelands that the BLM was failing to achieve the goals of the TGA of preventing soil deterioration and overgrazing. In 1970, a report by the Public Land Law Review Commission (PLLRC) focused public attention on the rangeland problems. The PLLRC recommended greater administrative flexibility and attention to wildlife that inhabit rangelands. It was not until 1976 that Congress finally acted on these recommendations with the enactment of the Federal Land Policy and Management Act (FLPMA). This Act restated the persistent need to improve federal public rangelands by highlighting resource protection. The BLM was directed by FLPMA to effectively manage public lands through a systematic inventory of rangelands, a land use planning process and along with the protection of some lands in their natural condition. Though FLPMA was an improvement over the Taylor Grazing Act, it failed to resolve basic management conflicts or make binding guidelines by neglecting to precisely define standards. Two years later, in 1978, Congress's next attempt to tackle this issue was the enactment of the Public Rangelands Improvement Act

(PRIA). Though PRIA included many innovative programs, its biggest contribution is the explicit directive that rangeland condition improvement be the highest management priority (Hudson, 1987). Over the next decade, it became clear that although Congress mandated that the BLM manage rangelands for the benefit of all and to ensure their future maintenance, much of the land remained in unsatisfactory condition.

The National Resources Defense Council (NRDC) challenged the BLM's actions on a number of grounds in the court case known as Natural Resources Defense Council v. Hodel in the area around Reno, NV in 1985. The NRDC claimed (Hudson, 1987, pgs. 191-2):

- "The grazing environmental impact statement (EIS) prepared by the BLM lacked the information and analysis necessary to allow reasoned decision making and informed public participation, contrary to the requirements of NEPA.
- The BLM's failure to take drastic and immediate actions to prevent overgrazing and unnecessary environment degradation was contrary to the mandates of FLPMA and PRIA as well as the agency's own regulations.
- Contrary to the planning requirements of FLPMA, PRIA and applicable regulations, the final use plan, or management framework plan (MFP), failed to establish the basic terms and objectives for future livestock grazing."

The court ultimately rejected the NRDC's arguments though it was noted that many of the complaints had factual merit suggesting bad management or inattentiveness to environmental concerns. The court granted summary judgment to the BLM despite the overwhelming evidence in the BLM's own studies showing serious environmental damage resulting from livestock overgrazing and mismanagement. Even with a recognition that reductions of grazing use were undoubtedly necessary, particularly in areas of fisheries and riparian habitat, the BLM's land use plan proposals were so vague as to not follow statutory mandates. This court's verdict, in this case, appeared to give the BLM unconstrained discretion in future management decisions (Hudson, 1987).

Further evidence of the ineffectiveness of the BLM to properly manage the western public rangeland was a report in the late 1980's by the U.S. General Accounting Office (GAO). The office concluded that (GAO, 1988, pg. 7):

- "although Congress mandated that BLM manage rangelands for the benefit of all and to ensure their future maintenance, much rangeland remained in unsatisfactory condition;
- almost 60 percent of the grazing allotments were in only poor or fair condition and the riparian areas were worse;
- the primary cause of rangeland and riparian degradation is poorly managed livestock grazing, since livestock tend to congregate in riparian areas, eat most of the vegetation, and trample streambanks;
- BLM has done little to reduce authorized grazing levels in overgrazed areas and has not established appropriate grazing levels;
- BLM staff believe that neither BLM management nor ranchers would support efforts to improve riparian areas; and
- BLM reduced staffing levels for those specialist positions needed to achieve range management goals."

The riparian areas were found to suffer worse degradation. The GAO (1988, pg. 3-4) stated in its report that the "impact of poorly managed livestock grazing is even more dramatic in riparian areas. Because of the availability of water, livestock tend to congregate in riparian areas for extended periods, eating most of the vegetation and trampling the streambanks. This results in badly eroded streambanks, radically altered streamflows, increased siltation, decreased shrub and grass growth, and lowered water tables. Further, contrary to multiple-use principles, the poorly controlled livestock grazing in riparian areas destroys fish habitat and reduces water, cover, and forage for other wildlife."

Regarding the riparian degradation, GAO recommended that the BLM needed to establish finite goals for restoration and to annually measure the progress made in achieving these goals.

This scathing review of the BLM explicitly states that the agency failed to properly manage public rangelands. Instead, it seems that its activities, or inactivity, have been focused on avoiding conflict with ranchers, rather than maintaining healthy or improving federal land.

8. U.S. Forest Service's Role

The U.S. Forest Service (USFS), an agency within the U.S. Department of Agriculture, manages 193 million acres including 155 national forest and 20 grasslands in 43 states and Puerto Rico. Historically, there has been a balancing act between utilizing resources for economic reasons and maintaining environmental standards that drive protection of wildlife and recreation services of citizens.

In 1960, the USFS passed the Multiple Use Sustained Yield Act (MUSYA) as a congressional assertion that the economic return was not the limiting factor in forest management decisions, and defined as follows:

- Multiple use: "management of all the various renewable surface resources of the national forests so that they are utilized in the combination that will best meet the needs of the American people ..." (§ 4(a))

- Sustained yield: "the achievement and maintenance in perpetuity of a high-level annual or regular periodic output of the various renewable resources of the national forests without impairment of the productivity of the land" (§ 4(b)).

Since there has been several efforts passed to address this balancing act and to acknowledge the importance of public involvement. The National Forest Management Act (NFMA) was passed in 1976 with the main objective being to develop plans, standards and policies regarding timber harvesting. It also provided for public involvement in planning and the acknowledgment of environmental impacts (NFMA, 1976).

In 1982, the National Forest System Land Management Planning Rule (planning rule) was established. This set of regulations aimed to start a process to develop, revise and adopt management plans required by the Forest and Rangeland Renewable Resources Planning Act of 1974 on National Forest system lands including; wilderness, wild and scenic rivers, national recreation areas and trails. Stated by the USFS, the "resulting plans shall provide for multiple use and sustained yield of goods and services from the National Forest System in a way that maximizes long term net public benefits in an environmentally sound manner" (USFS, 1982, Sec. 219.1).

Of particular interest to this study is Section 219.23 addressing water and soil resources. It states that forest planning shall provide for (USFS, 2017):

- "General estimates of current water uses, both consumptive and non-consumptive, including instream flow requirements within the area of land covered by the forest plan;
- Identification of significant existing impoundments, transmission facilities, wells, and other man-made developments on the area of land covered by the forest plan;
- Estimation of the probable occurrence of various levels of water volumes, including extreme events which would have a major impact on the planning area;

- Compliance with requirements of the Clean Water Act, the Safe Drinking Water Act, and all substantive and procedural requirements of Federal, State, and local governmental bodies with respect to the provision of public water systems and the disposal of waste water;
- Evaluation of existing or potential watershed conditions that will influence soil productivity, water yield, water pollution, or hazardous events; and
- Adoption of measures, as directed in applicable Executive orders, to minimize risk of flood loss, to restore and preserve floodplain values, and to protect wetlands."

In May 2012, this planning rule was revised from the 1982 framework that would allow the USFS (2012, pg. 1) to "meet modern and future needs, taking into account new understanding of science, land management, and the all-lands context for managing resources. It focuses on outcomes, rather than outputs, and would help units identify their unique roles in the broader landscape and create land management plans to guide proactive contributions to ecological, social, and economic sustainability." The use of the term "ecological sustainability" is a shift from past management plans and depicts a recent understanding of landscape ecology and a focus on environmental protection, rather than industrial interests of using public resources. Several highlights of the most recent planning rule, as they apply to this study of ecological disturbance research and a need for monitoring our riparian areas include (USFS, 2012, pg. 2):

- "Improved ability to respond to climate change and other stressors through an adaptive framework of assessment, planning and monitoring and new provisions intended to improve resiliency of ecosystems on each unit.

- An all-lands approach to land management planning for NFS lands, recognizing that many management issues, such as fire, water, and wildlife, will require an understanding of what is happening both on and off the National Forest System.
- Increased protections for water resources, watersheds, and riparian areas, including requirements to identify watersheds for priority restoration; maintain and restore aquatic ecosystems, watersheds, water quality and water resources including public water supplies, groundwater, lakes, streams, and wetlands; maintain and restore riparian areas; and provisions for best management practices for water quality.
- New requirements for a unit and landscape-scale monitoring program based on the latest science, strengthening the role of monitoring so that units can better track changing conditions and measure progress towards meeting objectives in the plan.
- New requirements to use and document the use of the best available scientific information to inform the assessment, plan decisions, and monitoring program."

The revised planning rule claims to reduce the time and cost involved in plan revision, allowing the FS to update more plans with the same amount of resources.

9. European Water Framework Directive

As a model for this system of assessment and monitoring, we can look to a policy passed in the European Union (E.U.). In December 2000, the European Water Framework Directive (WFD) became the central foundation for any water policy-related action by the E.U.

Some key principles framing the content of the WFD include (WFD, 2000):

- "water is not a commercial product like any other but, rather, a heritage which must be protected, defended and treated as such" (pg.1);

- “sustainable management and protection of freshwater resources” (pg. 3) will be achieved by the implementation of an “integrated Community policy,” (pg. 9, 18) which will be based on the prudent and rational use of natural resources and on principles such as the precautionary principle, preventive action, rectification of environmental damage and payment of costs by polluters (pg. 11);
- improving the aquatic environment primarily concerns the quality of water, which is influenced by quantitative aspects (pg.19);
- common definitions of the status of water, using technical specifications ensuring a coherent community approach (pg. 49), are needed and environmental objectives must be set to ensure good status (pg. 25, 26) which will be achieved through the political coordination of decisions (pg. 35) and through ecological coordination of measures at the river basin scale (pg. 36);
- finally, implementation may be flexible in regard to timetables and costs, (pg. 31) and derogations and exemptions to the general model may be set. In all cases, all these should be made on the basis of appropriate, evident, and transparent criteria.

Within this framework, all member states must assess all water bodies including; groundwater, coastal and transitional waters, rivers and lakes. Member states must attain or maintain “good status” as defined by good ecological and chemical status and to complete the following:

- elaborate the type-specific reference conditions of water bodies (Annex II, 1.3 WFD),
- define the quality targets for the ecological status assessment,
- pre-classify the different types of water bodies (natural, heavily modified or artificial) (Annex II, 1.1 WFD), and

- assess them in terms of current status achievement or failure, and risk (Annex II, 1.4 and 1.5 WFD).

As it applies, Member States must identify the appropriate competent authority for the application of the rules of this Directive for any international river basin district within its territory. For all river basin management plans, a general preliminary description of all river basins shall include (WFD, 2000):

- Mapping of the location and boundaries.
- Mapping of the ecoregions and surface water body types within the river basin.
- Identification of reference (unaltered) conditions for all surface water body types.

Each Member State derives its own technical specifications and methods for analysis and monitoring within the framework of WFD as it applies to their geographic location. The timetable for monitoring takes place at varying intervals, from months to years based on technical knowledge. Member States must submit assessment of progress made towards achieving environmental objectives which includes monitoring results for the period in GIS map form, and an explanation for any objectives not reached (WFD, 2000).

APPENDIX B.

RAPID-STREAM RIPARIAN ASSESSMENT (RSRA)

1. Site Identification:

Reach___________________Stream___________________Watershed ____________________

Survey Date______________Time__________Background information available? (yes/no) __

Observers____Email______________

Contact Info: Address____Phone ____________

Reach (UTM) Upstream_________________E_____________________N Elevation _____

Photo identification___________________________ (Preferred datum - NAD 83)

NAD _____ Downstream _________________ E_____________________N Elevation ______

Photo Identification:___________________________

Stream Transect Start___________________E_____________________N Upstream or

Down? _ (optional) Stream Transect Photo Id:____USGS Quad Map Name:________________

Scores: WQ ___ HG____F/AH____RV____TWH ___ Overall Rating__Condition ____________

Previous Ratings: DATE_____Overall Rating________Current Trend____________

Individual Previous Scores WQ_HG____F/AH___RV_____TWH _____

2. Field Worksheet

The worksheet that follows is used in the field to collect the data that are then used to calculate the scores for the indicators in the Rapid Stream Riparian Assessment. This completed worksheet should be attached to the RSRA Score Sheet and kept as part of the permanent record.

The worksheet is organized into physical areas of observation (study reach or individual transects). A GPS unit should be used to record the ends of the stream reach, individual transects, and other sample locations. This will allow other observers to return to the exact same location in future years and collect the same data. This will allow anyone to determine whether there have been any changes in the indicators over the intervening period (positive or negative).

The record for photographs also should include information that will allow others in the future to revisit the same site and take a similar photograph. This information includes the GPS location and the direction that the photograph was taken. Try to frame your picture to show both the ground and surrounding topography.

In some cases, the indicator assessment method calls for the user to count the number of observations that, for example, show the presence of filamentous algae. An efficient way to tally the data for these indicators is the “five strike” method where each count gets a vertical mark and the fifth then crosses through the other four to make five. This is continued in groups of five, and makes totaling the count easier.

Some of the indicators call for the calculation of averages of measures recorded on the field worksheet. On the score sheet, we ask that you record the score for each indicator and, where needed, the average measure for that indicator. This will aid us in developing a computer based data base of these data.

Field Worksheet, cont.

revised March 30, 2010

Stream reach identification:______________________Date: ______________

Whole Study Reach

Begin by recording the GPS locations of the ends of the study reach on the Score Sheet, and take reference photos at both ends of the study stream reach. Data for the following indicators are gathered on the whole reach walk through:

Indicator 5 (Hydraulic Habitat diversity), **Indicator 6** (Riparian Area Soil Integrity) **Indicator 7** (Beaver, Signs of activity), **Indicator 15** (Native Shrub Demography), **Indicator 16** (Native Tree Demography), **Indicator 17** (Non-Native Herbaceous species), **Indicator 18** (Non-Native Woody Plant Species), **Indicator 21** (Shrub Patch Density), **Indicator 22** (Mid-Canopy Patch Density), **Indicator 23** (Upper Canopy Patch Density), and **Indicator 24** (Fluvial Habitat Diversity).

Indicator 5: Hydraulic Habitat Diversity (number of different in stream below-water features).

Check each type of hydraulic (stream) features providing important aquatic habitats.

D edge water
D lateral pool
D high velocity or gradient riffle (high velocity run)
D low velocity or gradient riffle (low velocity run)
D scour pool
D cobble/boulder debris fans D
active, flowing side channels
D backwaters
D sand-floored runs
D other (type____)

Total number of different feature types: ___________

Indicator 6: Riparian Area Soil Integrity.

Notes____Percent soil area disturbed ______

Indicator 7: Beaver Activity.

Signs of beaver activity include tracks, drags, digging marks, cut stems, burrows, dams, and caches.

Signs observed ____

Indicator 15: Native Shrub Demography and recruitment.

Circle age classes present: seedling, immature, mature, old dead clumps.

Dominant native species:________________Other notes: ________________________________

Indicator 16: Native Tree Demography and Recruitment.
Circle age classes present: seedling, immature, mature, snags.
Dominant native species ____________________________________
Notes ____

Indicator 17: Non-Native Herbaceous Plant Species Cover.
Grasses and forbs, as percentage of total grass and forb cover.
Percent of non-native herbaceous plants ___________
Notes ____

Indicator 18: Non-Native Woody Plant Cover.
Shrubs and trees, as percentage of total shrub and tree cover.
Percent of non-native woody plant cover __________
Notes ____

Indicator 21: Shrub Patch Density.
Notes ____

Indicator 22: Mid-canopy Patch Density.
Notes ____

Indicator 23: Upper Canopy Patch Density.
Notes ____

Score sheet notes for Indicators 21, 22, 23

1 no patches in stream reach
2 few, isolated shrub patches
3 more patches but still isolated from each other
4 few large open areas between large patches
5 almost continuous dense cover for the layer

Indicator 24: Fluvial Habitat Diversity.
Check each type of geophysical feature within the riparian zone that provides a unique habitat for plants and animals:

D flood-plain ponds
D oxbows
D large and isolated sand or gravel bars
D wet meadows
D marsh
D stable cutbanks
D beaver pond
D others (name____)

Total number of fluvial habitat types ___________

Three Representative Reach Sites

Data for the following indicators are collected at three different and representative sites along the study reach. The locations used for each indicator may be the same or different as appropriate, and they do not need to be located in the 200m transect.

Indicator 2: Channel Shading and Solar Exposure.

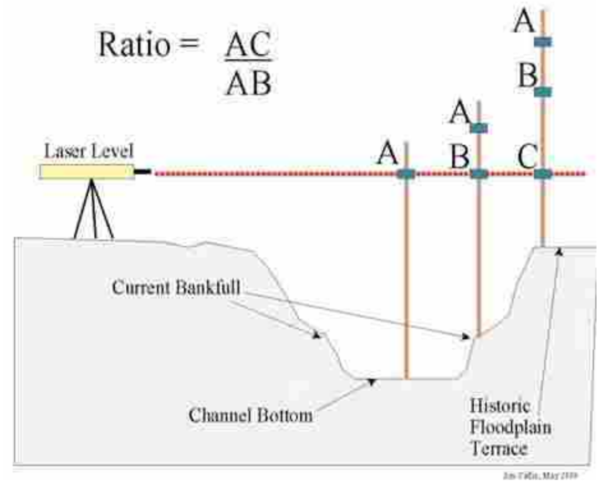
Percent of stream surface shaded at mid-day.

Time observed________________(if not mid-day, estimate what shading at noon would be like)

Observation Site 1: Percent stream shaded_____________%
(Optional) UTM E_______________________________N _____________________

Observation Site 2: Percent stream shaded_____________%
(Optional) UTM E_______________________________N _____________________

Observation site 3: Percent stream shaded_____________%
(Optional) UTM E_______________________________N _____________________
Average of three observation sites
________________%



Indicator 3: Floodplain Connection and Inundation.

Data are taken at three representative sites.

Site 1: Current bankfull depth (AB)__________
Historic floodplain height (AC)____________
Floodplain/bankfull ratio ________________
Ratio = (AC)/(AB)
(Optional) UTM E_______________________N ____________________
(Optional) Photo ID________________ Direction ________

Site 2: Current bankfull depth (AB)_____________
Historic floodplain height (AC)________________
Floodplain/bankfull ratio =(AC)/(AB)_________________
(Optional) UTM E_______________________N ____________________
(Optional) Photo ID_______________ Direction _________

(continued on next page)

Indicator 3 (Continued)

Site 3: Current bankfull depth (AB)_________Historic floodplain height (AC)____________
Floodplain/bankfull ratio =(AB)/(AC) ________
(Optional) UTM E_______________________________N ____________________
(Optional) Photo ID__________________________________Direction __________

Indicator 3, average of the three ratios for three sites _________________________

Three Representative Instream Riffle Sites

Collect the data for Indicators 10 and 11 at the same representative stream riffle locations (these sites may be different than those used for the other indicators. Make sure that these sites represent typical riffles in your reach.)

Indicator 10: Cobble Embeddedness (three representative riffles, examine six samples 3-8" in diameter per site).

Riffle site 1: Rock embedded______________________________________Average _______
(Optional) UTM E.____________________________N _________________

Riffle site 2: Rock embedded______________________________________Average _______
(Optional) UTM E.____________________________N _________________

Riffle site 3: Rock embedded______________________________________Average _______
(Optional) UTM E.____________________________N _________________

Overall average of averages of embeddedness: ___________________

Indicator 11: Aquatic Invertebrates
Examine at least six rocks at least six inches in diameter at each of the sites used to measure embeddedness. Use the key in Appendix 1 for identification. List the invertebrate orders found below and record which are most common or rare. Note the presence of crawfish, but for this protocol, do not include them in the final tally of the total number of orders found in the samples to determine the final score.

In-stream 200 meter transect

Data for the following assessment indicators are collected on this transect:
Indicator 1 (Algal Growth), **Indicator 4** (Vertical Bank Stability), **Indicator 8** (Riffle-Pool Distribution), **Indicator 9** (Underbank Cover),
Indicator 12 (Large Woody Debris), and
Indicator 13 (Overbank Cover and Terrestrial Invertebrate Habitat).

Location: UTM E______________________N ______________________

(Optional Photo) Identification________________Photo direction ________

Indicator 1: Algal Growth.

Beginning from the downstream end of the transect, record the presence of filamentous algae taken every 2 meters looking straight down with the ocular tube one meter into the stream from the bank. If the stream is less than 2 m wide, walk up the center of the channel.

Yes____

No____

Percent of total stops on transect that are "hits" for algae _________

Indicator 4: Vertical Stability of Stream Banks.

Meters of unstable bank (include both sides) _______________________________________

Meters of stable bank (include both sides) ____

Total____________Percent of transect ___________

Indicator 8: Riffle-Pool Distribution.

Number of riffle-pool units in transect ____________

Approximate amount of total transect with riffle/pool habitat _________________________

Indicator 9: Underbank Cover.

Meters of underbank cover (include both sides) ____________________________________

Meters lacking underbank cover (include both sides) ________________________________

Total_________Percent of transect __________

Indicator 12: Large Woody Debris.

6 inches or more in diameter and three feet or longer with some portion submerged in water.

Pieces of large woody debris___________________________ Total _________________

Indicator 13: Overbank Cover and Terrestrial Invertebrate Habitat.

Do not include rocks or cliff faces.

Meters of vegetation hanging over bank (include both sides) ___________________________

Meters lacking hanging vegetation (include both sides) ________________________________

Total____________Percent of stream transect __________________

Riparian Zone 200 meter transect

Data for the following indicators are collected on this transect:

Indicator 14 (Riparian Zone Plant Community Structure),
Indicator 19 (Mammalian [wild and domestic livestock] Grazing of Ground Cover), and
Indicator 20 (Mammal Browse of Shrubs).

Indicator 14: Riparian Zone Plant Community Structure.

Every 2m observe directly up and down for groundcover, shrub, middle and upper canopy layers.

Ground layer count (0-1 meter above ground):

Yes____

No____

NA ____

Total ground layer positive hits____________Percentage positive hits ___________

Shrub layer count (1-4 meters above ground):

Yes____

No____

NA ____

Total shrub count positive hits____________Percentage positive hits ___________

Middle layer canopy (4-10 meters above ground):

Yes____

No____

NA ____

Total middle canopy positive hits____________Percentage positive hits __________

Upper canopy layer (more than 10 meters above ground):

Yes____

No____

NA ____

Total upper canopy positive hits____________Percentage positive hits ___________

Average percent cover in upper riparian zone (all four layers) __________________

Indicator 19: Ungulate Grazing in Riparian Zone, Groundcover grazed.

Count grass and forb cover that show signs of grazing when performing observations for Indicator 14, Plant Community Structure and Cover.

No____

Yes____

NA ____

Total positive hits_________Percentage positive hits ___________

Indicator 20: Mammalian Browsing of Shrubs and Small Trees in Riparian Zone. Percent of trees and shrubs showing clipped branches in the Riparian Zone:

Browsed____

Not browsed ____

Total not browsed___________Total browsed ______

Percentage of woody plants browsed ____________

[NOTE: OPTIONAL SECOND RIPARIAN ZONE TRANSECT IN CASE OF VERY WIDE (>100m) FLOODPLAIN. Indicator 14b: Riparian Zone Plant Community Structure.

Every 2m observe directly up and down for groundcover, shrub, middle and upper canopy layers.

Ground layer count (0-1 meter above ground) :

Yes____

No____

NA ____

Total ground layer positive hits____________Percentage positive hits ___________

Shrub layer count (1-4 meters above ground):

Yes____

No____

NA ____

Total shrub count positive hits___________Percentage positive hits ___________

Middle layer canopy (4-10 meters above ground):

Yes____

No____

NA ____

Total middle canopy positive hits____________Percentage positive hits ___________

Upper canopy layer (more than 10 meters above ground):

Yes____

No____

NA ____

Total upper canopy positive hits____________Percentage positive hits ___________

Average percent cover in upper riparian zone (all four layers) ________

3. Score Sheets for Five Categories

Score (1-5 or N/A)	Indic ator N	Indicator	**Scoring Definitions and Directions** Scores of 5 indicate that the indicator is close to the potential of the geologically and biologically similar reference reach, and/or what would be expected to be found in a healthy ecosystem. Scores of 1 indicate	Notes on measurement methods
WATER QUALITY				
Score: %=	1	**Algal Growth**	1 = >50% of stream bottom covered by filamentous algae 2 = 26-50% of bottom covered by filamentous algae 3 = 11-25% of bottom covered by filamentous algae 4 = 1-10% of bottom covered by filamentous algae 5 = no	Walking upstream, use ocular tube to from bank every 2m in 200m in-stream transect. Do rocks.
%=	2	**Channel Shading, Solar Exposure**	1 = stream channel completely unshaded (0%) 2 = slight shading (1-15%) 3 = moderate shading (16-30%) 4 = substantial shading (31-60%) 5 = Channel mostly shaded (>60%)	Look up and down stream in three different representative points in the overall stream reach. Average the three points.
Water quality mean score:	Notes:			

HYDROGEOMORPHOLOGY (STREAM FORM)

Score: avg=	3	**Floodplain Connection and Inundation**	1 = >1.7 bankfull / depth ratio average of 3 locations 2 = >1.5 -1.7 bankfull / depth ratio 3 = >1.4 - 1.5 bankfull / depth ratio 4 = >1.3 - 1.4 bankfull / depth ratio 5 = 1.0 - 1.3 bankfull / depth ratio	Use field worksheet and measure ratios at three representative locations in the overall stream reach. Calculate the average of three ratios and score using Figure 3.
%=	4	**Vertical Bank Stability**	1 = >90% of channel banks are vertically unstable (use the average of both banks) 2 = 61 - 90% of banks are unstable 3 = 31 - 60% of banks are unstable 4 = 5 - 30% of banks are unstable 5 = <5% of banks are unstable	Estimate along both banks of 200m in-stream transect. Do not include rock or cliff faces in calculating total length of unstable banks (use "N/A").
	5	**Hydraulic Habitat Diversity**	1 = no diversity (variability) of stream form features 2 = low diversity, 2 habitat types present, 3 = moderate diversity, 3 types present, 4 = moderately high diversity, 4 types present, 5 = high diversity, 5 or more present.	Check in overall walk through. Examples include runs, pools, cobble or boulder debris fans, running side channels, backwaters, sand-floored runs, etc.
%=	6	**Riparian Area Soil Integrity**	1 = >25% of riparian soil surface disturbed 2 = 16 - 25% disturbed 3 = 6 - 15% disturbed 4 = 1 - 5% disturbed 5 = <1% disturbed	Check in overall walk through. Look for unnatural surface disturbances in the riparian zone from such things as vehicles, foot travel, and ungulate activity.
	7	**Beaver Activity**	1 = beavers not now present but were historically 2 = no beaver dams, a few signs of activity but none within the last year 3 = activity in past year but no dams 4 = beaver dams on some of the stream 5 = beaver activity and dams control stream	Check in overall walk through. Beaver sign includes tracks, drags, digging marks, cut stems, burrows, dams, and caches active within past season.

Hydrogeomorphology mean score:	Notes:

FISH/AQUATIC HABITAT

Qualifier: If the stream is no longer perennial, but used to be a fishery, the mean score entered for this section is a "1." (It is no longer functioning as fish/aquatic habitat.)

	8	**Riffle-Pool Distribution**	1 = no riffle-pool habitat in stream transect 2 = one to several riffle-pool systems 3 = limited to moderate riffle-pool distribution in reach 4 = moderate to abundant riffle-pool distribution 5 = riffle-pools abundant (>50% of transect has pools connected by riffles)	Check along 200m in-stream transect. Look for geomorphic consistency (e.g. high gradient streams will have more pools than low gradient streams).
%=	9	**Underbank Cover**	1 = no underbank cover in 200m stream transect 2 = <10% transect has underbank cover 3 = 10 - 25% of transect has underbank cover 4 = 26 - 50% of transect has underbank cover 5 = >50% of transect has underbank cover	Check along both banks of 200m in-stream transect. Undercut must be at least 15cm (6 in) into the streambank. Average the measures on both banks to score.
%=	10	**Cobble Embedded-ness**	1 = average of >50% of rock volume is imbedded in fine silt. (avg. of three sites) 2 = 41 - 50% of rock imbedded 3 = 26 - 40% of rock imbedded 4 = 20 - 25% of rock imbedded 5 = <20% of rock imbedded	Determine the percent embeddedness of a random sample of 6 rocks 3-8" in diameter from riffles in each of three different ran-dom points along the over-all stream reach.
	11	**Aquatic Macro-invertebrate Diversity**	1 = no aquatic (benthic) macroinvertebrates found 2 = 1 macroinvertebrate order present 3 = 2 macroinvertebrate orders present 4 = 3 macroinvertebrate orders present 5 = 4 or more orders present	Examine 6 rocks 15cm (6") or larger at the same sites used for Indicator 10. Use Appendix 1 or other guide to identify macroin-vertebrate orders.
	12	**Large Woody Debris**	1 = no large woody debris (LWD) in transect 2 = <3 LWD pieces in transect 3 = 3 - 5 LWD pieces in transect 4 = 6 - 10 LWD pieces in transect 5 = >10 LWD pieces in transect	Count woody debris pieces larger than 15cm (6") in diameter and 1m (3 ft) long or longer in the chan- nel in the 200m in-stream transect
%=	13	**Overbank Cover and Terrestrial Invertebrate Habitat**	1 = no grass, shrubs, or trees overhang water 2 = <10% of banks have grass, shrubs, or trees that overhang the water 3 = 10 - 25% of banks have overhanging veg. 4 = 26 - 50% of banks have overhanging veg. 5 = >50% of banks have overhanging veg.	Check along both banks of 200m in-stream transect. Look for geomorphic con-sistency. Do not include rocks or cliff faces (use "N/A"). Average both banks when scoring.

Fish/Aquatic Habitat mean score:	Notes:

RIPARIAN VEGETATION

G=______%
S=______%
MC=____%
UC=_____%

Score: avg= %	14	**Riparian Zone Plant Community Structure and Cover**	1 = <5% average plant cover in riparian zone 2 = 5 - 25% average plant cover 3 = 26 - 50% average plant cover 4 = 51 - 80% average plant cover 5 = >80% average plant cover	Use the field worksheet and ocular tube to determine the cover for the ground, shrub, midcanopy and upper canopy layers along 200m transect in the riparian zone. Look for geomorphic consistency.
Score:	15	**Shrub Demography and Recruitment**	1 = no native shrubs present in study reach 2 = one age class present 3 = two classes present, one class with seedlings or saplings 4 = three age classes present 5 = all age classes present	Determine during the overall walk through the number of age classes (seedlings, saplings, mature, standing dead) for the dominant (most cover) native shrub species.
	16	**Tree Demography and Recruitment**	1 = no native trees present in study reach 2 = one age class present 3 = two classes present, one class with seedlings or saplings 4 = three age classes present 5 = all age classes present	Determine during the overall walk through the number of age classes (seedlings, saplings, mature, standing dead) for the dominant (most cover) deciduous native tree species.
	17	**Non-native Herbaceous Plant Species**	1 = >50% of herbaceous plant cover are not native species 2 = 26 - 50% herbaceous not native 3 = 11 - 25% herbaceous not native 4 = 5 - 10% herbaceous not native 5 = <5% of herbaceous cover not native	Estimate on the overall walk through.
	18	**Non-native Woody Plant Species**	1 = >50% of woody plant cover are not native species 2 = 26 - 50% of woody cover not native 3 = 11 - 25% of woody cover not native 4 = 5 - 10% of woody cover not native 5 = <5% of woody cover not native	Estimate on the overall walk through.
%=	19	**Mammalian Herbivory (Grazing) Impacts on Ground Cover**	1 = >50% of plants impacted by grazing 2 = 26 - 50% of plants impacted 3 = 11 - 25% of plants impacted 4 = 5 - 10% of plants impacted 5 = <5% of plants impacted	Use the field worksheet and ocular tube to determine the number of “hits” showing herbivory on the ground covering plants (grasses and forbs) on the 200m riparian zone transect.

RIPARIAN VEGETATION, CONTINUED

%=	20	**Mammalian Herbivory (Browsing) Impacts on Shrubs and Small Trees**	1 = >50% of plants (shrubs and trees) impacted 2 = 26 - 50% of plants impacted 3 = 11 - 25% of plants impacted 4 = 5 - 10% of plants impacted 5 = <5% of plants impacted	Estimate the percentage of shrubs and small trees that have branch tips that have been clipped or eaten by large mammals.

Riparian Vegetation, mean score:	Notes:

TERRESTRIAL WILDLIFE HABITAT

	21	**Shrub Patch Density**	1 = no shrub patches in stream reach 2 = few, isolated small shrub patches 3 = more patches but still isolated 4 = few large open areas between large patches 5 = almost continuous dense shrub cover	In overall walk through, examine patches and clusters of shrubs (<4m tall) and openings between those clusters. Look for geomorphic consistency.
	22	**Mid-Canopy Patch Density**	1 = no mid-canopy shrub or tree patches in reach 2 = few isolated small patches in mid canopy 3 = more patches but still isolated 4 = few large open areas between large patches 5 = almost continuous dense mid-canopy cover	In overall walkthrough, examine clusters of mid-canopy large shrubs and trees (4-10m tall) and openings between those clusters. Look for geomorphic consistency.
	23	**Upper Canopy Patch Density**	1 = no upper-canopy trees present in reach 2 = few isolated small patches in upper canopy 3 = more patches but still isolated 4 = few large open areas between large patches 5 = almost continuous dense upper-canopy cover	In overall walk through, examine clusters of upper canopy trees (>10m tall) and openings between those clusters. Look for geomorphic consistency.
	24	**Fluvial Habitat Diversity**	1 = no other fluvial habitat besides the stream channel 2 = one other type of fluvial habitat present 3 = two other types present 4 = three other types present 5 = four or more other types present	Examine during overall walk through. Fluvial habitat types include flood-plain ponds, oxbows, sand bars, wet meadows, beaver ponds, and stable cutbanks.

Terrestrial Wildlife Habitat, mean score:	Notes:

FISH/AQUATIC HABITAT				
	8	**Riffle-Pool Distribution**	1 = no riffle-pool habitat in stream transect 2 = one to several riffle-pool systems 3 = limited to moderate riffle-pool distribution in reach 4 = moderate to abundant riffle-pool distribution 5 = riffle-pools abundant (>50% of transect has pools connected by riffles)	Check along 200m in-stream transect. Look for geomorphic consistency (e.g. high gradient streams will have more pools than low gradient streams).
%=	9	**Underbank Cover**	1 = no underbank cover in 200m stream transect 2 = <10% transect has underbank cover 3 = 10 - 25% of transect has underbank cover 4 = 26 - 50% of transect has underbank cover 5 = >50% of transect has underbank cover	Check along both banks of 200m in-stream transect. Undercut must be at least 15cm (6 in) into the streambank. Average the measures on both banks to score.
%=	10	**Cobble Embedded-ness**	1 = average of >50% of rock volume is imbedded in fine silt. (avg. of three sites) 2 = 41 - 50% of rock imbedded 3 = 26 - 40% of rock imbedded 4 = 20 - 25% of rock imbedded 5 = <20% of rock imbedded	Determine the percent embeddedness of a random sample of 6 rocks 3-8" in diameter from riffles in each of three different random points along the overall stream reach.
	11	**Aquatic Macro-invertebrate Diversity**	1 = no aquatic (benthic) macroinvertebrates found 2 = 1 macroinvertebrate order present 3 = 2 macroinvertebrate orders present 4 = 3 macroinvertebrate orders present 5 = 4 or more orders present	Examine 6 rocks 15cm (6") or larger at the same sites used for Indicator 10. Use Appendix 1 or other guide to identify macroinvertebrate orders.
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%=	13	**Overbank Cover and Terrestrial Invertebrate Habitat**	1 = no grass, shrubs, or trees overhang water 2 = <10% of banks have grass, shrubs, or trees that overhang the water 3 = 10 - 25% of banks have overhanging veg. 4 = 26 - 50% of banks have overhanging veg. 5 = >50% of banks have overhanging veg.	Check along both banks of 200m in-stream transect. Look for geomorphic consistency. Do not include rocks or cliff faces (use "N/A"). Average both banks when scoring.
Fish/Aquatic Habitat mean score:	Notes:			

RIPARIAN VEGETATION

G=______% S=______% MC=____% UC=_____%	Score: avg= %	14	**Riparian Zone Plant Community Structure and Cover**	1 = <5% average plant cover in riparian zone 2 = 5 - 25% average plant cover 3 = 26 - 50% average plant cover 4 = 51 - 80% average plant cover 5 = >80% average plant cover	Use the field worksheet and ocular tube to determine the cover for the ground, shrub, midcanopy and upper canopy layers along 200m transect in the riparian zone. Look for geomorphic consistency.
	Score:	15	**Shrub Demography and Recruitment**	1 = no native shrubs present in study reach 2 = one age class present 3 = two classes present, one class with seedlings or saplings 4 = three age classes present 5 = all age classes present	Determine during the overall walk through the number of age classes (seedlings, saplings, mature, standing dead) for the dominant (most cover) native shrub species.
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		18	**Non-native Woody Plant Species**	1 = >50% of woody plant cover are not native species 2 = 26 - 50% of woody cover not native 3 = 11 - 25% of woody cover not native 4 = 5 - 10% of woody cover not native 5 = <5% of woody cover not native	Estimate on the overall walk through.
	%=	19	**Mammalian Herbivory (Grazing) Impacts on Ground Cover**	1 = >50% of plants impacted by grazing 2 = 26 - 50% of plants impacted 3 = 11 - 25% of plants impacted 4 = 5 - 10% of plants impacted 5 = <5% of plants impacted	Use the field worksheet and ocular tube to determine the number of "hits" showing herbivory on the ground covering plants (grasses and forbs) on the 200m riparian zone transect.

RIPARIAN VEGETATION, CONTINUED

%=	20	**Mammalian Herbivory (Browsing) Impacts on Shrubs and Small Trees**	1 = >50% of plants (shrubs and trees) impacted 2 = 26 - 50% of plants impacted 3 = 11 - 25% of plants impacted 4 = 5 - 10% of plants impacted 5 = <5% of plants impacted	Estimate the percentage of shrubs and small trees that have branch tips that have been clipped or eaten by large mammals.

Riparian Vegetation, mean score:	Notes:

TERRESTRIAL WILDLIFE HABITAT

	21	**Shrub Patch Density**	1 = no shrub patches in stream reach 2 = few, isolated small shrub patches 3 = more patches but still isolated 4 = few large open areas between large patches 5 = almost continuous dense shrub cover	In overall walk through, examine patches and clusters of shrubs (<4m tall) and openings between those clusters. Look for geomorphic consistency.
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	23	**Upper Canopy Patch Density**	1 = no upper-canopy trees present in reach 2 = few isolated small patches in upper canopy 3 = more patches but still isolated 4 = few large open areas between large patches 5 = almost continuous dense upper-canopy cover	In overall walk through, examine clusters of upper canopy trees (>10m tall) and openings between those clusters. Look for geomorphic consistency.
	24	**Fluvial Habitat Diversity**	1 = no other fluvial habitat besides the stream channel 2 = one other type of fluvial habitat present 3 = two other types present 4 = three other types present 5 = four or more other types present	Examine during overall walk through. Fluvial habitat types include flood-plain ponds, oxbows, sand bars, wet meadows, beaver ponds, and stable cutbanks.

Terrestrial Wildlife Habitat, mean score:	Notes: